

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 516

REFRIGERATION SYSTEMS

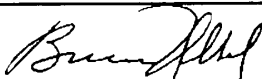
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CHAPTER 516

REFRIGERATION SYSTEMS

SECTION 1.

INTRODUCTION AND BASIC PRINCIPLES

516-1.1 INTRODUCTION

516-1.1.1 SCOPE. This purpose of this manual is to provide technical information to personnel who supervise, operate, or maintain refrigeration equipment for refrigerated ship stores, air-conditioning, and various self-contained applications. Background information on the theory of refrigeration has been included so that operating personnel may better understand the subject. This manual is not intended to be a composite of all design and detail maintenance information. Refrigerant piping design information has been included, not so that personnel may be able to design refrigerant piping, but so they may recognize a deficient installation that could be causing operational or maintenance problems.

516-1.1.2 RECIPROCATING COMPRESSOR PLANTS. High-speed (1,750-rpm) reciprocating compressors were first installed in Navy ships around 1950. Since that time manufacturers have continued to modify or change various parts to improve original compressors. All these changes have been made on all units in ships of the active fleet. Available service information from manufacturers on part changes was reviewed and documented in this general manual so that personnel may be informed of compressor modifications. There is no assurance that every single modification that manufacturers made throughout the years is recorded herein, although all the available information was used. Maintenance personnel should be aware that reciprocating compressors essentially use commercial parts. Manufacturers usually support older models by making those parts noted in technical manuals available. Although every compressor need not be updated, any necessary modifications will be made using ship alterations (SHIPALT's).

516-1.1.3 CENTRIFUGAL COMPRESSOR PLANTS. The problems associated with reciprocating compressor plant part changes are not applicable to centrifugal compressors. On centrifugal compressors, controls or other minor items may change from unit to unit, making many compressors unique. The technical manuals covering centrifugal compressors are current and explicit. The presentation on these units herein provides general information for a better understanding of the function and operation of the centrifugal refrigerant system.

516-1.2 BASIC PRINCIPLES

516-1.2.1 DEFINITION. Refrigeration is the process of cooling or removing heat. It is the process by which the temperature of a substance or a given space is lowered below that of the atmosphere or surrounding materials. This is done by transferring the heat from the substance or space being refrigerated to a colder medium, the refrigerant. The refrigerant is subjected to certain temperatures, pressures, and physical states to permit it to take up heat from the substance to be cooled and to reject the absorbed heat to the atmosphere or seawater. Knowledge of the nature and effects of heat and physical conditions affecting the refrigerant are necessary to understand the operation of any refrigerant plant.

516-1.2.2 TERMS. The following paragraphs describe terms and language peculiar to the refrigeration industry; familiarity with them saves time and permits more concise instructions.

516-1.2.2.1 Pumping Down. Whenever a reciprocating system is to be opened to the atmosphere for service operations or repairs, it is necessary to remove the refrigerant from the part of the system to be opened. The refrigerant is confined to the receiver by closing the liquid-line stop valve and operating the machine. Thus, all the gas is drawn back to the compressor and condensed in the condenser but is prevented from going farther by the liquid stop valve.

516-1.2.2.2 Backseating a Valve. The compressor discharge and suction stop valves are usually provided with a double seating valve and a gauge tap. Turning the valve stem all the way to the right (forward) closes the valve outlet, and in this position, the gauge connection is open to the pressure in the compressor. Turning the valve stem all the way to the left (out) backseats the valve and closes off the gauge connection. Therefore, when attaching a gauge or charging line to the gauge opening, backseat the valve to prevent escape of refrigerant from the gauge tap.

516-1.2.2.3 Charging. This term denotes addition of refrigerant from an external cylinder to a system.

516-1.2.2.4 Purging. Purging is the release of air or noncondensable gases from a system, usually through a petcock placed on or near the top of the condenser.

516-1.2.2.5 Slugging. The liquid refrigerant returning to the compressor causes noisy valves. Also, the oil being pumped out of the compressor crankcase or returning to the compressor in a solid mass causes knock in the compressor.

516-1.2.2.6 Low-Side. Low-side is that part of a system lying between the expansion valve and the suction valve in the compressor. It includes the evaporating or cooling surface, the suction line, and the compressor crankcase, which is that portion of the system under suction pressures. Sometimes the term is used to designate the evaporator coils.

516-1.2.2.7 High-Side. High-side designates the remainder of the system, excluding the low-side, that is under high pressure. It includes the discharge line, condenser, receiver, liquid line, and the compression discharge manifold. The term is also used sometimes to designate the condensing unit.

516-1.2.2.8 Water Regulating Valve. This valve is operated by the discharge (head) pressure. Located in the condenser water line inlet or outlet, the valve regulates water flow through the condenser to maintain a relatively constant head pressure. The valve should be configured to ensure the condenser tubes are full of water at all times.

516-1.2.2.9 Low-Pressure Control. The low-pressure control is an electrical contact device operated by the suction line pressure. It prevents compressor operation when the suction pressure falls below a predetermined point. It may be used either as an operating or safety control.

516-1.2.2.10 High-Pressure Control. This control is an electrical contact device operated by discharge pressure. It acts as a safety control to prevent damage to the compressor in case of dangerously high discharge pressure.

516-1.2.2.11 Frosting Back. This item refers to the appearance of frost on the suction line, extending as far back as the compressor.

516-1.2.2.12 Saturation. Saturation is the condition of the gaseous refrigerant in the presence of boiling liquid at a given pressure. In tables of refrigerant properties, corresponding temperatures and pressures are given at the saturation point.

516-1.2.2.13 Superheat. Superheat is the additional heat beyond that required to produce saturation at any specific pressure. Superheat is usually spoken of in terms of degrees Fahrenheit (degrees F) above the saturation temperature. For example, [Table 516-1-1](#) shows that the saturation temperature corresponding to 84 pounds gauge pressure is 80°F. If the temperature of the refrigerant at 84 pounds pressure is 90°F, the gas would have 10°F of superheat.

Table 516-1-1. R-12 PROPERTIES OF LIQUID AND SATURATED VAPOR

Temp (°F)	Pressure (psi)		Specific Volume ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
-40	9.32	10.92*	0.010564	3.8750	94.58	0.2557	0.00	73.50	73.50	-40
-38	9.82	9.91*	0.010586	3.6922	94.39	0.2683	0.40	73.34	73.34	-38
-36	10.34	8.87*	0.010607	3.5198	94.20	0.2815	0.81	73.17	73.98	-36
-34	10.87	7.80*	0.010629	3.3571	93.99	0.2951	1.21	73.01	74.22	-34
-32	11.43	6.66*	0.010651	3.2035	93.79	0.3092	1.62	72.84	74.46	-32
-30	12.02	5.45*	0.010674	3.0585	93.59	0.3238	2.03	72.67	74.70	-30
-28	12.62	4.23*	0.010696	2.9214	93.39	0.3390	2.44	72.50	74.94	-28
-26	13.26	2.93*	0.010719	2.7917	93.18	0.3546	2.85	72.33	75.18	-26
-24	13.90	1.63*	0.010741	2.6691	92.98	0.3706	3.25	72.16	75.41	-24
-22	14.58	0.24*	0.010764	2.5529	92.78	0.3871	3.66	71.98	75.64	-22
-20	15.28	0.58	0.010788	2.4429	92.58	0.4042	4.07	71.80	75.87	-20
-18	16.01	1.31	0.010811	2.3387	92.38	0.4219	4.48	71.63	76.11	-18
-16	16.77	2.07	0.010834	2.2399	92.18	0.4403	4.89	71.45	76.34	-16
-14	17.55	2.85	0.010858	2.1461	91.97	0.4593	5.30	71.27	76.57	-14
-12	18.37	3.67	0.010882	2.0572	91.77	0.4789	5.72	71.09	76.81	-12
-10	19.20	4.50	0.010906	1.9727	91.57	0.4993	6.14	70.91	77.05	-10
-8	20.06	5.38	0.010931	1.8924	91.35	0.5203	6.57	70.72	77.29	-8
-6	20.98	6.28	0.010955	1.8161	91.14	0.5420	6.99	70.53	77.52	-6
-4	21.91	7.21	0.010980	1.7436	90.93	0.5644	7.41	70.34	77.75	-4
-2	22.87	8.17	0.011005	1.6745	90.72	0.5872	7.83	70.15	77.96	-2
0	23.87	9.17	0.011030	1.6089	90.52	0.6109	8.25	69.96	78.21	0
2	24.89	10.19	0.011056	1.5463	90.31	0.6352	8.67	69.77	78.44	2
4	25.96	11.26	0.011082	1.4867	90.11	0.6606	9.10	69.57	78.67	4
6	27.05	12.35	0.011107	1.4299	89.88	0.6864	9.53	69.37	78.90	6
8	28.18	13.48	0.011134	1.3758	89.68	0.7129	9.96	69.17	79.13	8
10	29.35	14.65	0.011160	1.3241	89.45	0.7402	10.39	68.97	79.36	10
12	30.56	15.86	0.011187	1.2748	89.24	0.7687	10.82	68.77	79.59	12
14	31.80	17.10	0.011214	1.2778	89.03	0.7981	11.26	68.56	79.82	14
16	33.08	18.38	0.011241	1.1828	88.81	0.8288	11.70	68.35	80.05	16
18	34.40	19.70	0.011268	1.1399	88.58	0.8598	12.12	68.15	80.27	18
20	35.75	21.05	0.011296	1.0988	88.37	0.8921	12.55	67.94	80.49	20
22	37.15	22.45	0.011324	1.0596	88.13	0.9251	13.00	67.72	80.72	22

Table 516-1-1. R-12 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
24	38.58	23.88	0.011352	1.0220	87.91	0.9588	13.44	67.51	80.95	24
26	40.07	25.37	0.011380	0.98612	87.68	0.9930	13.88	67.29	81.17	26
28	41.59	26.89	0.011409	0.95173	87.47	1.028	14.32		81.39	28
30	43.16	28.46	0.011438	0.91880	87.24	1.065	14.76	66.85	81.61	30
32	44.77	30.07	0.011468	0.88725	87.02	1.102	15.21	66.62	81.83	32
34	46.42	31.72	0.011497	0.85702	86.78	1.140	15.65	66.40	82.05	34
36	48.13	33.43	0.011527	0.82803	86.55	1.180	16.10	66.17	82.27	36
38	49.88	35.18	0.011557	0.80023	86.33	1.221	16.55	65.94	82.49	38
40	51.68	36.98	0.011588	0.77357	85.88	1.263	17.00	65.71	82.71	40
42	53.51	38.81	0.011619	0.74798	85.66	1.304	17.46	65.47	82.93	42
44	55.40	40.70	0.011650	0.72341	85.43	1.349	17.91	65.24	83.15	44
46	57.35	42.65	0.011682	0.69982	85.19	1.393	18.36	65.00	83.36	46
48	59.35	44.65	0.011714	0.67715		1.438	18.82	64.74	83.57	48
50	61.39	46.69	0.011746	0.65537	84.94	1.485	19.27	64.51	83.78	50
52	63.49	48.79	0.011779	0.63444	84.71	1.534	19.72	64.27	83.99	52
54	65.63	50.93	0.011811	0.61431	84.50	1.583	20.18	64.02	84.20	54
56	67.84	53.14	0.011845	0.59495	84.28	1.633	20.64	63.77	84.41	56
58	70.10	55.40	0.011879	0.57632	84.04	1.686	21.11	63.51	84.62	58
60	72.41	57.71	0.011913	0.55839	83.78	1.740	21.57	63.25	84.82	60
62	74.77	60.07	0.011947	0.54112	83.57	1.795	22.03	62.99	85.02	62
64	77.20	62.50	0.011982	0.52450	83.34	1.851	22.49	62.73	85.22	64
66	79.67	64.97	0.012017	0.50848	83.10	1.909	22.95	62.47	85.42	66
68	82.24	67.54	0.012053	0.49305	82.86	1.968	23.42	62.20	85.62	68
70	84.82	70.12	0.012089	0.47818	82.60	2.028	23.90	61.92	85.82	70
72	87.50	72.80	0.012126	0.46383	82.37	2.090	24.37	61.65	86.02	72
74	90.20	75.50	0.012163	0.45000	82.12	2.153	24.84	61.38	86.22	74
76	93.00	78.30	0.012201	0.43666	81.87	2.218	25.32	61.10	86.42	76
78	95.85	81.15	0.012239	0.42378	81.62	2.284	25.80	60.81	86.61	78
80	98.76	84.06	0.012277	0.41135	81.39	2.353	26.28	60.52	86.80	80
82	101.7	87.00	0.012316	0.39935	81.12	2.423	26.76	60.23	86.99	82
84	104.8	90.10	0.012356	0.38776	80.87	2.495	27.24	59.94	87.18	84

Table 516-1-1. R-12 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
86	107.9	93.20	0.012396	0.37657	80.63	2.569	27.72	59.65	87.37	86
88	111.1	96.40	0.012437	0.36575	80.37	2.645	28.21	59.35	87.56	88
90	114.3	99.6	0.012478	0.35529	80.11	2.721	28.70	59.04	87.74	90
92	117.7	103.0	0.012520	0.34518	79.86	2.799	29.19	58.73	87.92	92
94	121.0	106.3	0.012562	0.33540	79.60	2.880	29.68	58.42	88.10	94
96	124.5	109.8	0.012605	0.32594	79.32	2.963	30.18	58.10	88.28	96
98	128.0	133.3	0.012649	0.31679	79.06	3.048	30.67	57.78	88.45	98
100	131.6	116.9	0.012693	0.30794	78.80	3.135	31.16	57.46	88.62	100
102	135.3	120.6	0.012738	0.29937	78.54	3.224	31.65	57.14	88.79	102
104	139.0	124.3	0.012783	0.29106	78.27	3.316	32.15	57.00	88.95	104
106	142.8	128.1	0.012829	0.28303	78.00	3.411	32.65	56.46	89.17	106
108	146.8	132.1	0.012876	0.27524	77.73	3.509	33.15	56.12	89.21	108
110	150.7	136.0	0.012924	0.26769	77.46	3.610	33.65	55.78	89.43	110
112	154.8	140.1	0.012972	0.26037	77.18	3.714	34.15	55.43	89.58	112
114	158.9	144.2	0.013022	0.25328	76.89	3.828	34.65	55.08	89.73	114
116	163.1	148.4	0.013072	0.24641	76.60	3.934	35.15	54.72	89.87	116
118	167.4	152.7	0.013123	0.23974	76.32	4.049	35.65	54.36	90.01	118
120	171.8	157.1	0.013174	0.23326	76.02	4.167	36.16	53.99	90.15	120
122	176.2	161.5	0.013227	0.22698	75.72	4.288	36.66	53.62	90.28	122
124	180.8	166.1	0.013280	0.22089	75.40	4.413	37.16	53.24	90.40	124
126	185.4	170.7	0.013333	0.22089	75.10	4.541	37.67	52.85	90.52	126
128	190.1	175.4	0.013386	0.21480	74.78	4.673	38.18	52.46	90.64	128
130	194.9	180.2	0.013447	0.20262	74.46	4.808	38.69	52.07	90.76	130
132	199.8	185.1	0.013500	0.19653	74.13	4.948	39.19	51.67	90.86	132
134	204.8	190.1	0.013553	0.19044	73.81	5.094	39.70	51.26	90.96	134
136	209.9	195.2	0.013606	0.18435	73.46	5.247	40.21	50.85	91.06	136
138	215.0	200.3	0.013659	0.17826	73.10	5.405	40.72	50.43	91.15	138
140	220.2	205.5	0.013746	0.17799	72.73	5.571	41.24	50.00	91.24	140

NOTE: Inches of mercury below one atmosphere.

516-1.2.2.14 Refrigeration Plant. A refrigeration plant is any type of unit that takes away heat from a medium.

516-1.3 HEAT

516-1.3.1 GENERAL. Heat is a form of energy. It cannot be created or destroyed. Heat is never lost and can only be transferred from one object to another. It cannot be seen, shaped, or touched. It is known through its effects on the human body and on other matter. When air is cooled, a certain amount of heat is transferred from it to some other substance at a lower temperature.

516-1.3.2 CHARACTERISTICS OF HEAT. Since refrigeration is the definite transfer of heat, it is helpful to discuss briefly some characteristics of heat itself. Heat is a distinct property of all matter and the quantity of heat depends upon the temperature, the quantity of substance, and the type of substance involved. As stated, heat always flows from the warmer to the colder substance and it is this fact that gives us the basis of the science of refrigeration.

516-1.3.3 HEAT MEASUREMENT. Heat is measured by its intensity and by the quantity of it possessed by its substance. This is readily understood by comparing a spoonful of hot water with a pail full of warm water; the hot water in the spoon has a greater intensity of heat but the warm water in the pail possesses a larger quantity of heat, though at a lower intensity.

516-1.3.3.1 Intensity. Heat intensity or temperature is ordinarily measured by a thermometer. The unit of temperature most used in the refrigeration industry is the degree Fahrenheit (degrees F). The degree Fahrenheit is 1/180 of the difference between the temperature of melting ice and that of water boiling under standard atmospheric pressure. On this scale the boiling point of water is 212°F and the melting point of ice is 32°F, the difference between these two points being 180°F as mentioned above. The following equations are used to convert between °C and °F:

$$^{\circ}\text{F} = 9/5 (^{\circ}\text{C} + 32)$$

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$$

516-1.3.3.2 Quantity. The quantity of heat is most commonly measured in terms of the British thermal unit (Btu). The Btu is the quantity of heat required to raise the temperature of 1 pound of pure water at or near 39°F the temperature at which water is at maximum density by 1°F. For example, to raise the temperature of 5 pounds of water from 39°F to 49°F or from 160°F to 170°F requires $5 \times 10 = 50$ Btu. The quantity of heat required to change the temperature of 1 pound of water 1°F does vary slightly with the initial temperature of the water. The variation is slight, however, and for most practical purposes may be disregarded.

516-1.4 KINDS OF HEAT

516-1.4.1 SPECIFIC HEAT. The specific heat of a substance is the ratio of the amount of heat required to raise the temperature of a unit weight of the substance 1°F to the heat required to raise the same weight of water 1°F. Since by definition the specific heat of water is equal to 1, the specific heat of other substances is expressed in decimals. The specific heat of a substance is thus numerically the quantity of heat required to change the temperature of 1 pound of the substance by 1°F. A few examples are ice, 0.504; cast iron, 0.119; and alcohol, 0.70. Thus it takes about half as much heat to change the temperature of a pound of ice by 1°F as it does to change the temperature of a pound of water.

516-1.4.2 SENSIBLE HEAT. Matter can exist in three different physical states; solid, liquid, or gas. For example, water is a liquid, but this same substance can exist as ice, which is a solid, or as steam, which is a gas. Sensible heat is that heat added or removed from matter that can be measured by a change in temperature of the matter. The term sensible heat is used because the change in temperature it causes is indicated by a thermometer and can be detected with the human senses. For example, if a person puts a finger in a cup of water, his or her senses indicate whether it is cold, cool, hot, or very hot.

516-1.4.3 LATENT HEAT. Latent heat is that heat added or removed that cannot be measured by a change in temperature but accomplishes a change in state. It is the heat contained in a substance by virtue of its physical state. When the change of state occurs between the solid and liquid phases, or conversely between the liquid and solid phases, the heat involved is known as the latent heat of fusion. When the change occurs between the liquid and vapor phases, or conversely between the vapor and liquid phases, the heat involved is known as the latent heat of vaporization.

516-1.4.3.1 Latent Heat of Fusion. If heat is added to a piece of ice at a low temperature such as 0°F, the temperature of the ice gradually rises. This change in temperature, which is indicated by a thermometer placed on the ice, is a measure of sensible heat. No change of state occurs during this rise in temperature. The ice remains a solid. But as more heat is added to the ice, a temperature is finally reached at which the ice begins to melt or turn into a liquid. This added heat now changes the physical state of the water from the solid state to the liquid state. The temperature of the ice stops rising and remains constant throughout the melting period (32°F at sea-level atmospheric pressure). In other words, the heat added at this temperature does not cause any rise in the temperature until the conversion from the solid to the liquid state is complete. Heat, when used in the conversion of a solid to a liquid, is called latent heat of fusion, the word latent meaning hidden or not indicated on a thermometer as a temperature change. Note that if we continue to apply heat after the last bit of ice melts, the temperature will again rise. The heat is now called sensible heat. The reverse process can also take place. If liquid water at 32 °F and at sea-level atmospheric pressure is cooled, it is converted (frozen) to ice. The latent heat of fusion for pure water at 32°F at sea-level pressure is approximately 144 Btu per pound. Other substances have different latent heat quantities.

516-1.4.3.2 Latent Heat of Vaporization. Similarly, if heat is applied to a container filled with cold water, the temperature of the liquid water gradually rises, as indicated on a thermometer placed in it. The heat causing the rise in temperature is sensible heat. The water undergoes no physical change of state, it remains a liquid until the temperature rises to 212°F. At this point, the liquid begins to boil, then turns into steam (vapor) and the temperature stops rising. Throughout the boiling (the vaporization) of the liquid water, its temperature remains unchanged at 212°F. All the heat added is the heat of vaporization, which acts entirely to change the physical state of the water from a liquid to a vapor. For the same amount of a particular substance, exactly the same quantity of latent heat of vaporization shall be added in changing it from a liquid to a vapor as shall be removed in changing it from a vapor to a liquid. All substances differ in the quantity of latent heat required per unit amount. For pure water at 212°F at sea-level pressure, the latent heat of vaporization is approximately 970 Btu per pound. This value varies, of course, for different pressures and temperatures of the same substance. The reverse process also takes place. If steam at 212°F at sea-level pressure is cooled, it converts (condenses) to liquid water. Throughout this condensation process, no change in temperature occurs. All the heat removed is latent heat of vaporization, which is used entirely in condensing the vapor to a liquid, that is, in changing its physical state.

516-1.4.4 TOTAL HEAT. The total heat of a substance (sometimes referred to as heat content) at any particular condition is the sum total of all the sensible and latent heat calculated from absolute zero (-460°F). This measure is not practical, however, and is not used. For engineering calculations, only differences in total heat at the start and the end of a process are of interest. Consequently, the total heat is generally calculated from some arbitrary

trary zero point. For example, 32°F is the arbitrary zero point for liquid water and steam and -40°F is the zero point for refrigerants. The total heat of a substance then is: Total Heat = Sensible Heat + Latent Heat.

516-1.4.5 SIMPLE HEAT DIAGRAM. In [Figure 516-1-1](#), the data on changes of state, variation of temperature, and the number of Btus required in such a change for 1 pound of water, are presented for a temperature range from 0°F to 225°F at normal atmospheric pressure.

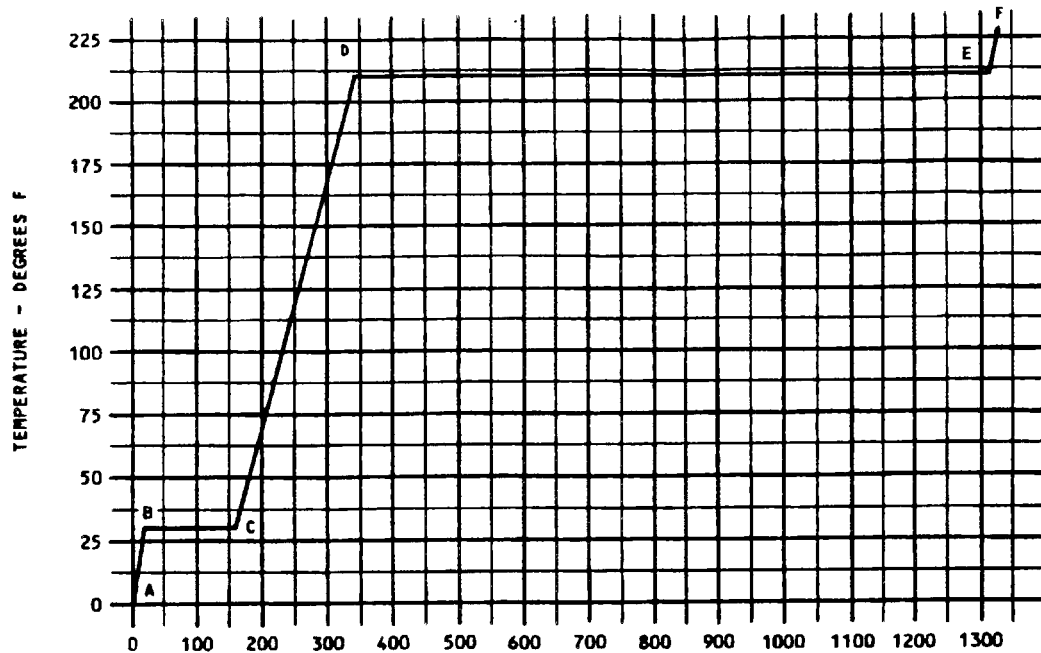


Figure 516-1-1. Change of State and Btu Required for Water

516-1.4.6 HEAT TRANSFER. A transfer of heat will occur from one body to another when a temperature difference exists between the two bodies. If the temperature of the bodies is the same, there is no heat transfer. Heat is always transferred from the higher temperature to the lower temperature. The transfer of heat from one body to another can occur either singly or in combination, as described in paragraphs [516-1.4.7](#) through [516-1.4.9](#).

516-1.4.7 RADIATION. Heat transfer by radiation from one body to another occurs in the form of a wave motion similar to light waves or radio waves. No intervening matter is required for heat transfer by radiation. The sun transmits great amounts of heat energy to the Earth by radiation across the vacuum of space. The heat radiated by a fire can be readily felt by anyone standing close to it. Heat transfer by radiation will occur between any two bodies that are visible to one another and have differing temperatures.

516-1.4.8 CONDUCTION. Heat transfer by conduction occurs when energy is transmitted by direct contact between molecules of a single body or between molecules of two or more bodies in physical contact with each other. For example, if one end of a metal rod is heated over a flame, heat will be transferred by conduction to the cooler end of the rod. Also, as the rod is heated, the air immediately surrounding the rod will be heated by conduction. Some of the heat supplied to the rod by the flame is thus conducted to the air. Thus, physical contact is necessary for conduction of heat.

516-1.4.9 CONVECTION. Heat transfer by convection occurs when heat moves from one place to another by means of currents within some fluid medium. For example, if a tank of water is heated by a flame applied to a

point on its bottom, heat will be conducted through the bottom to the water inside. As the water near the flame is heated, it expands and begins to rise. The warmer water is replaced by cooler, denser water pushing in from the sides. As the new water is heated it too rises and is replaced by cooler water. Heat is thus transferred throughout the water in the tank by means of the convection, or motion, of the heated stream of water particles.

516-1.4.10 THERMAL CONDUCTIVITY. Heat transfer will occur between two materials of different temperature, the heat flowing from the high temperature body to the low temperature body. All materials, however, do not conduct heat at the same rate. Some materials, such as metals, conduct heat readily, whereas others, such as wood and cork, offer considerable resistance to the conduction of heat. The relative capacity of a material to conduct heat is known as its thermal conductivity. In general, solids are better conductors of heat than liquids and liquids are better conductors than gases. Materials that are poor conductors (have a low thermal conductivity) are used as heat insulators. If a substance or an enclosed space shall be kept hot, the heat already present shall be prevented from flowing out. If a substance shall be kept cold, heat shall be prevented from flowing in. Fortunately, this can be done fairly successfully by using the low thermal conductances of certain substances.

516-1.5 PRESSURE AND TEMPERATURE

516-1.5.1 ATMOSPHERIC PRESSURE. Everything on or in the Earth is subject to various pressures; for example, everything open to the air is under atmospheric pressure, which is caused by the weight of the air above it. With the air near sea level at 32°F, the weight or pressure of a column of air 1-inch square in a cross-sectional area at the base and reaching from sea level to the upper limit of the Earth’s atmosphere is 14.696 pounds. This value varies slightly from day to day because of changing conditions in the atmosphere. For practical engineering purposes, standard sea-level pressure is considered as 14.7 pound force per square inch (psi).

516-1.5.2 VARIATIONS OF PRESSURE AND TEMPERATURE. If an uncovered container filled with fresh water at sea level is heated until the water boils, a thermometer inserted in the water shows that its temperature is 212°F, and a barometer shows that the atmospheric pressure is approximately 14.7 psi. However, if the pot of boiling water is on a hilltop 1,000 feet above sea level, the thermometer shows that the water boils at 210°F when the barometer reads approximately 14.14 psi. Similar variations in boiling point and barometric pressure are observed at different heights as indicated in [Table 516-1-2](#).

Table 516-1-2. PRESSURE-TEMPERATURE RELATIONSHIP

Altitude Above Sea Level in Feet	Pressure in Psi	Boiling Point of Water in °F
0	14.70	212
2000	13.57	208
4000	12.49	204
6000	11.54	200
8000	10.62	196

516-1.5.3 PRESSURE-TEMPERATURE RELATIONSHIP. It is not variations of pressure and temperature at different altitudes to which special attention is directed here but the relationship between the vaporization temperature and the corresponding pressure. It is not necessary to go to different heights to obtain different pressures. Different pressures may be obtained by mechanical means at any location; for example, a boiling liquid and its vapor may be contained in an airtight metal cylinder with a piston. By pushing in or pulling out the piston the pressure within may be increased or decreased. If the piston is pushed in, thus increasing the pressure inside, a thermometer shows that the change of state from liquid to vapor requires a temperature higher than 212°F. If the

piston is pulled out, thus decreasing the pressure within, the thermometer shows that the change of state from liquid to vapor takes place at a temperature lower than 212°F; therefore, a liquid can be vaporized at any desired temperature by changing the pressure above it. The science of refrigeration is based on this fact. This relationship of vaporization temperature and pressure, which varies for different substances, follows an exact law and may be tabulated accurately for each substance or refrigerant.

516-1.6 CHANGE OF STATE

516-1.6.1 EBULLITION. Ebullition is the technical term for ordinary boiling. It is a rapid and visible process. By looking into an uncovered container of boiling water, one can see that ebullition (bubbling) is taking place. Starting from the bottom and sides, large and small bubbles rise to the surface and break out of the liquid.

516-1.6.2 EVAPORATION. Evaporation is a slow and invisible process that takes place only from the surface of a liquid. Under ordinary conditions evaporation cannot be seen. Any liquid in an uncovered container will gradually evaporate, its level falling very slowly until all the liquid is gone. Water vapor continually evaporates from the surfaces of all open bodies of water, rivers, lakes, and seas. Wet clothing or washed articles hung on a line dry by evaporation. Since evaporation is a form of vaporization, it results in the removal of latent heat; therefore, it is a cooling process, although a slow one. When people go swimming on a cool day with a wind blowing, the evaporation process makes them feel uncomfortable as they come out of the water rather than the temperature itself.

516-1.6.3 SUBLIMATION. There is a third method of converting from one physical state to another. This process is called sublimation and consists of changing from a solid state directly to the vapor state, without passing through an intermediate liquid state. Ice and snow, even when much below the freezing point, slowly disappear without melting. Washed clothing hung outdoors in a temperature below 32°F, first freeze stiff and then dry soft. Both these phenomena are caused by sublimation. Sublimation has little application to refrigeration engineering. It has, however, considerable use in the small-scale cooling of bottled goods, ice cream, and other foodstuffs by the use of solid carbon dioxide (dry ice), which sublimates to a vapor under atmospheric pressure.

516-1.7 VAPORS

516-1.7.1 SATURATED VAPOR. When the temperature of a liquid is raised to the boiling point corresponding to its pressure, the liquid and gas can exist together in a condition described as saturated. The temperature of the system in this condition is called the saturation temperature. A vapor ordinarily exists in either of two conditions, as saturated vapor or as superheated vapor (paragraph [516-1.7.1.3](#)). A saturated vapor is one that is at the temperature corresponding to the boiling point of its liquid at any given pressure. The boiling liquid and its saturated vapor are always at the same temperature. A saturated vapor may also be described as a vapor at a temperature such that any cooling of the vapor will cause a portion of the vapor to condense to the liquid state. It is important to understand that the saturation temperature of the liquid (the temperature at which the liquid will vaporize if heat is applied) and the saturation temperature of the vapor (the temperature at which the vapor will condense if heat is removed) are the same for any given pressure.

516-1.7.1.1 Wet Saturated Vapor. When a vapor contains some liquid particles in the form of fine mist or tiny droplets, it is called wet saturated vapor. The amount of liquid in the vapor is often referred to as the quality of the vapor and generally is expressed as percent liquid (or percent wet).

516-1.7.1.2 Dry Saturated Vapor. When no liquid particles are present, the vapor is said to be dry saturated vapor. In practice, vapors are usually wet. It is not easy to produce a completely dry vapor because boiling, by its agitation of the liquid and rising bubbles of vapor, always throws a number of liquid particles out beyond the surface of the liquid. Some of these liquid particles remain suspended and are carried by the vapor. Another example is in any long piping system, a small loss of heat through the pipes is probable. This causes some condensation with the resulting appearance of liquid mist in the vapor.

516-1.7.1.3 Superheated Vapor. Saturated vapor and the boiling liquid with which it is in contact have only one temperature and that temperature is the result of the existing pressure. If a vapor is not in contact with a boiling liquid, either because the liquid has all been converted into vapor or because the vapor has been separated from contact with the boiling liquid, further application of heat produces a rise in the temperature of the vapor under the same given pressure. Such a vapor is called superheated vapor.

516-1.7.1.4 Quantity of Superheat. The quantity of superheat in such a vapor is equal to the difference between its temperature and the temperature of its saturated vapor at the same pressure. For example, superheated vapor at 20°F above its saturated temperature is said to contain 20°F of superheat.

516-1.7.2 SUBCOOLED LIQUID. If, after condensation at any given pressure, a liquid is cooled so that its temperature is reduced below the corresponding saturation temperature, the liquid is said to be subcooled. A liquid at any temperature below the saturation temperature and above the fusion point is a subcooled liquid.

516-1.8 EFFECTS OF HEAT ON VOLUME

516-1.8.1 VARIATION IN VOLUME. A change in temperature affects the volume of a substance. In general, all substances - solids, liquids, and gases - decrease in volume when cooled and increase in volume when heated. In gases and vapors, the amount of change is relatively large; in liquids and solids, it is relatively small. In all cases, great forces are produced particularly with liquids as they are incompressible. It is necessary to allow for the operation of these forces. Different substances vary in the amount of change in volume they undergo for the same difference in temperature. With a change in volume, the density changes; the larger the volume a substance assumes, the lower the density; and the smaller the volume a substance assumes, the higher the density.

516-1.8.1.1 Specific Volume. The specific volume of a substance is the number of cubic feet occupied by 1 pound of that substance at a given temperature and pressure. Specific volume varies greatly for different substances and for the same substance at different temperatures and pressures. For example, the specific volume of liquid boiling water at atmospheric pressure is 0.0167 cubic feet per pound, and of steam at the same pressure, is 26.79 cubic feet per pound. Thus, water in changing its state from liquid to vapor at ordinary atmospheric pressure increases in volume approximately 1,604 times (26.79 divided by 0.0167).

516-1.8.1.2 Density. The density of a material is the weight in pounds of 1 cubic foot of the material. Density is the reciprocal of specific volume, that is, one divided by the specific volume. For example, the density of liquid water boiling at atmospheric pressure is approximately 59.88 pounds (1 divided by 0.0167) and of steam at the same pressure is approximately 0.0373 pounds (1 divided by 26.79).

516-1.8.2 REFRIGERANTS. In any refrigerating process the medium employed as the heat absorber or cooling agent is called the refrigerant. Refrigerants in common use are fluids that are affected by heat, temperature, and pressure in a manner similar to water. Water is the refrigerant used in lithium-bromide absorption plants and steam jet plants. Many different fluids are used as refrigerants, their selection being based on low boiling points

and other desirable characteristics. A considerable number of substances can be used as refrigerants, such as chloroform, ether, air, ammonia, methyl chloride, carbon dioxide, butane, propane, and sulfur dioxide. None of these fluids, however, have all of the characteristics desirable in a refrigerant.

516-1.8.3 DEVELOPMENT OF SYNTHESIZED REFRIGERANTS. As a result of research and development, physical chemists exploring the field of hydrocarbons of the methane and ethane series found that by juggling atoms of these hydrocarbons, and substituting chlorine or fluorine atoms, or both chlorine and fluorine atoms for hydrogen atoms, almost any type of refrigerant needed for a specific use or for a specific type of equipment can be synthesized. This permitted development of nonflammable and less dangerous refrigerants having suitable operating characteristics. These halogenated hydrocarbons were originally known as Freons (trademark of DuPont de Nemours and Co.). These refrigerants are currently available under a variety of trade names in addition to Freon. Refrigerants are identified by a standard designation system developed by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers. The following six halocarbon refrigerants are normally used in naval shipboard refrigerating systems:

- a. Chemical Name: Dichlorodifluoromethane; Formula: CCl_2F_2 ; Standard Designation: R-12
- b. Chemical Name: Trichloromonofluoromethane; Formula: CCl_3F ; Standard Designation: R-11
- c. Chemical Name: Monochlorodifluoromethane; Formula: CHClF_2 ; Standard Designation: R-22
- d. Chemical Name: 1,2-dichlorotetrafluoroethane; Formula: $\text{C}_2\text{Cl}_2\text{F}_4$; Standard Designation: R-114
- e. Chemical Name: 1,1,1,2-tetrafluoroethane; Formula: CH_2FCF_3 ; Standard Designation: R-134a
- f. Chemical Name: 1,1,1,3,3,3-hexafluoropropane; Formula: $\text{CF}_3\text{CH}_2\text{CF}_3$; Standard Designation: R-236fa

516-1.8.3.1 Halocarbon Refrigerants. Halocarbon refrigerants are colorless and practically odorless in concentrations of less than 20 percent by volume in air. In higher concentrations some have a slightly sweet ethereal odor resembling that of the dry cleaning fluid tetrachloroethylene. These refrigerants are all heavier than air but have different specific volumes, boiling points, and various pressures at which they liquefy under ordinary temperatures. These characteristics are given in [Table 516-1-1](#), [Table 516-1-3](#), [Table 516-1-4](#), [Table 516-1-5](#), [Table 516-1-6](#), and [Table 516-1-7](#).

Table 516-1-3. R-11 PROPERTIES OF LIQUID AND SATURATED VAPOR

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
-40	0.7391	28.42*	0.00988	44.21	101.25	0.02262	0.00	87.48	87.48	-40
-38	0.7916	28.31*	0.00989	41.47	101.10	0.02411	0.39	87.33	87.72	-38
-36	0.8471	28.20*	0.00991	38.93	100.96	0.02569	0.79	87.17	87.96	-36
-34	0.9060	28.08*	0.00992	36.57	100.81	0.02735	1.18	87.02	88.20	-34
-32	0.9682	27.95*	0.00993	34.37	100.66	0.02910	1.58	86.86	88.44	-32
-30	1.034	27.81*	0.00995	32.33	100.52	0.03093	1.97	86.70	88.67	-30
-28	1.103	27.67*	0.00996	30.44	100.37	0.03285	2.36	86.55	88.91	-28
-26	1.176	27.53*	0.00998	28.68	100.22	0.03487	2.75	86.40	89.15	-26
-24	1.253	27.37*	0.00999	27.03	100.07	0.03700	3.15	86.24	89.39	-24
-22	1.334	27.20*	0.01001	25.50	99.92	0.03922	3.55	86.08	89.63	-22
-20	1.420	27.03*	0.01002	24.06	99.77	0.04157	3.94	85.93	89.87	-20
-18	1.510	26.85*	0.01004	22.72	99.63	0.04401	4.33	85.78	90.11	-18
-16	1.605	26.65*	0.01005	21.47	99.48	0.04658	4.73	85.62	90.35	-16
-14	1.705	26.45*	0.01007	20.30	99.33	0.04927	5.12	85.47	90.59	-14
-12	1.810	26.24*	0.01008	19.20	99.18	0.05209	5.52	85.31	90.83	-12
-10	1.920	26.01*	0.01010	18.17	99.03	0.05503	5.91	85.16	91.07	-10
-8	2.035	25.78*	0.01011	17.21	98.87	0.05810	6.31	85.00	91.31	-8
-6	2.156	25.53*	0.01013	16.32	98.72	0.06129	6.70	84.85	91.55	-6
-4	2.283	25.27*	0.01015	15.47	98.57	0.06464	7.10	84.69	91.79	-4
-2	2.416	25.00*	0.01016	14.68	98.42	0.06813	7.49	84.54	92.03	-2
0	2.555	24.72*	0.01018	13.94	98.27	0.07176	7.89	84.38	92.27	0
2	2.700	24.42*	0.01019	13.24	98.11	0.07554	8.28	84.23	92.51	2
4	2.852	24.11*	0.01021	12.58	97.96	0.07949	8.68	84.07	92.75	4
5**	2.931	23.95*	0.01022	12.27	97.88	0.08152	8.88	84.00	92.88	5**
6	3.012	23.79*	0.01022	11.96	97.81	0.08361	9.08	83.92	93.00	6
8	3.179	23.45*	0.01024	11.38	97.65	0.08790	9.48	83.76	93.24	8
10	3.352	23.10*	0.01026	10.83	97.50	0.09233	9.88	83.60	93.48	10
12	3.534	22.73*	0.01027	10.31	97.34	0.09697	10.28	83.45	93.72	12
14	3.724	22.34*	0.01029	9.823	97.19	0.1018	10.68	83.29	93.97	14
16	3.923	21.94*	0.01031	9.359	97.03	0.1068	11.07	83.14	94.21	16
18	4.129	21.52*	0.01032	8.925	96.88	0.1120	11.47	92.98	94.45	18
20	4.342	21.08*	0.01034	8.519	96.72	0.1174	11.87	82.82	94.69	20

Table 516-1-3. R-11 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
22	4.567	20.62*	0.01036	8.129	96.57	0.1230	12.27	82.66	94.94	22
24	4.801	20.15*	0.01037	7.760	96.41	0.1289	12.68	82.50	95.18	24
26	5.043	19.66*	0.01039	7.414	96.25	0.1349	13.08	82.34	95.42	26
28	5.294	19.14*	0.01041	7.087	96.10	0.1411	13.48	82.18	95.66	28
30	5.557	18.61*	0.01042	6.776	95.94	0.1476	13.88	82.03	95.91	30
32	5.830	18.05*	0.01044	6.481	95.78	0.1543	14.28	81.87	96.15	32
34	6.115	17.47*	0.01046	6.200	95.62	0.1613	14.68	81.71	96.39	34
36	6.411	16.87*	0.01048	5.934	95.46	0.1685	15.08	81.55	96.63	36
38	6.718	16.25*	0.01049	5.682	95.30	0.1760	15.49	81.38	96.87	38
40	7.032	15.61*	0.01051	5.447	95.14	0.1836	15.89	81.22	97.11	40
42	7.362	14.94*	0.01053	5.220	94.98	0.1916	16.30	81.06	97.36	42
44	7.702	14.24*	0.01055	5.006	94.82	0.1998	16.70	80.90	97.60	44
46	8.055	13.52*	0.01056	4.802	94.66	0.2083	17.11	80.73	97.84	46
48	8.422	12.78*	0.01058	4.607	94.50	0.2170	17.52	80.57	98.08	48
50	8.804	12.00*	0.01060	4.421	94.34	0.2262	17.92	80.40	98.32	50
52	9.199	11.20*	0.01062	4.245	94.18	0.2356	18.33	80.24	98.56	52
54	9.605	10.37*	0.01064	4.078	94.02	0.2452	18.74	80.07	98.81	54
56	10.02	9.53*	0.01066	3.921	93.85	0.2550	19.15	79.90	99.05	56
58	10.45	8.65*	0.01067	3.770	93.69	0.2652	19.56	79.73	99.29	58
60	10.90	7.73*	0.01069	3.626	93.53	0.2758	19.96	79.57	99.53	60
62	11.37	6.78*	0.01071	3.487	93.36	0.2868	20.37	79.40	99.77	62
64	11.85	5.80*	0.01073	3.356	93.20	0.2980	20.78	79.23	100.01	64
66	12.35	4.78*	0.01075	3.229	93.04	0.3097	21.19	79.06	100.25	66
68	12.87	3.72*	0.01077	3.107	92.87	0.3219	21.61	78.88	100.49	68
70	13.40	2.64*	0.01079	2.993	92.71	0.3342	22.02	78.71	100.73	70
72	13.95	1.53*	0.01081	2.883	92.54	0.3469	22.43	78.54	100.97	72
74	14.51	0.39*	0.01083	2.779	92.38	0.3598	22.84	78.37	101.21	74
76	15.09	0.39	0.01085	2.679	92.21	0.3732	23.26	78.19	101.45	76
78	15.69	0.99	0.01086	2.584	92.04	0.3870	23.68	78.01	101.69	78
80	16.31	1.61	0.01088	2.492	91.88	0.4012	24.09	77.84	101.93	80
82	16.94	2.24	0.01090	2.406	91.71	0.4157	24.51	77.66	102.17	82

Table 516-1-3. R-11 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
84	17.60	2.90	0.01092	2.322	91.54	0.4307	24.93	77.48	102.41	84
86**	18.28	3.58	0.01094	2.242	91.38	0.4461	25.34	77.31	102.65	86**
88	18.97	4.27	0.01096	2.185	91.21	0.4619	25.76	77.13	102.89	88
90	19.69	4.99	0.01098	2.091	91.04	0.4783	26.18	76.95	103.12	90
92	20.43	5.73	0.01101	2.020	90.87	0.4950	26.60	76.76	103.36	92
94	21.19	6.49	0.01103	1.952	90.70	0.5122	27.01	76.58	103.59	94
96	21.97	7.27	0.01105	1.887	90.53	0.5299	27.43	76.40	103.83	96
98	22.77	8.07	0.01107	1.825	90.36	0.5480	27.85	76.21	104.07	98
100	23.60	8.90	0.01109	1.765	90.19	0.5666	28.27	76.03	104.30	100
102	24.45	9.75	0.01111	1.707	90.02	0.5857	28.70	75.84	104.54	102
104	25.33	10.63	0.01113	1.652	89.85	0.6054	29.12	75.65	104.77	104
106	26.23	11.53	0.01115	1.599	89.68	0.6256	29.54	75.46	105.00	106
108	27.15	12.45	0.01117	1.548	89.51	0.6461	29.97	75.27	105.24	108
110	28.09	13.39	0.01119	1.499	89.34	0.6671	30.40	75.08	105.47	110
112	29.05	14.35	0.01122	1.452	89.16	0.6885	30.82	74.89	105.71	112
114	30.04	15.34	0.01124	1.407	88.99	0.7107	31.24	74.70	105.94	114
116	31.07	16.37	0.01126	1.363	88.82	0.7335	31.67	74.50	106.17	116
118	32.11	17.41	0.01128	1.321	88.65	0.7570	32.10	74.30	106.40	118
120	33.20	18.50	0.01130	1.281	88.47	0.7808	32.53	74.10	106.63	120
122	34.29	19.59	0.01133	1.243	88.30	0.8049	32.95	73.91	106.86	122
124	35.42	20.72	0.01135	1.206	88.12	0.8296	33.38	73.71	107.09	124
126	36.56	21.86	0.01137	1.170	87.95	0.8550	33.81	73.51	107.32	126
128	37.74	23.04	0.01139	1.135	87.77	0.8811	34.24	73.31	107.55	128
130	38.96	24.26	0.01142	1.101	87.60	0.9080	34.67	73.11	107.78	130
132	40.23	25.53	0.01144	1.068	87.42	0.9361	35.10	72.90	108.00	132
134	41.50	26.80	0.01146	1.037	87.25	0.9646	35.54	72.69	108.23	134
136	42.80	28.10	0.01149	1.007	87.07	0.9927	35.97	72.49	108.46	136
138	44.12	29.42	0.01151	0.9785	86.88	1.022	36.40	72.28	108.68	138
140	45.50	30.80	0.01154	0.9505	86.69	1.052	36.84	72.07	108.91	140
142	46.92	32.22	0.01156	0.9231	86.50	1.083	37.28	71.85	109.13	142
144	48.35	33.65	0.01159	0.8970	86.32	1.115	37.71	71.64	109.35	144

Table 516-1-3. R-11 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
146	49.81	35.11	0.01161	0.8719	86.14	1.147	38.15	71.43	109.58	146
148	51.31	36.61	0.01163	0.8476	85.96	1.180	38.59	71.21	109.80	148
150	52.85	38.15	0.01166	0.8240	85.78	1.214	39.02	71.00	110.02	150
152	54.41	39.71	0.01168	0.8014	85.60	1.248	39.46	70.78	110.24	152
154	56.01	41.31	0.01171	0.7794	85.41	1.283	39.91	70.56	110.47	154
156	57.65	42.95	0.01173	0.7581	85.23	1.319	40.35	70.34	110.69	156
158	59.32	44.62	0.01176	0.7376	85.04	1.356	40.79	70.12	110.90	158
160	61.04	46.34	0.01179	0.7176	84.85	1.394	41.23	69.89	111.12	160
*Inches of mercury below one atmosphere.										
**Standard ton temperature.										

Table 516-1-4. R-114 PROPERTIES OF LIQUID AND SATURATED VAPOR

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
-40	1.866	26.12*	0.00978	14.02	102.25	0.07132	0.00	65.91	65.91	-40
-38	1.990	25.87*	0.00980	13.20	102.08	0.07574	0.45	65.74	66.19	-38
-36	2.121	25.60*	0.00981	12.44	101.90	0.08038	0.91	65.56	66.47	-36
-34	2.259	25.32*	0.00983	11.73	101.72	0.08524	1.36	65.38	66.74	-34
-32	2.404	25.03*	0.00985	11.07	101.55	0.09034	1.81	65.21	67.02	-32
-30	2.557	24.72*	0.00987	10.45	101.37	0.09568	2.27	65.03	67.30	-30
-28	2.718	24.39*	0.00988	9.877	101.19	0.1013	2.72	64.86	67.58	-28
-26	2.887	24.04*	0.00990	9.338	101.01	0.1071	3.17	64.68	67.86	-26
-24	3.064	23.68*	0.00992	8.833	100.83	0.1132	3.63	64.51	68.14	-24
-22	3.249	23.31*	0.00994	8.362	100.65	0.1196	4.08	64.34	68.42	-22
-20	3.444	22.91*	0.00995	7.921	100.47	0.1263	4.54	64.16	68.70	-20
-18	3.648	22.49*	0.00997	7.508	100.29	0.1332	4.99	63.99	68.98	-18
-16	3.862	22.06*	0.00999	7.121	100.11	0.1404	5.44	63.81	69.26	-16
-14	4.085	21.61*	0.01001	6.757	99.92	0.1480	5.90	63.64	69.54	-14
-12	4.319	21.13*	0.01003	6.416	99.74	0.1559	6.35	63.46	69.82	-12
-10	4.564	20.63*	0.01005	6.095	99.56	0.1641	6.81	63.29	70.10	-10
-8	4.819	20.11*	0.01006	5.794	99.37	0.1726	7.26	63.11	70.38	-8
-6	5.086	19.57*	0.01008	5.510	99.19	0.1815	7.72	62.94	70.66	-6
-4	5.365	19.00*	0.01010	5.244	99.00	0.1907	8.18	62.77	70.94	-4
-2	5.655	18.41*	0.01012	4.992	98.81	0.2003	8.63	62.59	71.22	-2
0	5.958	17.79*	0.01014	4.756	98.62	0.2103	9.09	62.42	71.50	0
2	6.274	17.15*	0.01016	4.533	98.44	0.2206	9.54	62.24	71.78	2
4	6.603	16.48*	0.01018	4.322	98.25	0.2314	10.00	62.07	72.07	4
5**	6.772	16.14*	0.01019	4.221	98.15	0.2369	10.23	61.98	72.21	5**
6	6.945	15.78*	0.01020	4.123	98.06	0.2425	10.46	61.89	72.35	6
8	7.301	15.06*	0.01022	3.935	97.87	0.2541	10.91	61.71	72.63	8
10	7.671	14.31*	0.01024	3.758	97.68	0.2661	11.37	61.54	72.91	10
12	8.057	13.52*	0.01026	3.591	97.48	0.2785	11.83	61.36	73.19	12
14	8.457	12.71*	0.01028	3.432	97.29	0.2914	12.29	61.19	73.47	14
16	8.873	11.86*	0.01030	3.282	97.10	0.3047	12.75	61.01	73.75	16
18	9.305	10.98*	0.01032	3.140	96.90	0.3185	13.20	60.83	74.04	18
20	9.753	10.07*	0.01034	3.005	96.71	0.3328	13.66	60.65	74.32	20

Table 516-1-4. R-114 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
22	10.22	9.12*	0.01036	2.877	96.51	0.3476	14.12	60.48	74.60	22
24	10.70	8.14*	0.01038	2.756	96.32	0.3629	14.58	60.30	74.88	24
26	11.20	7.12*	0.01040	2.641	96.12	0.3786	15.05	60.12	75.17	26
28	11.72	6.07*	0.01043	2.532	95.92	0.3949	15.51	59.94	75.45	28
30	12.25	4.99*	0.01045	2.429	95.73	0.4118	15.97	59.76	75.73	30
32	12.81	3.85*	0.01047	2.330	95.53	0.4292	16.43	59.58	76.01	32
34	13.38	2.69*	0.01049	2.236	95.33	0.4472	16.89	59.40	76.29	34
36	13.98	1.47*	0.01051	2.147	95.13	0.4658	17.36	59.22	76.58	36
38	14.59	0.22*	0.01053	2.062	94.93	0.4849	17.82	59.04	76.86	38
40	15.22	0.52	0.01056	1.982	94.73	0.5047	18.28	58.86	77.14	40
42	15.88	1.18	0.01058	1.905	94.52	0.5250	18.75	58.67	77.42	42
44	16.56	1.86	0.01060	1.832	94.32	0.5460	19.21	58.49	77.70	44
46	17.26	2.56	0.01063	1.762	94.12	0.5676	19.68	58.31	77.99	46
48	17.98	3.28	0.01065	1.695	93.91	0.5899	20.14	58.12	78.27	48
50	18.73	4.03	0.01067	1.632	93.71	0.6129	20.61	57.94	78.55	50
52	19.50	4.80	0.01070	1.571	93.50	0.6365	21.08	57.75	78.83	52
54	20.29	5.59	0.01072	1.513	93.30	0.6609	21.54	57.56	79.11	54
56	21.11	6.41	0.01074	1.458	93.09	0.6859	22.01	57.38	79.39	56
58	21.96	7.26	0.01077	1.405	92.88	0.7117	22.48	57.19	79.67	58
60	22.83	8.13	0.01079	1.354	92.68	0.7383	22.95	57.00	79.95	60
62	23.72	9.02	0.01082	1.306	92.47	0.7655	23.42	56.81	80.23	62
64	24.64	9.94	0.01084	1.260	92.26	0.7936	23.89	56.62	80.51	64
66	25.59	10.89	0.01086	1.216	92.05	0.8225	24.36	56.43	80.79	66
68	26.57	11.87	0.01089	1.174	91.84	0.8521	24.83	56.24	81.07	68
70	27.57	12.87	0.01091	1.133	91.63	0.8826	25.30	56.04	81.35	70
72	28.61	13.91	0.01094	1.094	91.41	0.9140	25.78	55.85	81.62	72
74	29.67	14.97	0.01097	1.057	91.20	0.9462	26.25	55.65	81.90	74
76	30.76	16.06	0.01099	1.021	90.99	0.9793	26.73	55.45	82.18	76
78	31.88	17.18	0.01102	0.9869	90.77	1.013	27.20	55.26	82.46	78
80	33.04	18.34	0.01104	0.9541	90.56	1.048	27.68	55.06	82.73	80
82	34.22	19.52	0.01107	0.9226	90.34	1.084	28.15	54.86	83.01	82

S9086-RW-STM-010/CH-516R4

S9086-RW-STM-010/CH-516R4

Table 516-1-5. R-22 PROPERTIES OF LIQUID AND SATURATED VAPOR

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
-50	11.674	6.154*	0.011235	4.2224	89.004	0.23683	-2.511	101.656	99.144	-50
-49	11.996	5.498*	0.011248	4.1166	88.905	0.24292	-2.262	101.519	99.257	-49
-48	12.324	4.829*	0.011261	4.0140	88.806	0.24913	-2.012	101.381	99.369	-48
-47	12.660	4.144*	0.011273	3.9145	88.707	0.25546	-1.762	101.242	99.480	-47
-46	13.004	3.445*	0.011286	3.8179	88.607	0.26192	-1.511	101.103	99.592	-46
-45	13.354	2.732*	0.011298	3.7243	88.507	0.26851	-1.260	100.963	99.703	-45
-44	13.712	2.002*	0.011311	3.6334	88.407	0.27523	-1.009	100.823	99.814	-44
-43	14.078	1.258*	0.011324	3.5452	88.307	0.28207	-0.757	100.683	99.925	-43
-42	14.451	0.498*	0.011337	3.4596	88.207	0.28905	-0.505	100.541	100.036	-42
-41	14.833	0.137	0.011350	3.3764	88.107	0.29617	-0.253	100.399	100.147	-41
-40	15.222	0.526	0.011363	3.2957	88.006	0.30342	0.000	100.257	100.257	-40
-39	15.619	0.923	0.011376	3.2173	87.905	0.31082	0.253	100.114	100.367	-39
-38	16.024	1.328	0.011389	3.1412	87.805	0.31835	0.506	99.971	100.477	-38
-37	16.437	1.741	0.011402	3.0673	87.703	0.32602	0.760	99.826	100.587	-37
-36	16.859	2.163	0.011415	2.9954	87.602	0.33384	1.014	99.682	100.696	-36
-35	17.290	2.594	0.011428	2.9256	87.501	0.34181	1.269	99.536	100.805	-35
-34	17.728	3.032	0.011442	2.8578	87.399	0.34992	1.524	99.391	100.914	-34
-33	18.176	3.480	0.011455	2.7919	87.297	0.35818	1.779	99.244	101.023	-33
-32	18.633	3.937	0.011469	2.7278	87.195	0.36660	2.035	99.097	101.132	-32
-31	19.098	4.402	0.011482	2.6655	87.093	0.37517	2.291	98.949	101.240	-31
-30	19.573	4.877	0.011495	2.6049	86.991	0.38389	2.547	98.801	101.348	-30
-29	20.056	5.360	0.011509	2.5460	86.888	0.39278	2.804	98.652	101.456	-29
-28	20.549	5.853	0.011523	2.4887	86.785	0.40182	3.061	98.503	101.564	-28
-27	21.052	6.536	0.011536	2.4329	86.682	0.41103	3.318	98.353	101.671	-27
-26	21.564	6.868	0.011550	2.3787	86.579	0.42040	3.576	98.202	101.778	-26
-25	22.086	7.390	0.011564	2.3260	86.476	0.42993	3.834	98.051	101.885	-25
-24	22.617	7.921	0.011578	2.2746	86.372	0.43964	4.093	97.899	101.992	-24
-23	23.159	8.463	0.011592	2.2246	86.269	0.44951	4.352	97.746	102.098	-23
-22	23.711	9.015	0.011606	2.1760	86.165	0.45956	4.611	97.593	102.204	-22
-21	24.272	9.576	0.011620	2.1287	86.061	0.46978	4.871	97.439	102.310	-21
-20	24.845	10.149	0.011634	2.0826	85.956	0.48018	5.131	97.285	102.415	-20
-19	25.427	10.731	0.011648	2.0377	85.852	0.49075	5.391	97.129	102.521	-19

Table 516-1-5. R-22 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
-18	26.020	11.324	0.011662	1.9940	85.747	0.50151	5.652	96.974	102.626	-18
-17	26.624	11.928	0.011677	1.9514	85.642	0.51245	5.913	96.817	102.730	-17
-16	27.239	12.543	0.011691	1.9099	85.537	0.52358	6.175	96.660	102.835	-16
-15	27.865	13.169	0.011705	1.8695	85.431	0.53489	6.436	96.502	102.939	-15
-14	28.501	13.805	0.011720	1.8302	85.326	0.54640	6.699	96.344	103.043	-14
-13	29.149	14.453	0.011734	1.7918	85.220	0.55810	6.961	96.185	103.146	-13
-12	29.809	15.113	0.011749	1.7544	85.114	0.56999	7.224	96.025	103.250	-12
-11	30.480	15.784	0.011764	1.7180	85.008	0.58207	7.488	95.865	103.353	-11
-10	31.162	16.466	0.011778	1.6825	84.901	0.59436	7.751	95.704	103.455	-10
-9	31.856	17.160	0.011793	1.6479	84.795	0.60685	8.015	95.542	103.558	-9
-8	32.563	17.867	0.011808	1.6141	84.688	0.61954	8.280	95.380	103.660	-8
-7	33.281	18.585	0.011823	1.5812	84.581	0.63244	8.545	95.217	103.762	-7
-6	34.011	19.315	0.011838	1.5491	84.473	0.64555	8.810	95.053	103.863	-6
-5	34.754	20.058	0.011853	1.5177	84.366	0.65887	9.075	94.889	103.964	-5
-4	35.509	20.813	0.011868	1.4872	84.258	0.67240	9.341	94.724	104.065	-4
-3	36.277	21.581	0.011884	1.4574	84.150	0.68615	9.608	94.558	104.166	-3
-2	37.057	22.361	0.011899	1.4283	84.042	0.70012	9.874	94.391	104.266	-2
-1	37.850	23.154	0.011914	1.4000	83.933	0.71431	10.142	94.224	104.366	-1
0	38.657	23.961	0.011930	1.3723	83.825	0.72872	10.409	94.056	104.465	0
1	39.476	24.780	0.011945	1.3453	83.716	0.74336	10.677	93.888	104.565	1
2	40.309	25.613	0.011961	1.3189	83.606	0.75822	10.945	93.718	104.663	2
3	41.155	26.459	0.011976	1.2931	83.497	0.77332	11.214	93.548	104.762	3
4	42.014	27.318	0.011992	1.2680	83.387	0.78865	11.483	93.378	104.860	4
5	42.888	28.192	0.012008	1.2434	83.277	0.80422	11.752	93.206	104.958	5
6	43.775	29.079	0.012024	1.2195	83.167	0.82003	12.022	93.034	105.056	6
7	44.676	29.980	0.012040	1.1961	83.057	0.83608	12.292	92.861	105.153	7
8	45.591	30.895	0.012056	1.1732	82.946	0.85237	12.562	92.688	105.250	8
9	46.521	31.825	0.012072	1.1509	82.835	0.86892	12.833	92.513	105.3446	9
10	47.464	32.768	0.012088	1.1290	82.724	0.88571	13.104	92.338	105.442	10
11	48.423	33.727	0.012105	1.1077	82.612	0.90275	13.376	92.162	105.538	11
12	49.396	34.700	0.012121	1.0869	82.501	0.92005	13.648	91.986	105.633	12

Table 516-1-5. R-22 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
13	50.348	35.688	0.012138	1.0665	82.389	0.93761	13.920	91.808	105.728	13
14	51.387	36.691	0.012154	1.0466	82.276	0.95544	14.193	91.630	105.823	14
15	52.405	37.709	0.012171	1.0272	82.164	0.97352	14.466	91.451	105.917	15
16	53.438	38.742	0.012188	1.0082	82.051	0.99188	14.739	91.272	106.011	16
17	54.487	39.791	0.012204	0.98961	81.938	1.0105	15.013	91.091	106.105	17
18	55.551	40.855	0.012221	0.97144	81.825	1.0294	15.288	90.910	106.198	18
19	56.631	41.935	0.012238	0.95368	81.711	1.0486	15.562	90.728	106.290	19
20	57.727	43.031	0.012255	0.93631	81.597	1.0680	15.837	90.545	106.383	20
21	58.839	44.143	0.012273	0.91932	81.483	1.0878	16.113	90.362	106.475	21
22	59.967	45.271	0.012290	0.90270	81.368	1.1078	16.389	90.178	106.566	22
23	61.111	46.415	0.012307	0.88645	81.253	1.1281	16.665	89.993	106.657	23
24	62.272	47.576	0.012325	0.87055	81.138	1.1487	16.942	89.807	106.748	24
25	63.450	48.754	0.012342	0.85500	81.023	1.1696	17.219	89.620	106.839	25
26	64.644	49.948	0.012360	0.83978	80.907	1.1908	17.496	89.433	106.928	26
27	65.855	51.159	0.012378	0.82488	80.791	1.2123	17.774	89.244	107.018	27
28	67.083	52.387	0.012395	0.81031	80.675	1.2341	18.052	89.055	107.107	28
29	68.328	53.632	0.012413	0.79604	80.558	1.2562	18.330	88.865	107.196	29
30	69.591	54.895	0.012431	0.78208	80.441	1.2786	18.609	88.674	107.284	30
31	70.871	56.175	0.012450	0.76842	80.324	1.3014	18.889	88.483	107.372	31
32	72.169	57.473	0.012468	0.75503	80.207	1.3244	19.169	88.290	107.459	32
33	73.485	58.789	0.012486	0.74194	80.089	1.3478	19.449	88.097	107.546	33
34	74.818	60.122	0.012505	0.72911	79.971	1.3715	19.729	87.903	107.632	34
35	76.170	61.474	0.012523	0.71655	79.852	1.3956	20.010	87.708	107.719	35
36	77.540	62.844	0.012542	0.70425	79.733	1.4199	20.292	87.512	107.804	36
37	78.929	64.233	0.012561	0.69221	79.614	1.4447	20.574	87.316	107.889	37
38	80.336	65.640	0.012579	0.68041	79.495	1.4697	20.856	87.118	107.974	38
39	81.761	67.065	0.012598	0.66885	79.375	1.4951	21.138	86.920	108.058	39
40	83.206	68.510	0.012618	0.65753	79.255	1.5208	21.422	86.720	108.142	40
41	84.670	69.974	0.012637	0.64643	79.134	1.5469	21.705	86.520	108.225	41
42	86.153	71.457	0.012656	0.63557	79.013	1.5734	21.989	86.319	108.308	42
43	87.655	72.959	0.012676	0.62492	78.892	1.6002	22.273	86.117	108.390	43

Table 516-1-5. R-22 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
44	89.177	74.481	0.012695	0.61448	78.770	1.6274	22.558	85.914	108.472	44
45	90.719	76.023	0.012715	0.60425	78.648	1.6549	22.843	85.710	108.553	45
46	92.280	77.584	0.012735	0.59422	78.526	1.6829	23.129	85.506	108.634	46
47	93.861	79.165	0.012755	0.58440	78.403	1.7112	23.415	85.300	108.715	47
48	95.463	80.767	0.012775	0.57476	78.280	1.7398	23.701	85.094	108.795	48
49	97.085	82.389	0.012795	0.56632	78.157	1.7689	23.988	84.886	108.874	49
50	98.727	84.031	0.012815	0.55606	78.033	1.7984	24.275	84.678	108.953	50
51	100.39	85.69	0.012836	0.54696	77.909	1.8282	24.563	84.468	109.031	51
52	102.07	87.38	0.012856	0.53808	77.784	1.8585	24.851	84.258	109.109	52
53	103.78	89.08	0.012877	0.52934	77.659	1.8891	25.139	84.047	109.186	53
54	105.50	90.81	0.012898	0.52078	77.534	1.9202	25.429	83.834	109.263	54
55	107.25	92.56	0.012919	0.51238	77.408	1.9517	25.718	83.621	109.339	55
56	109.02	94.32	0.012940	0.50414	77.282	1.9836	26.008	83.407	109.415	56
57	110.81	96.11	0.012961	0.49606	77.155	2.0159	26.298	83.191	109.490	57
58	112.62	97.93	0.012982	0.48813	77.028	2.0486	26.589	82.975	109.564	58
59	114.46	99.76	0.013004	0.48035	76.900	2.0818	26.880	82.758	109.638	59
60	116.31	101.62	0.013025	0.47272	76.773	2.1154	27.172	82.540	109.712	60
61	118.19	103.49	0.013047	0.46523	76.644	2.1495	27.464	82.320	109.785	61
62	120.09	105.39	0.013069	0.45788	76.515	2.1840	27.757	82.100	108.857	62
63	122.01	107.32	0.013091	0.45066	76.386	2.2190	28.050	81.878	109.929	63
64	123.96	109.26	0.013114	0.44358	76.257	2.2544	28.344	81.656	110.000	64
65	125.93	111.23	0.013136	0.43663	76.126	2.2903	28.638	81.432	110.070	65
66	127.92	113.22	0.013159	0.42981	75.996	2.3266	28.932	81.208	110.140	66
67	129.94	115.24	0.013181	0.42311	75.865	2.3635	29.228	80.982	110.209	67
68	131.97	117.28	0.013204	0.41653	75.733	2.4008	29.523	80.755	110.278	68
69	134.04	119.34	0.013227	0.41007	75.601	2.4386	29.819	80.527	110.346	69
70	136.12	121.43	0.013251	0.40373	75.469	2.4769	30.116	80.298	110.414	70
71	138.23	123.54	0.013274	0.39751	75.336	2.5157	30.413	80.068	110.480	71
72	140.37	125.67	0.013297	0.39139	75.202	2.5550	30.710	79.836	110.547	72
73	142.52	127.83	0.013321	0.38539	75.068	2.5948	31.008	79.604	110.612	73
74	144.71	130.01	0.013345	0.37949	74.934	2.6351	31.307	79.370	110.677	74

Table 516-1-5. R-22 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
75	146.91	132.22	0.013369	0.37369	74.799	2.6760	31.606	79.135	110.741	75
76	149.15	134.45	0.013383	0.36800	74.664	2.7174	31.906	78.899	110.805	76
77	151.40	136.71	0.013418	0.36241	74.528	2.7593	32.206	78.662	110.868	77
78	153.69	138.99	0.013442	0.35691	74.391	2.8018	32.506	78.423	110.930	78
79	155.99	141.30	0.013467	0.35151	74.254	2.8449	32.808	79.184	110.991	79
80	158.33	143.63	0.013492	0.34621	74.116	2.8885	33.109	77.943	111.052	80
81	160.68	145.99	0.013518	0.34099	73.978	2.9326	33.412	77.701	111.112	81
82	163.07	148.37	0.013543	0.33587	73.839	2.9774	33.714	77.457	111.171	82
83	165.48	150.78	0.013569	0.33083	73.700	3.0227	34.018	77.212	111.230	83
84	167.92	153.22	0.013594	0.32588	73.560	3.0686	34.322	76.966	111.288	84
85	170.38	155.68	0.013620	0.32101	73.420	3.1151	34.626	76.719	111.345	85
86	172.87	158.17	0.013647	0.31623	73.278	3.1622	34.931	76.470	111.401	86
87	175.38	160.69	0.013673	0.31153	73.137	3.2100	35.237	76.220	111.457	87
88	177.93	163.23	0.013700	0.30690	72.994	3.2583	35.543	75.968	111.512	88
89	180.50	165.80	0.013727	0.30236	72.851	3.3073	35.850	75.716	111.566	89
90	183.09	168.40	0.013754	0.29789	72.708	3.3570	36.158	75.461	111.619	90
91	185.72	171.02	0.013781	0.29349	72.564	3.4073	36.468	75.206	111.671	91
92	188.37	173.67	0.013809	0.28917	72.419	3.4582	36.774	74.949	111.723	92
93	191.05	176.35	0.013836	0.28491	72.273	3.5098	37.084	74.690	111.774	93
94	193.76	179.06	0.013864	0.28073	72.127	3.5621	37.394	74.430	111.824	94
95	196.50	181.80	0.013893	0.27662	71.980	3.6151	37.704	74.168	111.873	95
96	199.26	184.56	0.013921	0.27257	71.833	3.6688	38.016	73.905	111.921	96
97	202.05	187.36	0.013950	0.26859	71.685	3.7232	38.328	73.641	111.968	97
98	204.87	190.18	0.013979	0.26467	71.536	3.7783	38.640	73.375	112.015	98
99	207.72	193.03	0.014008	0.26081	71.386	3.8341	38.953	73.107	112.060	99
100	210.60	195.91	0.014038	0.25702	71.236	3.8907	39.267	72.838	112.105	100
101	213.51	198.82	0.014068	0.25329	71.084	3.9481	39.582	72.567	112.149	101
102	216.45	201.76	0.014098	0.24962	70.933	4.0062	39.897	72.294	112.192	102
103	219.42	204.72	0.014128	0.24600	70.780	4.0651	40.213	72.020	112.233	103
104	222.42	207.72	0.014159	0.24244	70.626	4.1247	40.530	71.744	112.274	104
105	225.45	210.75	0.014190	0.23894	70.472	4.1852	40.847	71.467	112.314	105

Table 516-1-5. R-22 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
106	228.50	213.81	0.014221	0.23549	70.317	4.2465	41.166	71.187	112.353	106
107	231.59	216.90	0.014253	0.23209	70.161	4.3086	41.485	70.906	112.391	107
108	234.71	220.02	0.014285	0.22875	70.005	4.3715	41.804	70.623	112.427	108
109	237.86	223.17	0.014317	0.22546	69.847	4.4354	42.125	70.338	112.463	109
110	241.04	226.35	0.014350	0.22222	69.689	4.5000	42.446	70.052	112.498	110
111	244.25	229.56	0.014382	0.21903	69.529	4.5656	42.768	69.763	112.531	111
112	247.50	232.80	0.014416	0.21589	69.369	4.6321	43.091	69.473	112.564	112
113	250.77	236.08	0.014449	0.21279	69.208	4.6994	43.415	69.180	112.595	113
114	254.08	239.38	0.014483	0.20974	69.046	4.7677	43.739	68.886	112.626	114
115	257.42	242.72	0.014517	0.20674	68.883	4.8370	44.065	68.590	112.655	115
116	260.79	246.10	0.014552	0.20378	68.719	4.9072	44.391	68.291	112.682	116
117	264.20	249.50	0.014587	0.20087	68.554	4.9784	44.718	67.991	112.709	117
118	267.63	252.94	0.014622	0.19800	68.388	5.0506	45.046	67.688	112.735	118
119	271.10	256.41	0.014658	0.19517	68.221	5.1238	45.375	67.384	112.759	119
120	274.60	259.91	0.014694	0.19238	68.054	5.1981	45.705	67.077	112.782	120
121	278.14	263.44	0.014731	0.18963	67.885	5.2734	46.036	66.767	112.803	121
122	281.71	267.01	0.014768	0.18692	67.714	5.3498	46.368	66.456	112.824	122
123	285.31	270.62	0.014805	0.18426	67.543	5.4272	46.701	66.142	112.843	123
124	288.95	274.25	0.014843	0.18163	67.371	5.5058	47.034	65.826	112.860	124
125	292.62	277.92	0.014882	0.17903	67.197	5.5856	47.369	65.507	112.877	125
126	296.33	281.63	0.014920	0.17648	67.023	5.6665	47.705	65.186	112.891	126
127	300.07	285.37	0.014960	0.17396	66.847	5.7486	48.042	64.863	112.905	127
128	303.84	289.14	0.014999	0.17147	66.670	5.8319	48.380	64.537	112.917	128
129	307.65	292.95	0.015039	0.16902	66.492	5.9164	48.719	64.208	112.927	129
130	311.50	296.80	0.015080	0.16681	66.312	6.0022	49.059	63.877	112.936	130
131	315.38	300.68	0.015121	0.16422	66.131	6.0893	49.400	63.543	112.943	131
132	319.29	304.60	0.015163	0.16187	65.949	6.1777	49.743	63.206	112.949	132
133	323.25	308.55	0.015206	0.15956	65.766	6.2674	50.087	62.866	112.953	133
134	327.23	312.54	0.015248	0.15727	65.581	6.3585	50.432	62.523	112.955	134
135	331.26	316.56	0.015292	0.15501	65.394	6.4510	50.778	62.178	112.956	135
136	335.32	320.63	0.015336	0.15279	65.207	6.5450	51.125	61.829	112.954	136

Table 516-1-5. R-22 PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
137	339.42	324.73	0.015381	0.15059	65.017	6.6405	51.474	61.477	112.951	137
138	343.56	328.86	0.015426	0.14843	64.826	6.7374	51.824	61.123	112.947	138
139	347.73	333.04	0.015472	0.14629	64.634	6.8359	52.175	60.764	112.940	139
140	351.94	337.25	0.015518	0.14418	64.440	6.9360	52.528	60.403	112.931	140
141	356.19	341.50	0.015566	0.14209	64.244	7.0377	52.883	60.038	112.921	141
142	360.48	345.79	0.015613	0.14004	64.047	7.1410	53.238	59.670	112.908	142
143	364.81	350.11	0.015662	0.13801	63.848	7.2461	53.596	59.298	112.893	143
144	369.17	354.48	0.015712	0.13600	63.647	7.3529	53.955	58.922	112.877	144
*Inches of mercury below one atmosphere.										
**Based on 0 for the saturated liquid at -40°F										

Table 516-1-6. R-134A PROPERTIES OF LIQUID AND SATURATED VAPOR

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
-40	7.42	14.82*	0.0113	5.7904	88.31	0.1727	0.0	97.2	97.2	-40
-38	7.86	13.92*	0.0113	5.4825	88.11	0.1824	0.6	96.9	97.5	-38
-36	8.33	12.97*	0.0114	5.1948	87.91	0.1925	1.2	96.6	97.8	-36
-34	8.81	11.98*	0.0114	4.9261	87.71	0.2030	1.8	96.3	98.1	-34
-32	9.32	10.95*	0.0114	4.6729	87.51	0.2140	2.4	96.0	98.4	-32
-30	9.85	9.86*	0.0115	4.4366	87.31	0.2254	3.0	95.7	98.7	-30
-28	10.41	8.73*	0.0115	4.2141	87.11	0.2373	3.6	95.4	99.0	-28
-26	10.99	7.55*	0.0115	4.0032	86.91	0.2498	4.2	95.1	99.3	-26
-24	11.59	6.32*	0.0115	3.8066	86.71	0.2627	4.8	94.8	99.6	-24
-22	12.23	5.03*	0.0116	3.6306	86.51	0.2762	5.4	94.5	99.9	-22
-20	12.89	3.69*	0.0116	3.4471	86.30	0.2901	6.0	94.2	100.2	-20
-18	13.57	2.29*	0.0116	3.2819	86.10	0.3047	6.6	93.9	100.5	-18
-16	14.29	0.83*	0.0116	3.1270	85.89	0.3198	7.2	93.6	100.8	-16
-14	15.04	0.34	0.0117	2.9806	85.69	0.3355	7.8	93.3	101.1	-14
-12	15.81	1.12	0.0117	2.8417	85.48	0.3519	8.4	92.9	101.4	-12
-10	16.62	1.92	0.0117	2.7115	85.28	0.3688	9.0	92.6	101.7	-10
-8	17.46	2.77	0.0118	2.5880	85.07	0.3864	9.7	92.3	102.0	-8
-6	18.33	3.64	0.0118	2.4716	84.86	0.4046	10.3	92.0	102.3	-6
-4	19.24	4.55	0.0118	2.3613	84.65	0.4235	10.9	91.7	102.5	-4
-2	20.18	5.49	0.0118	2.2568	84.44	0.4431	11.5	91.3	102.8	-2
0	21.16	6.47	0.0119	2.1580	84.23	0.4634	12.1	91.0	103.1	0
2	22.18	7.48	0.0119	2.0644	84.02	0.4844	12.7	90.7	103.4	2
4	23.23	8.54	0.0119	1.9755	83.81	0.5062	13.4	90.4	103.7	4
6	24.31	9.63	0.0120	1.8911	83.60	0.5288	14.0	90.0	104.0	6
8	25.45	10.76	0.0120	1.8113	83.38	0.5521	14.6	89.7	104.3	8
10	26.63	11.93	0.0120	1.7355	83.17	0.5762	15.2	89.4	104.6	10
12	27.84	13.14	0.0121	1.6633	82.95	0.6012	15.9	89.0	104.9	12
14	29.10	14.40	0.0121	1.5949	82.73	0.6270	16.5	88.7	105.2	14
16	30.40	15.70	0.0121	1.5298	82.52	0.6537	17.1	88.3	105.5	16
18	31.74	17.04	0.0122	1.4678	82.30	0.6813	17.7	88.0	105.7	18
20	33.13	18.43	0.0122	1.4090	82.08	0.7097	18.4	87.7	106.0	20
22	34.57	19.87	0.0122	1.3528	81.86	0.7392	19.0	87.3	106.3	22
24	36.05	21.35	0.0122	1.2995	81.64	0.7695	19.6	87.0	106.6	24

Table 516-1-6. R-134A PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
26	37.58	22.89	0.0123	1.2486	81.41	0.8009	20.3	86.6	106.9	26
28	39.17	24.47	0.0123	1.2000	81.19	0.8333	20.9	86.2	107.2	28
30	40.80	26.10	0.0124	1.1538	80.96	0.08667	21.6	85.9	107.4	30
32	42.49	27.79	0.0124	1.1098	80.74	0.9011	22.2	85.5	107.7	32
34	44.23	29.53	0.0124	1.0676	80.51	0.9367	22.8	85.2	108.0	34
36	46.02	31.32	0.0125	1.0274	80.28	0.9733	23.5	84.8	108.3	36
38	47.87	33.17	0.0125	0.9890	80.05	1.0111	24.1	84.4	108.6	38
40	49.77	35.08	0.0125	0.9523	79.82	1.0501	24.8	84.1	108.8	40
42	51.73	37.04	0.0126	0.9173	79.59	1.0902	25.4	83.7	109.1	42
44	53.75	39.06	0.0126	0.8837	79.35	1.1316	26.1	83.3	109.4	44
46	55.84	41.14	0.0126	0.8516	79.12	1.1742	26.7	82.9	109.7	46
48	57.98	43.28	0.0127	0.8210	78.88	1.2181	27.4	82.5	109.9	48
50	60.18	45.48	0.0127	0.7916	78.64	1.2633	28.0	82.1	110.2	50
52	62.45	47.75	0.0128	0.7634	78.41	1.3099	28.7	81.8	110.5	52
54	64.78	50.08	0.0128	0.7365	78.16	1.3578	29.4	81.4	110.7	54
56	67.17	52.47	0.0128	0.7106	77.92	1.4072	30.0	81.0	111.0	56
58	69.64	54.94	0.0129	0.6859	77.68	1.4579	30.7	80.6	111.3	58
60	72.17	57.47	0.0129	0.6622	77.43	1.5102	31.4	80.2	111.5	60
62	74.77	60.07	0.0130	0.6394	77.19	1.5640	32.0	79.7	111.8	62
64	77.44	62.74	0.0130	0.6175	76.94	1.6194	32.7	79.3	112.0	64
66	80.18	65.49	0.0130	0.5965	76.69	1.6764	33.4	78.9	112.3	66
68	83.00	68.30	0.0131	0.5764	76.44	1.7350	34.0	78.5	112.5	68
70	85.89	71.19	0.0131	0.5570	76.18	1.7952	34.7	78.1	112.8	70
72	88.86	74.16	0.0132	0.5384	75.93	1.8573	35.4	77.6	113.0	72
74	91.90	77.20	0.0132	0.5206	75.67	1.9210	36.1	77.2	113.3	74
76	95.02	80.32	0.0133	0.5034	75.41	1.9866	36.8	76.8	113.5	76
78	98.22	83.52	0.0133	0.4868	75.15	2.0541	37.4	76.3	113.8	78
80	101.49	86.80	0.0134	0.4709	74.89	2.1234	38.1	75.9	114.0	80
82	104.86	90.16	0.0134	0.4556	74.62	2.1948	38.8	75.4	114.3	82
84	108.29	93.59	0.0134	0.4409	74.35	2.2681	39.5	75.0	114.5	84
86	111.83	97.13	0.0135	0.4267	74.08	2.3436	40.2	74.5	114.7	86
88	115.44	100.75	0.0135	0.4130	73.81	2.4211	40.9	74.1	115.0	88

Table 516-1-6. R-134A PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
90	119.14	104.44	0.0136	0.3999	73.54	2.5009	41.6	73.6	115.2	90
92	122.93	108.23	0.0137	0.3872	73.26	2.5829	42.3	73.1	115.4	92
94	126.81	112.11	0.0137	0.3749	72.98	2.6672	43.0	72.7	115.7	94
96	130.78	116.08	0.0138	0.3631	72.70	2.7539	43.7	72.2	115.9	96
98	134.84	120.14	0.0138	0.3517	72.42	2.8430	44.4	71.7	116.1	98
100	139.00	124.30	0.0139	0.3408	72.13	2.9347	45.1	71.2	116.3	100
102	143.25	128.55	0.0139	0.3302	71.84	3.0289	45.8	70.7	116.5	102
104	147.59	132.90	0.0140	0.3199	71.55	3.1259	46.6	70.2	116.7	104
106	152.04	137.34	0.0140	0.3100	71.25	3.2246	47.3	69.7	117.0	106
108	156.58	141.89	0.0141	0.3005	70.96	3.3282	48.0	69.2	117.2	108
110	161.23	146.53	0.0142	0.2912	70.66	3.4337	48.7	68.6	117.4	110
112	165.97	151.28	0.0142	0.2823	70.35	3.5423	49.5	68.1	117.6	112
114	170.83	156.14	0.0143	0.2737	70.05	3.6539	50.2	67.6	117.8	114
116	175.79	161.09	0.0143	0.2653	69.74	3.7689	50.9	67.0	117.9	116
118	180.85	166.15	0.0144	0.2573	69.42	3.8872	51.7	66.5	118.1	118
120	186.02	171.33	0.0145	0.2494	69.10	4.0089	52.4	65.9	118.3	120
122	191.31	176.61	0.0145	0.2419	68.78	4.1343	53.1	65.4	118.5	122
124	196.70	182.01	0.0146	0.2346	68.46	4.2634	53.9	64.8	118.7	124
126	202.21	187.52	0.0147	0.2275	68.13	4.3964	54.6	64.2	118.8	126
128	207.83	193.14	0.0147	0.2206	67.80	4.5334	55.4	63.6	119.0	128
130	213.57	198.88	0.0148	0.2139	67.46	4.6745	56.2	63.0	119.2	130
132	219.43	204.73	0.0149	0.2075	67.12	4.8200	56.9	62.4	119.3	132
134	225.41	210.71	0.0150	0.2012	66.77	4.9700	57.7	61.8	119.5	134
136	231.50	216.81	0.0151	0.1951	66.42	5.1248	58.5	61.2	119.6	136
138	237.72	223.03	0.0151	0.1892	66.06	5.2844	59.2	60.5	119.8	138
140	244.07	229.37	0.0152	0.1835	65.70	5.4491	60.0	59.9	119.9	140
*Inches of mercury below one atmosphere.										

Table 516-1-7. R-236fa PROPERTIES OF LIQUID AND SATURATED VAPOR

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
-40	2.100	25.65*	0.01027	13.94	97.41	0.07172	0.00	76.81	76.81	-40
-38	2.246	25.35*	0.01029	13.09	97.20	0.07638	0.54	76.60	77.14	-38
-36	2.400	25.03*	0.01031	12.30	97.00	0.08128	1.08	76.39	77.47	-36
-34	2.563	24.70*	0.01033	11.57	96.80	0.08644	1.63	76.17	77.80	-34
-32	2.735	24.35*	0.01035	10.89	96.59	0.09186	2.17	75.96	78.13	-32
-30	2.916	23.98*	0.01037	10.25	96.39	0.09756	2.71	75.75	78.46	-30
-28	3.107	23.60*	0.01040	9.659	96.18	0.1035	3.26	75.53	78.79	-28
-26	3.308	23.19*	0.01042	9.108	95.98	0.1098	3.81	75.31	79.12	-26
-24	3.519	22.76*	0.01044	8.594	95.77	0.1164	4.35	75.10	79.45	-24
-22	3.742	22.30*	0.01046	8.114	95.57	0.1232	4.90	74.88	79.78	-22
-20	3.975	21.83*	0.01049	7.666	95.36	0.1305	5.45	74.66	80.11	-20
-18	4.221	21.33*	0.01051	7.247	95.16	0.1380	6.00	74.44	80.44	-18
-16	4.479	20.80*	0.01053	6.855	94.95	0.1459	6.56	74.22	80.77	-16
-14	4.749	20.25*	0.01055	6.488	94.75	0.1541	7.11	74.00	81.11	-14
-12	5.033	19.68*	0.01058	6.145	94.54	0.1627	7.66	73.78	81.44	-12
-10	5.330	19.07*	0.01060	5.823	94.33	0.1717	8.22	73.55	81.77	-10
-8	5.641	18.44*	0.01062	5.521	94.13	0.1811	8.77	73.33	82.10	-8
-6	5.966	17.78*	0.01065	5.238	93.92	0.1909	9.33	73.10	82.43	-6
-4	6.307	17.08*	0.01067	4.972	93.71	0.2011	9.89	72.88	82.77	-4
-2	6.663	16.36*	0.01069	4.722	93.50	0.2118	10.45	72.65	83.10	-2
0	7.035	15.60*	0.01072	4.487	93.30	0.2228	11.01	72.42	83.43	0
2	7.423	14.81*	0.01074	4.267	93.09	0.2344	11.57	72.20	83.77	2
4	7.829	13.98*	0.01077	4.059	92.88	0.2464	12.13	71.97	84.10	4
6	8.252	13.12*	0.01079	3.863	92.67	0.2589	12.69	71.74	84.43	6
8	8.693	12.23*	0.01082	3.678	92.46	0.2719	13.26	71.51	84.77	8
10	9.152	11.29*	0.01084	3.504	92.25	0.2854	13.82	71.28	85.10	10
12	9.631	10.32*	0.01086	3.340	92.04	0.2994	14.39	71.04	85.43	12
14	10.13	9.30*	0.01089	3.185	91.38	0.3140	14.96	70.81	85.77	14
16	10.65	8.24*	0.01091	3.039	91.62	0.3291	15.52	70.58	86.10	16
18	11.19	7.14*	0.01094	2.900	91.41	0.3448	16.09	70.34	86.43	18
20	11.75	6.00*	0.01097	2.770	91.20	0.3611	16.66	70.11	86.77	20
22	12.33	4.82*	0.01099	2.646	90.98	0.3780	17.24	69.86	87.10	22

Table 516-1-7. R-236fa PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
24	12.94	3.58*	0.01102	2.529	90.77	0.3955	17.81	69.62	87.43	24
26	13.57	2.30*	0.01104	2.418	90.56	0.4136	18.38	69.39	87.77	26
28	14.22	0.98*	0.01107	2.313	90.34	0.4324	18.96	69.14	88.10	28
30	14.90	0.20	0.01110	2.213	90.13	0.4518	19.53	68.90	88.43	30
32	15.60	0.90	0.01112	2.119	89.91	0.4720	20.11	68.65	88.76	32
34	16.33	1.63	0.01115	2.029	89.70	0.4928	20.69	68.41	89.10	34
36	17.09	2.39	0.01118	1.944	89.48	0.5144	21.27	68.16	89.43	36
38	17.87	3.17	0.01120	1.863	89.26	0.5366	21.85	67.91	89.76	38
40	18.68	3.98	0.01123	1.787	89.05	0.5597	22.43	67.66	90.04	40
42	19.52	4.82	0.01126	1.714	88.83	0.5835	23.01	67.42	90.43	42
44	20.38	5.68	0.01129	1.644	88.61	0.6081	23.60	67.16	90.76	44
46	21.28	6.58	0.01131	1.578	88.39	0.6336	24.18	66.91	91.09	46
48	22.21	7.51	0.01134	1.516	88.17	0.6598	24.77	66.65	91.42	48
50	23.16	8.46	0.01137	1.456	87.95	0.6869	25.36	66.39	91.75	50
52	24.16	9.46	0.01140	1.399	87.73	0.7149	25.95	66.13	92.08	52
54	25.18	10.48	0.01143	1.344	87.51	0.7438	26.54	65.87	92.41	54
56	26.23	11.53	0.01146	1.293	87.28	0.7736	27.13	65.62	92.75	56
58	27.32	12.62	0.01149	1.243	87.06	0.8044	27.72	65.36	93.08	58
60	28.45	13.75	0.01152	1.196	86.83	0.8360	28.31	65.09	93.40	60
62	29.61	14.91	0.01155	1.151	86.61	0.8687	28.91	64.82	93.73	62
64	30.80	16.10	0.01158	1.108	86.38	0.9024	29.51	64.55	94.06	64
66	32.04	17.34	0.01161	1.067	86.16	0.9371	30.10	64.29	94.39	66
68	33.31	18.61	0.01164	1.028	85.93	0.9729	30.70	64.02	94.72	68
70	34.62	19.92	0.01167	0.9903	85.70	1.010	31.30	63.75	95.05	70
72	35.96	21.26	0.01170	0.9545	85.47	1.048	31.90	63.47	95.37	72
74	37.35	22.65	0.01173	0.9201	85.24	1.087	32.51	63.19	95.70	74
76	38.78	24.08	0.01176	0.8873	85.00	1.127	33.11	62.92	96.03	76
78	40.25	25.55	0.01180	0.8558	84.77	1.169	33.71	62.64	96.35	78
80	41.76	27.06	0.01183	0.8257	84.54	1.211	34.32	62.36	96.68	80
82	43.32	28.62	0.01186	0.7968	84.30	1.255	34.93	62.07	97.00	82
84	44.92	30.22	0.01190	0.7691	84.07	1.300	35.54	61.78	97.32	84

Table 516-1-7. R-236fa PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
86	46.56	31.86	0.01193	0.7426	83.83	1.347	36.15	61.50	97.65	86
88	48.25	33.55	0.01196	0.7171	83.59	1.395	36.76	61.21	97.97	88
90	49.98	35.28	0.01200	0.6927	83.35	1.444	37.37	60.92	98.29	90
92	51.77	37.07	0.01203	0.6692	83.11	1.494	37.99	60.62	98.61	92
94	53.60	38.90	0.01207	0.6467	82.86	1.546	38.61	60.32	98.93	94
96	55.47	40.77	0.01210	0.6251	82.62	1.600	39.22	60.03	99.25	96
98	57.40	42.70	0.01214	0.6043	82.37	1.655	39.84	59.73	99.57	98
100	59.38	44.68	0.01218	0.5843	82.13	1.711	40.46	59.43	99.89	100
102	61.41	46.71	0.01221	0.5651	81.88	1.769	41.09	59.11	100.20	102
104	63.49	48.79	0.01225	0.5467	81.63	1.829	41.71	58.81	100.52	104
106	65.63	50.93	0.01229	0.5289	81.38	1.891	42.33	58.50	100.83	106
108	67.82	53.12	0.01233	0.5118	81.12	1.954	42.96	58.18	101.14	108
110	70.06	55.36	0.01237	0.4954	80.87	2.019	43.59	57.87	101.46	110
112	72.36	57.66	0.01241	0.4795	80.61	2.085	44.22	57.55	101.77	112
114	74.72	60.02	0.01245	0.4643	80.35	2.154	44.85	57.23	102.08	114
116	77.13	62.43	0.01249	0.4496	80.09	2.224	45.49	56.80	102.39	116
118	79.60	64.90	0.01253	0.4354	79.83	2.297	46.12	56.57	102.69	118
120	82.13	67.43	0.01257	0.4217	79.57	2.371	46.76	56.24	103.00	120
122	84.72	70.02	0.01261	0.4086	79.30	2.448	47.40	55.90	103.30	122
124	87.38	72.68	0.01265	0.3959	79.03	2.526	48.04	55.57	103.61	124
126	90.09	75.39	0.01270	0.3836	78.76	2.607	48.68	55.23	103.91	126
128	92.87	78.07	0.01274	0.3718	78.49	2.690	49.32	54.89	104.21	128
130	95.71	81.01	0.01279	0.3603	78.21	2.775	49.97	54.54	104.51	130
132	98.62	83.92	0.01283	0.3493	77.94	2.863	50.62	54.18	104.80	132
134	101.6	86.9	0.01288	0.3387	77.66	2.953	51.27	53.87	105.10	134
136	104.6	89.9	0.01292	0.3284	77.37	3.045	51.92	53.47	105.39	136
138	107.7	93.0	0.01297	0.3184	77.09	3.141	52.57	53.11	105.68	138
140	110.9	96.2	0.01302	0.3088	76.80	3.238	53.23	52.74	105.97	140
142	114.2	99.5	0.01307	0.2995	76.51	3.339	53.89	52.37	106.26	142
144	117.5	102.8	0.01312	0.2905	76.22	3.442	54.55	52.00	106.55	144
146	120.9	106.2	0.01317	0.2818	75.92	3.549	55.21	51.62	106.83	146

Table 516-1-7. R-236fa PROPERTIES OF LIQUID AND SATURATED VAPOR - Continued

Temp (°F)	Pressure (psi)		Specific Volume (ft ³ /lb)		Density (lb/ft ³)		Heat Content Above -40°F (Btu/lb)			Temp (°F)
t	Absolute P	Gauge P _d	Liquid V _f	Vapor V _g	Liquid 1/v _f	Vapor 1/v _g	Liquid h _f	Latent h	Total of Vapor h _g	t
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11
148	124.3	109.6	0.01322	0.2734	75.62	3.658	55.87	51.24	107.11	148
150	127.9	113.2	0.01328	0.2652	75.32	3.771	56.54	50.85	107.39	150

*Inches of mercury below one atmosphere.

516-1.8.3.1.1 The halocarbon refrigerants used in naval shipboard systems are nontoxic in low concentrations. These refrigerants will not contaminate or poison food or other supplies with which they may come in contact. Refrigerant vapor and air mixtures in all proportions are nonirritating to eyes, nose, throat, and lungs. The vapor is nonpoisonous at low concentrations but will not support respiration and produces a dangerous anesthetic effect if inhaled in sufficient quantities. In high concentrations the vapor will affect the heart beat and cause asphyxiation and death. The liquid or vapor is nonflammable and nonexplosive. Its air mixtures, at 0 psig, are not capable of propagating a flame; air mixtures at high pressures may be explosive (see paragraph [516-1.10.2](#)).

516-1.8.3.1.2 Refrigerants used in naval shipboard systems are noncorrosive to metals commonly used in refrigerating system components. In the presence of moisture, however, these refrigerants hydrolyze forming hydrofluoric and hydrochloric acids that will attack metals. It is thus very important to keep air with its entrained moisture from entering the refrigerant circuit. These refrigerants will decompose in an open flame or in when contact with a hot surface (approximately 1,000°F).

516-1.8.3.1.3 Toxic gases such as hydrofluoric and hydrochloric acids and other extremely toxic materials are produced when thermal decomposition occurs. Products of refrigerant decomposition are pungent and irritating, making them noticeable even in minute quantities and thus, giving warning before concentrations dangerous to health are reached. Halocarbon refrigerants and cleaning fluids are excellent solvents and will loosen and wash away any and all particles such as dirt, scale, oil, and other contaminants with which they may come in contact in a refrigerating system.

516-1.8.4 SHIPPING AND STORAGE. Refrigerants are generally shipped and stored liquefied, under pressure, in steel cylinders or drums. Because of the higher pressures at normal ambient temperatures, refrigerants with lower boiling points such as R-12, R-22, R-114, and R-134a are shipped and stored in steel high-pressure cylinders. Refrigerants with higher boiling points such as R-11, are shipped and stored in metal drums, similar to drums used for oil and other fluids. In submarines, all refrigerants, regardless of boiling points, are stored in steel cylinders to minimize leakage of refrigerant into the submarine atmosphere. All refrigerant cylinders and drums for military use are orange with the name of the refrigerant stenciled on the body of the cylinder. Decals may also be applied to the shoulder of the cylinder to identify the contents.

516-1.8.5 REFRIGERANT CHARACTERISTICS. Certain physical and thermal characteristics of these refrigerants, at various pressures and corresponding saturation temperatures, are found in [Table 516-1-1](#), [Table 516-1-3](#), [Table 516-1-4](#), [Table 516-1-5](#), [Table 516-1-6](#), and [Table 516-1-7](#). These tables are extremely valuable as a basis for most refrigeration calculations and also to establish an understanding of the operation of the equipment. These tables include only the saturation data for refrigerant liquid or refrigerant vapor and do not include data on superheated gas. Superheated gas tables are available in many textbooks on refrigeration, but such tables have been purposely omitted from this manual because their proper application requires a further study of thermodynamics. Their omission does not limit or affect the usefulness of this manual.

516-1.8.6 REFRIGERANT PROPERTIES. Refrigerant [Table 516-1-1](#), [Table 516-1-3](#), [Table 516-1-4](#), [Table 516-1-5](#), [Table 516-1-6](#), and [Table 516-1-7](#) show properties of liquid and saturated vapors. The tables can be described as follows:

- a. Column 1 - The temperature of the refrigerant as a liquid or saturated gas (vapor).
- b. Column 2 - The pressure in psia corresponding to the temperature shown in column 1.
- c. Column 3 - The pressure in psig corresponding to the temperature shown in column 1. Pressures in column 3 are those that would be read on a gauge installed in the refrigerating system.

- d. Column 4 - The specific volume of liquid refrigerant at the temperature shown in column 1 in cubic feet per pound
- e. Column 5 - The specific volume of saturated refrigerant vapor at the temperature shown in column 1 in cubic feet per pound
- f. Column 6 - The density or weight of liquid refrigerant in pounds per cubic foot.
- g. Column 7 - The density or weight of refrigerant gas (vapor) in pounds per cubic foot.
- h. Column 8 - The heat content of liquid refrigerant in Btu per pound. This is the heat that shall be added in Btu to raise the temperature of 1 pound of liquid refrigerant from -40°F to the temperature shown in column 1.
- i. Column 9 - The latent heat of evaporation or the amount of heat necessary to change 1 pound of refrigerant from a liquid at the temperature shown in column 1 to a gas at the same temperature. Or conversely, it is the amount of heat that shall be extracted if 1 pound of saturated refrigerant gas at the temperature shown in column 1 is to be condensed to a liquid at the same temperature.
- j. Column 10 - Total heat of the vapor, consisting of the sum of the heat of the liquid, as shown in column 8, plus the latent heat shown in column 9.

516-1.8.7 LIQUID REFRIGERANTS. Large quantities of heat are absorbed when liquids evaporate. Cooling by an evaporating liquid was used by the ancient Egyptians. Containers with porous surfaces impregnated with water kept contents cool using the evaporating water. This process is very effective in warm, dry climates. Liquids boiling at low temperatures are the most desirable medium for removing heat. Many liquids used as refrigerants boil at temperatures below 0°F at standard atmospheric pressure.

516-1.8.7.1 Refrigeration can be obtained by using one of several refrigerants alone without any equipment. An insulated compartment can be cooled if a liquid refrigerant, such as R-12, is poured into an open container surrounded by air. R-12 will begin to boil at -21.6°F and then there will be a continuous flow of heat from the warm surrounding air through the walls of the refrigerant container to the boiling liquid. To eliminate the hazards associated with filling the compartment with refrigerant, a drum of refrigerant can be connected to a coil as in [Figure 516-1-2](#) and vaporized refrigerant piped outdoors. This will provide adequate refrigeration. Because the cost of replacing refrigerant is prohibitive, a means of using the refrigerant repeatedly is also necessary. For this purpose, other equipment is needed in addition to that shown in [Figure 516-1-2](#)

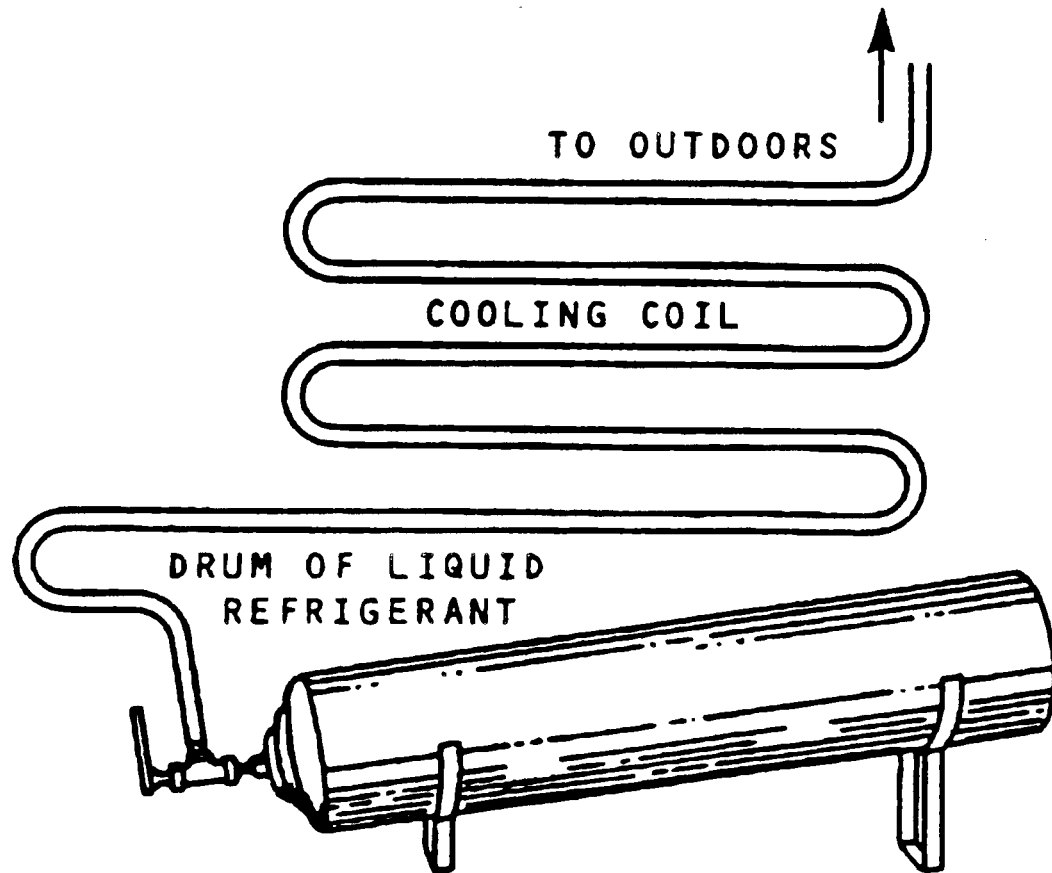


Figure 516-1-2. Simple Cooling System

516-1.8.7.2 The refrigerant is delivered to the evaporator or cooling coil as a liquid because it can absorb heat only by vaporizing. Since the refrigerant leaves the cooling coil in the form of a vapor, condensation to a liquid is required before it can be used again. The simplest way to do this would be to condense the vaporized refrigerant as it leaves the cooling coil. To condense the refrigerant vapor, the latent heat surrendered by the vapor during condensation is transferred to some other medium. Water or air is ordinarily used for this purpose.

516-1.9 ELEMENTARY REFRIGERATION CYCLE

516-1.9.1 APPLICATION. An elementary refrigeration cycle is shown in [Figure 516-1-3](#). The fluid or refrigerant is evaporated in the cooling chamber, taking the necessary heat from the surrounding air to provide the latent heat of evaporation. The evaporating refrigerant passes through tube A to the condensing chamber. The water cascading over the outer surface of the condensing chamber absorbs heat, causing the vapor inside to condense to a liquid. The condensed liquid then flows through tube B back to the cooling chamber. [Figure 516-1-3](#) illustrates the absorption and rejection of heat. Since heat always flows from a warmer to a cooler object, the water used over the condensing chamber shall be colder than the gas to be condensed. Since colder water is required, it makes the proposed diagram impractical. If colder water were available, it could be used as a refrigerant directly in the cooling chamber and no further refrigeration would be necessary.

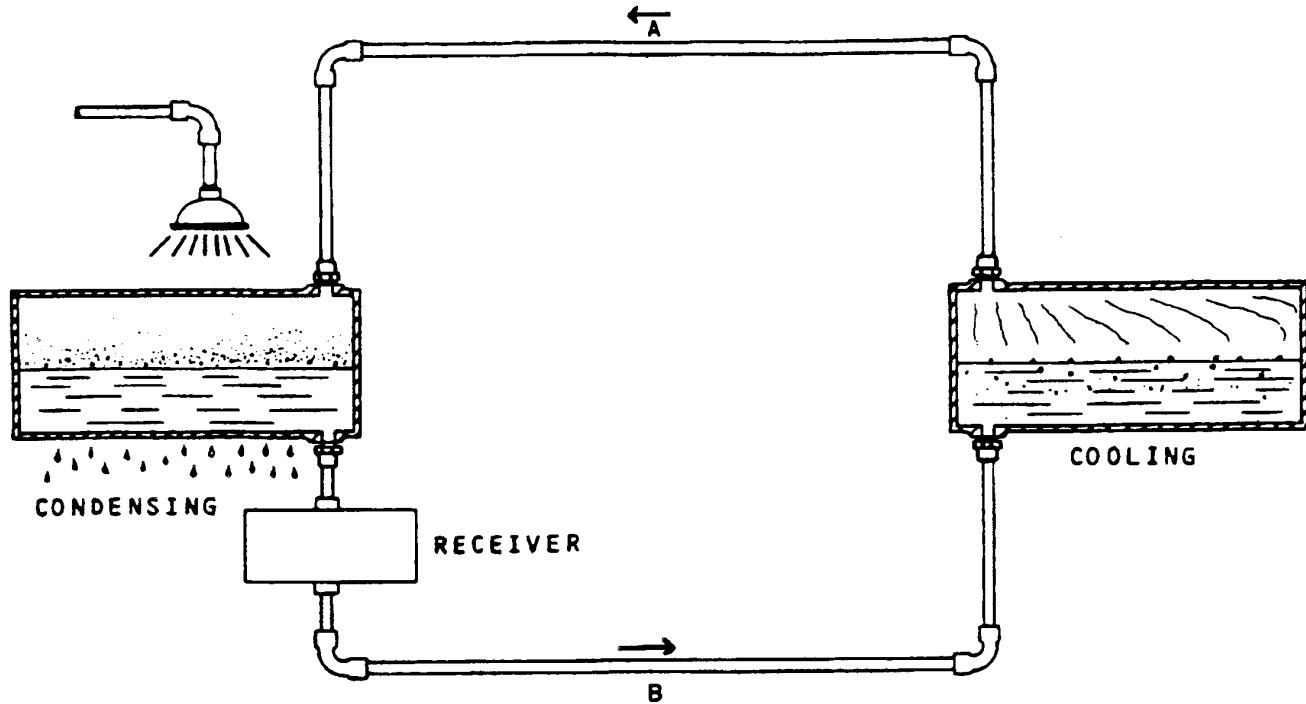


Figure 516-1-3. Elementary Refrigeration Cycle

516-1.9.2 COMPRESSION AND CONDENSATION. As the temperature of available water or air is usually higher than the temperature of the boiling refrigerant in the evaporator, the refrigerant cannot be condensed as it leaves the evaporator. To condense the vapor, its pressure shall be increased to such a point that its condensing temperature will be above the temperature of the water available for condensing purposes. The refrigerant vapor leaving the evaporator shall be compressed to some pressure at which its condensing temperature will be above the temperature of the available water or air. For this purpose a compressor is needed.

516-1.9.2.1 After the pressure of the refrigerant vapor has been increased sufficiently, the refrigerant may be liquefied in the condenser with comparatively warm water. With the introduction of the compressor and condenser, the system is able to use the same refrigerant repeatedly. The cost of compressing and condensing the vaporized refrigerant is far less than the cost of continuously replacing lost refrigerant. In the elementary form of the refrigeration cycle, there is no control over the rate of evaporation and, therefore, no control of the refrigeration effect. An additional item needed is a refrigerant flow control, commonly referred to as the expansion valve, or another restrictor device, such as a capillary tube which is to controls the flow of refrigerant to the evaporator. [Figure 516-1-4](#) illustrates a complete refrigerating system. The receiver, in which the liquid refrigerant is stored, replaces the drum of [Figure 516-1-2](#).

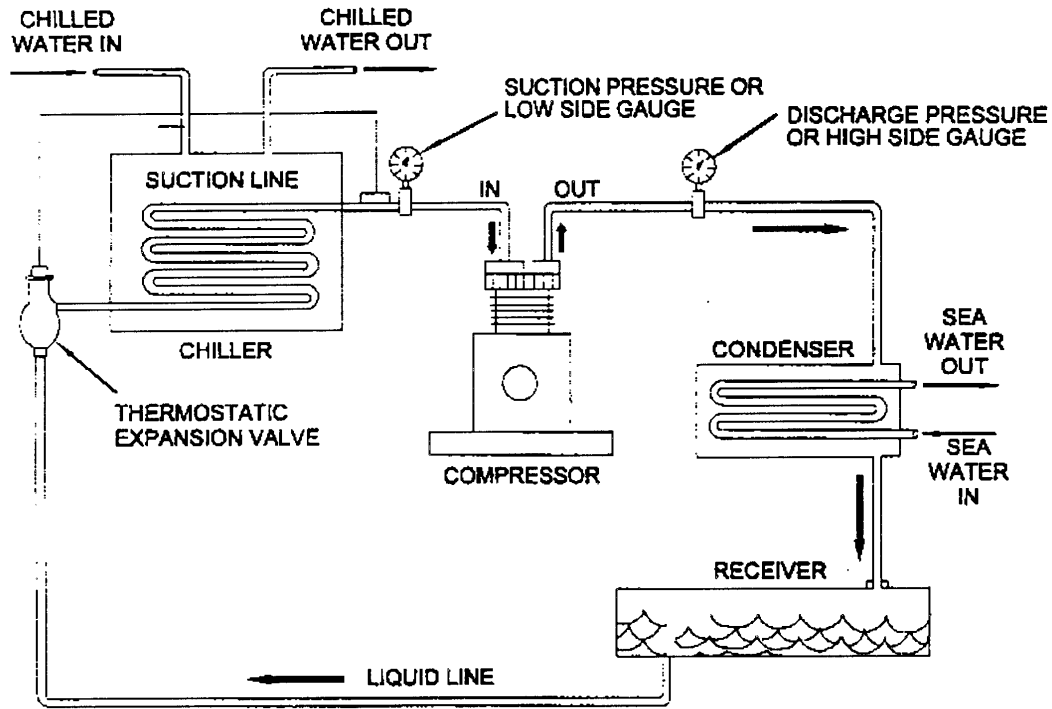
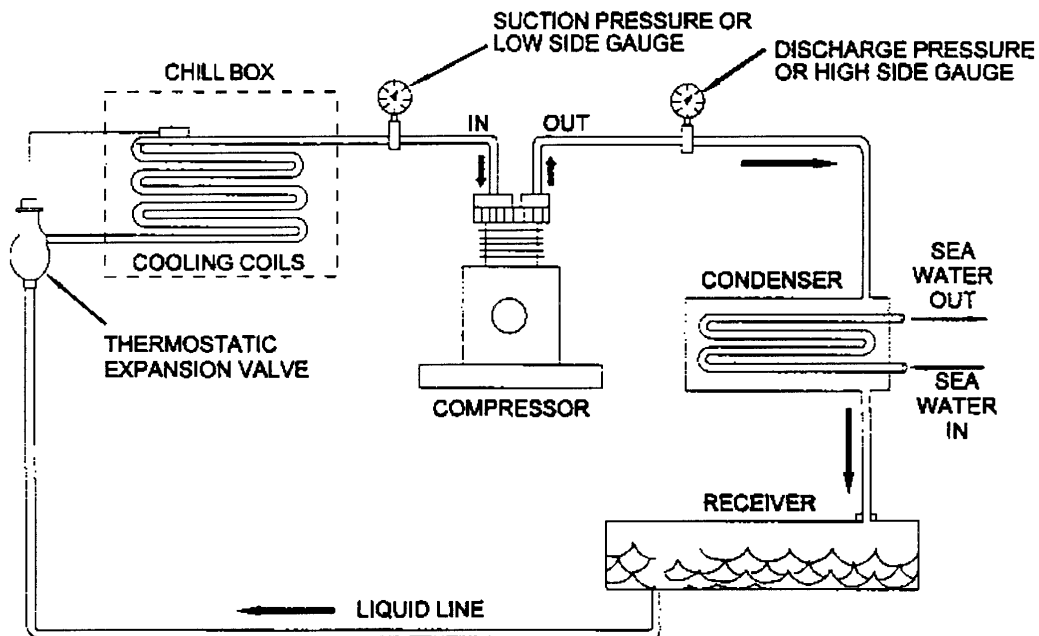
**BASIC AIR CONDITIONING CYCLE****BASIC REFRIGERATION CYCLE**

Figure 516-1-4. Mechanical Refrigeration System

516-1.9.2.2 On leaving the receiver, the liquid refrigerant flows through the expansion valve, which is essentially nothing more than a needle valve. The compressor maintains a difference in pressure between the evaporator and the condenser. Without the expansion valve this difference in pressure could not be maintained. The expansion valve separates the high-pressure part of the system from the low-pressure part. This valve acts as a pressure-reducing valve because the pressure of the liquid flowing through it is lowered. Only a trickle of refrigerant fluid flows through the valve into the evaporator and the valve is always adjusted so that only as much liquid can pass through it as can be vaporized in the cooling coil.

516-1.9.3 SUMMARY OF CYCLE OPERATION. The vapor compression refrigeration process is as follows:

- a. Liquid refrigerant is admitted to the evaporator at the proper pressure by the refrigerant flow control.
- b. The liquid refrigerant vaporizes in the evaporator, absorbing heat from the medium being cooled.
- c. The low-temperature, low-pressure vapor then flows to the compressor where it is compressed into a high-pressure, high-temperature vapor.
- d. After compression, the high-pressure, high-temperature vapor is discharged into the condenser where it gives up heat to the lower temperature condensing medium (usually air or water).
- e. The heat given off by the vapor in the condenser is carried away by the condensing medium.
- f. The resulting condensed liquid, whose saturation temperature and pressure will be the same as those of the condensing vapor, flows out of the condenser into the liquid receiver and is ready to be recirculated to the evaporator.

NOTE

The refrigerant is merely a continuously recycled heat transfer agent that carries heat from the refrigerated space to the outside. The refrigerant does this by absorbing heat from the low temperature refrigerated space in the evaporator, carrying it out of the space, and transferring it to the condensing medium.

516-1.9.4 SYSTEM COMPLEXITIES. Actual refrigeration systems are more complex than the simple system just described. For example, pressure drop resulting from the flow of refrigerant will occur in the refrigerant lines and across the evaporator, condenser, and other components. Also, subcooling of the liquid and superheating of the vapor will occur as follows:

- a. Superheating will take place in the evaporator coil and in the compressor suction line. This is due to the absorption of heat by the refrigerant from the relatively warmer piping.
- b. Subcooling will take place in the condenser where the condensed liquid is slightly cooled below the condensing (saturation) temperature through contact with relatively cold condenser tubes. Subcooling can also be carried out in a liquid line-to-suction vapor line heat exchanger where the suction vapor is superheated and the liquid refrigerant is subcooled.

516-1.9.5 TYPICAL R-12 REFRIGERATION SYSTEM. A typical R-12 vapor compression refrigeration system, similar to that used in many naval ship applications, is shown in [Figure 516-1-5](#). A comparison to the basic cycle shown in [Figure 516-1-4](#) shows that many accessories and valves have been added to assist in control and function of the system. In many cases, the particular refrigeration application will require modifications and addi-

tions to the basic system. In addition, use of a refrigerant other than R-12 will require changes to the system and components (such as a compressor, evaporator, and condenser) because of the particular characteristics of the refrigerant used.

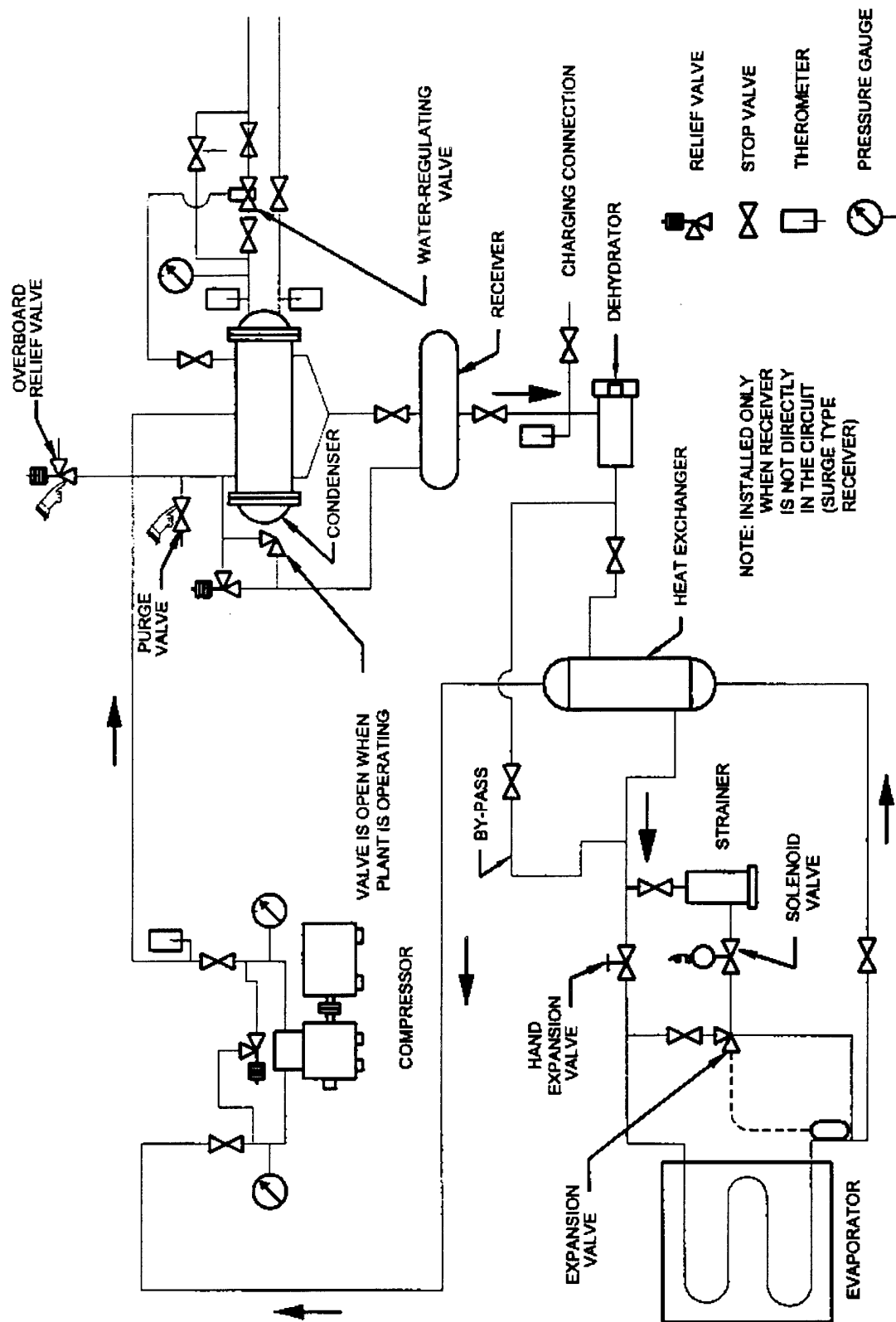


Figure 516-1-5. Mechanical Refrigeration Application

516-1.9.6 COMPONENT FUNCTIONS. The functions of the principal components of the system were described previously. Some additional components shown in [Figure 516-1-5](#) are the following:

- a. A purge valve to bleed off air and other noncondensed gases from the refrigerant system at the condenser.
- b. A water-regulating valve to control the flow of cooling water through the condenser.
- c. A dehydrator to remove moisture from the refrigerant system.
- d. A charging connection to add or remove refrigerant from the system.
- e. A strainer to remove foreign particles carried by the refrigerant.
- f. A solenoid valve, which is an electrically operated automatic stop valve controlled by a thermostat sensing the temperature in the space or medium being cooled.
- g. A hand expansion valve permitting manual control of the refrigerant flow to the evaporator during repair or replacement of the thermostatic expansion valve.
- h. Relief valves to protect system components from overpressure due to malfunction or improper operation.
- i. A heat exchanger intended both to subcool the condensed liquid, and to help prevent liquid refrigerant from being carried back to the compressor through the switch line.

516-1.9.6.1 Additional information on these and other system components are included in later sections of this manual.

516-1.9.7 CYCLE OPERATION. Application of the refrigeration cycle is exemplified by the refrigeration system shown in [Figure 516-1-5](#). It is assumed that R-12 is boiling in the evaporator coil at 20° F, with a corresponding pressure of 21.05 psig ([Table 516-1-1](#)). Disregarding any pressure losses in the suction line piping, the pressure at the inlet of the compressor would also be 21.05 psig. The pressure of the R-12 is then raised from 21.05 psig to 124.3 psig, at which pressure it is discharged to condensing coils. Since the water is cooler than the gas in the condenser, the hot gas will surrender heat to the water and condensation will occur. For the gas to condense it has to be saturated; therefore, the temperature of the gas can be determined by referring to [Table 516-1-1](#). The R-12 saturated gas at 124.3 psig has a temperature of 104°F, which is the condensing temperature. The higher pressure in the condenser forces the liquid through the liquid refrigerant piping to the expansion valve where it is metered into the evaporator as required. In the evaporator, the liquid is re-evaporated and the cycle repeated.

516-1.9.8 SUPERHEATING AND SUBCOOLING. This analysis of the refrigeration cycle has been considered on the theoretical basis that the refrigerant would be in a saturated condition. In actual practice, the refrigerant is superheated and subcooled during the refrigeration cycle. Superheating takes place in the cooling coil (evaporator) and suction refrigerant line due to the absorption of heat after evaporation between the cold vapor and warmer piping. Superheating is desirable because it ensures complete vaporization of the liquid refrigerant before it enters the compressor. Subcooling takes place in the condenser where the condensed liquid is slightly cooled below the condensing temperature through contact with the relatively cold condenser tubes. Subcooling will also occur in an installed liquid-suction heat exchanger where the liquid refrigerant is subcooled and the refrigerant vapor is superheated. Liquid subcooling is desirable because it increases the refrigerating effect at the cooling coil; it also reduces the possibility of liquid vaporizing ahead of the expansion valve due to pressure loss in the piping.

516-1.9.9 SYSTEM DESCRIPTION. Use the refrigeration system shown in [Figure 516-1-5](#) to cover any refrigeration application, whether air-conditioning, food preservation, water cooling, or special processes where

R-12 is the refrigerant in use. Some adaptation and some additional equipment may be added to the system. To trace the circuit and identify the accessories shown, the refrigeration system, starting with the compressor, will again be described.

516-1.9.9.1 Larger systems are provided with an internal compressor relief valve to relieve high-pressure gas into the low-pressure side of the system. This is done to protect the compressor from damage in the event of accidental stoppage of the discharge line or inadvertent closing of a discharge valve. Pressure and temperature gauges are installed in various locations throughout the system to analyze operation of the plant. The hot gas enters the condenser where it comes in contact with the relatively colder tubes that contain the seawater. Contact with these colder tubes causes the gas temperature to drop and in so doing, change the gas to a liquid which flows by gravity to a receiver. The receiver is a container used to collect the liquid refrigerant in the system. To protect the receiver, safety devices are provided.

516-1.9.9.2 [Figure 516-1-5](#) shows the installation of a relief valve around the shutoff valve that would allow excessive pressure to be relieved to the condenser. The refrigerant from the receiver is then directed through a dehydrator used to pick up any moisture contained in the refrigerant. Some systems use an automatic shutoff valve (king solenoid valve) installed in the main liquid line. This solenoid valve shuts off the flow of all the refrigerant when the compressor shuts down under its safety controls.

516-1.9.9.3 The liquid refrigerant line connects to one or more cooling coils (evaporators) located in areas where cooling is necessary. Before entering the cooling coils, the liquid first goes through a strainer to remove foreign substances that could block the small orifice in the expansion valve. After leaving the strainer, liquid usually goes through a solenoid valve, an electrically operated stop valve under the control of a thermostat that is actuated by refrigerated space temperature. The liquid then goes through a thermostatically-controlled expansion valve that meters the proper amount of refrigerant into the cooling coil. A hand expansion valve, used in case of an emergency where replacement or repair of other controls is not feasible, may be placed around the thermostatically-controlled expansion valve.

516-1.9.9.4 The refrigerant entering the cooling coil is exposed to a relatively low pressure brought about by the suction from the compressor. This causes the refrigerant, changing from a high-pressure liquid to a low-pressure liquid, to boil and flash into a vapor by absorbing heat from its surroundings. The cooling coil may be an air-conditioning coil with a forced air blower, a finned pipe coil inside a refrigerated space, or tubes inside a water chiller. The cold vapor or gas from the cooling coil then returns to the compressor.

516-1.9.10 **SYSTEM CAPACITY.** An operating system will function to remove heat from the product or space involved. The compressor capacity will vary depending upon the suction pressure; the higher the compressor suction pressure, the higher the compressor capacity; and the lower the compressor suction pressure, the lower the compressor capacity. The available load is balanced with the compressor capacity, resulting in a specific suction pressure. Since a refrigeration application covers a wide range of loads from pulldown to light loads, some means of capacity control is required. This is done by automatically preventing specific cylinders from pumping refrigerant. This reduces compressor capacity consistent with the load requirement and with a suction pressure that will permit the compressor to continue operating. Refer to [Section 3](#) for details on capacity controls.

516-1.9.11 **SYSTEM LOAD REQUIREMENTS.** Any refrigerating system shall be capable of taking care of a predetermined cooling load condition. The calculations of cooling load are made during system design. The load is based on the heat given off by products, people, and equipment within the space that needs to be absorbed, the heat infiltrating through the boundaries, and the heat of the air leaking into or entering the space. The capacity of any refrigerating system is the rate at which it will remove heat from the refrigerated space. It is usually stated

either in Btu per hour or in tons of refrigeration. A ton of refrigeration is defined as a cooling rate of 12,000 Btu per hour, and is based on the cooling effect of 1 ton of ice (2,000 pounds x 144 Btu pounds = 288,000 Btu) melting in 1 day. Thus, if 1 ton of ice melts in 1 day, it will absorb heat at the rate of 288,000 divided by 24 or 12,000 Btu per hour. The capacity of a mechanical refrigeration system depends upon two factors:

- a. The weight of refrigerant circulated per unit of time.
- b. The refrigerating effect of each pound circulated.

516-1.9.12 REFRIGERANT COMPARISONS. The physical characteristics of R-12, R-134a, and R-22 make these refrigerants more suitable for use in positive displacement machines such as reciprocating rotary or helical screw compressors, while R-11, R-114, and R-236fa are more suitable for centrifugal compressors. Centrifugal compressors for R-134a are currently being developed. The reciprocating plants may be in a package arrangement using the refrigerant directly or using a second refrigerant, usually water, as the cooling medium. Reciprocating plants may also be arranged as separate components with the refrigerant piped to various cooling coils throughout the ship. The centrifugal plants or plants with helical screw compressors are usually in a package arrangement using a secondary refrigerant, water or glycol, as the cooling medium depending upon compartment temperature. Besides convenient pressure-temperature levels, another important characteristic of refrigerants is miscibility with oil. R-12 is much more miscible with oil than R-22. Under certain conditions, R-22 and oil separate and each fluid exists separately inside the refrigerant piping system. The traditional Navy refrigerants R-11, R-12, R-22, and R-114 are miscible with mineral oil. The new hydrofluorocarbon refrigerants R-134a and R-236fa, however, do not mix well with mineral oils; they require commercial-grade polyolester oils that conform to NAVSEA Commercial Item Description (CID) A-A-XXX87 and CID (TBD), respectively.

516-1.9.13 REFRIGERANT PIPING. One of the main features of a refrigeration plant is how the system is put together. Piping is an important part of every system design and installation. Arrangement of the piping and the care with which it is installed can mean the difference between a trouble-free refrigeration or air-conditioning system and a system plagued with problems.

516-1.9.14 REFRIGERANT PIPING DESIGN. While shipboard operating and maintenance personnel are not involved with the design and installation of refrigeration piping systems, it is important that they be familiar with good piping practices and be able to recognize where a poor or deficient installation was made. In some cases, the difference between a reliable plant and a continuously troublesome one is the piping design and installation. The following sections on piping design are included for information background of operating personnel.

516-1.9.14.1 Refrigeration piping involves extremely complex relationships in the flow of refrigerant and oil. Fluid flow is the name given to the study of the flow of any fluid, whether it is a gas or a liquid, and the interrelationship of velocity, pressure, friction, density, viscosity, and the work required to cause the flow. Fluid flow theories generally deal with the flow of one homogeneous fluid and little mention is made of a combination flow of liquid, gas, and oil as occurs in any refrigeration system. Because of its changing nature, such a flow is too complex to be governed by a simple mathematical equation. Practically all working knowledge of refrigeration piping is based on practical experience and test data. As a result, the general type of gas and liquid flow that shall be maintained to avoid problems is known; however, there is seldom one exact answer to any refrigeration piping problem.

516-1.9.14.2 The design of refrigeration piping systems is a series of compromises. It is desirable to have maximum capacity, minimum cost, proper oil return, minimum power consumption, minimum liquid charge, and good flexibility of system operation. All of these goals cannot be satisfied. In general, pressure drop in refrigerant lines

tends to decrease capacity and increase power requirements; therefore, avoid excessive pressure drops. The magnitude of the pressure drop allowable varies depending upon the particular segment of piping involved. Consider each part of the system separately. A good piping designer realizes, however, that pressure drop is not the only criterion to consider in sizing refrigerant lines. Often refrigerant velocities rather than pressure drops are the determining factors in system design for proper oil return. In addition to the critical nature of oil return, there is no better invitation to system difficulties than an excessive refrigerant charge. A reasonable pressure drop is far more preferable than oversized lines that can contain refrigerant far in excess of the system needs. An excessive refrigerant charge in some applications can result in serious problems in liquid refrigerant control and erratic operation of refrigerant control devices.

516-1.9.14.3 The size of the service valve supplied on a compressor, or the size of the connection on a condenser, evaporator, or other accessory, does not determine the size of line to be used. Manufacturers select a valve size or connection fitting on the basis of its application in an average system. The type of application, length of connecting lines, type of system control, variation in load, and other factors can be very important in determining the proper line size. It is quite possible the required line size may be either smaller or larger than the fittings on various system components. In such cases, use reducing fittings.

516-1.9.14.4 Since some oil shall pass through compressor cylinders to provide lubrication, a small amount of oil is always circulating with the refrigerant. Refrigeration oils are soluble in liquid refrigerant, and at normal room temperatures they will mix completely. Oil and refrigerant vapor, however, do not mix readily. The oil can be properly circulated through the system only if the mass velocity of the refrigerant vapor is great enough to sweep the oil along. To ensure proper oil circulation, adequate refrigerant velocities shall be maintained, not only in suction and discharge lines, but in evaporator circuits as well. Several factors combine to make oil return most critical at low evaporating temperatures. As the suction pressure decreases and the refrigerant vapor becomes less dense, it becomes more difficult to sweep the oil along. With a decrease in density the weight of refrigerant circulated decreases. Refrigeration oil alone has the consistency of molasses at temperatures below 0°F. As long as the oil is mixed with sufficient liquid refrigerant, however, it flows freely. At low temperature conditions, these factors can create a critical condition. The density of the gas decreases, the mass velocity flow decreases, and as a result, the oil starts accumulating in the evaporator and lower sections of pipe, rather than returning to the compressor. This results in wide variations in the compressor crankcase oil level in poorly designed systems. Oil accumulation can be minimized with adequate velocities and a properly designed system.

516-1.9.14.5 Copper tubing or copper pipe is generally used for refrigerant systems. Occasionally, stainless steel or other special materials are used in refrigerant piping. Copper tubing and piping intended for use in refrigerant systems are shipped from the factory cleaned, deoxidized, dehydrated, and sealed. Leave seal caps on the end of tube sections until connection to the system is made. If seal caps have been removed and the cleanliness of the tube is doubtful, blow out each length of tube with dry air and pull a cloth swab back and forth in the tube until the tube is bright and shiny. Seal ends of the tube after cleaning until the tube is used. Copper tubing commonly used for plumbing usually has oils and grease or other contaminants on its interior walls. These can cause serious operating problems if not removed. Interconnections of pipe or tube sections and various system components in refrigerant systems are generally made with brazed joints using wrought copper or forged brass fittings. Avoid cast fittings since they may be porous to refrigerants. Never use soft solder as this type of joint will not hold up on board ship. Where occasional disassembly or disconnection may be required, mechanical fittings are provided.

516-1.9.15 BASIC PRINCIPLES FOR APPLICATION. Except for self-contained or packaged units, refrigerant piping shall be tailored to suit each job. It is important, therefore, that good piping principles are followed to provide the correct piping system for the intended application. It is impossible to give rules that would cover all

problems arising during the design and installation of refrigeration or air-conditioning piping. There are several basic rules, however, that shall always be followed in laying out piping to provide a neat, serviceable installation. Adherence to these rules will, in most cases, ensure good system operation. These basic rules are the following:

- a. Keep refrigerant lines short and as direct as possible. Short, direct lines will minimize tube and refrigerant requirements and contribute to proper system performance by reducing pressure drops.
- b. Locate refrigerant piping so that access to system components is not hindered and the piping does not interfere with normal use of the space. All system components will require periodic inspection and maintenance; these functions will be simplified if access to equipment is possible without climbing over and under piping.
- c. Avoid locations where copper tube will be exposed to possible damage. If this is not feasible, enclose the tube in a protective conduit.
- d. Use as few joints and fittings as possible to reduce cost, avoid leak sources, and minimize pressure drop. Fittings shall be the long radius type which have better flow characteristics than short radius fittings.
- e. Pitch all horizontal suction and discharge lines a minimum of 1/2 inch in 10 feet in the direction of refrigerant flow. Avoid unnecessary traps.
- f. Do not expose piping to external sources of heat if it can be avoided.

516-1.9.16 PIPING SIZING. While oversizing of horizontal or vertical piping downward lines will have no detrimental effect on system operation, proper sizing of vertical or upward sloping risers is extremely important to ensure oil return, particularly in suction lines. Generally, these lines are sized to provide the minimum refrigerant flow rate necessary to ensure oil return under all operating conditions and without an excessive pressure drop at maximum flow.

516-1.9.17 DISCHARGE PIPING. Pressure drop in discharge lines is probably less critical than in any other part of the system. Frequently, the effect of discharge line pressure drop on capacity is overestimated since it is assumed the compressor discharge pressure and the condensing pressure are the same. In fact, the compressor discharge pressure is greater than the condensing pressure by the amount of the discharge line pressure drop. An increase in pressure drop in the discharge line may increase the compressor discharge pressure materially, but have little effect on the condensing pressure. A reasonable pressure drop in the discharge line is often desirable to dampen compressor pulsation, and thereby reduce noise and vibration.

516-1.9.17.1 Some discharge line mufflers derive most of their efficiency from pressure drop through the muffler. Discharge lines on factory-built condensing units usually are not a field problem. However, on systems installed in the field with remote condensers, select line sizes to provide proper system performance. Because of high temperatures existing in the discharge line, oil flows freely and oil circulation through both horizontal and vertical lines can be maintained satisfactorily with reasonably low velocities. The discharge line from the compressor to a remote condenser normally should be looped to the floor before being run vertically to prevent drainage of oil back to the compressor head during shutdown periods.

516-1.9.18 LIQUID PIPING. Since liquid refrigerant and oil mix completely, velocity is not essential for oil circulation in the liquid line. The primary concern in liquid line sizing is to ensure a solid liquid head of refrigerant at the expansion valve. If the pressure of the liquid refrigerant falls below its saturation temperature, a portion of the liquid will flash into vapor to cool the liquid refrigerant to the new saturation temperature. This can occur in a liquid line if the pressure drops sufficiently due to friction or vertical lift.

516-1.9.18.1 Flash gas in the liquid line has a detrimental effect on system performance in several ways. It increases the pressure drop due to friction, reduces the capacity of the expansion device, may erode the expansion valve pin and seat, can cause excessive noise, and may cause erratic feeding of the liquid refrigerant to the evaporator. For proper system performance, it is essential that liquid refrigerant reaching the expansion device be subcooled slightly below its saturation temperature. On most systems, the liquid refrigerant is sufficiently subcooled as it leaves the condenser to provide for normal system pressure drops. The amount of subcooling necessary, however, depends on the individual system design.

516-1.9.19 SUCTION PIPING. Suction line layout and sizing is most critical from a design and system standpoint. In general, avoid trapped sections of the suction line except where necessary for oil return. Oil or liquid refrigerant accumulating in the suction line during the off cycle can return to the compressor at high velocity as liquid slugs on startup, and can break compressor valves or cause other damage. Any pressure drop occurring due to frictional resistance to flow results in a decrease in the pressure at the compressor suction valve, compared with the pressure at the evaporator outlet. As the suction pressure decreases, each pound of refrigerant returning to the compressor occupies a greater volume, and the weight of the refrigerant pumped by the compressor decreases. This results in a decrease in capacity.

516-1.9.19.1 Maintain Adequate Oil Velocity. Of equal importance in sizing suction lines is the necessity of maintaining adequate velocities to properly return oil to the compressor. Studies have shown that oil is most viscous in a system after the suction vapor has warmed up a few degrees from the evaporating temperature, so that the oil is no longer saturated with refrigerant. This condition occurs in the suction line after the refrigerant vapor has left the evaporator. Movement of oil through suction lines depends on both the mass and velocity of the suction vapor. As the mass or density decreases, higher velocities are required to force the oil along. Tests have shown that in vertical risers the oil tends to crawl up the inner surface of the tubing. The larger the tubing, the greater the velocity required in the tubing center to maintain tube surface velocities that will carry the oil. The exact velocity required in vertical lines depends on both the evaporating temperature and the line size.

516-1.9.19.2 Double Risers. Even though a system might have a much larger design capacity, the suction line sizing shall be based on the minimum capacity anticipated in operation under light-load conditions, after allowing for the maximum reduction in capacity from capacity control, if provided. Since the dual goals of low-pressure drop and high velocities are in direct conflict, compromises shall be made in both areas. Generally, in suction line design, keep velocities as high as possible by sizing lines on the basis of the maximum pressure drop that can be tolerated; but in no case should gas velocity be allowed to fall below the minimum levels necessary to return oil. Tentative selection of suction line sizes is made on the basis of a total pressure drop equivalent to a 2°F change in the saturated evaporating temperature. On systems equipped with capacity control compressors, single suction line risers may result in either unacceptably high or low gas velocities. A line properly sized for light-load conditions may have too high a pressure drop at maximum load, and if the line is sized on the basis of full-load conditions, velocities may not be adequate at light-load conditions to move oil through the tubing.

516-1.9.19.2.1 In air-conditioning applications where somewhat higher pressure drops at maximum load conditions can be tolerated without any major penalty in overall system performance, it is usually preferable to accept the additional pressure drop imposed by a single vertical riser. But on medium or low temperature applications where pressure drop is more critical and where separate risers from individual evaporators are not desirable or possible, a double riser may be necessary to avoid an excessive loss of capacity.

516-1.9.19.2.2 A typical double riser configuration is shown in [Figure 516-1-6](#). The two lines shall be sized so that the total cross-sectional area is equivalent to the cross-sectional area of a single riser that would have both satisfactory gas velocity and acceptable pressure drop at maximum load conditions. The two lines normally dif-

fer in size. With the larger line trapped as shown, the smaller line is sized to provide adequate velocities and acceptable pressure drop when the entire minimum load is carried in the smaller riser. During operation at maximum load conditions, gas and entrained oil will be flowing through both risers. At minimum load conditions, the gas velocity will not be high enough to carry oil up both risers. The entrained oil will drop out of the refrigerant gas flow and accumulate in the P trap, forming a liquid seal. This will force all of the flow up the smaller riser, thereby raising the velocity and ensuring oil circulation through the system.

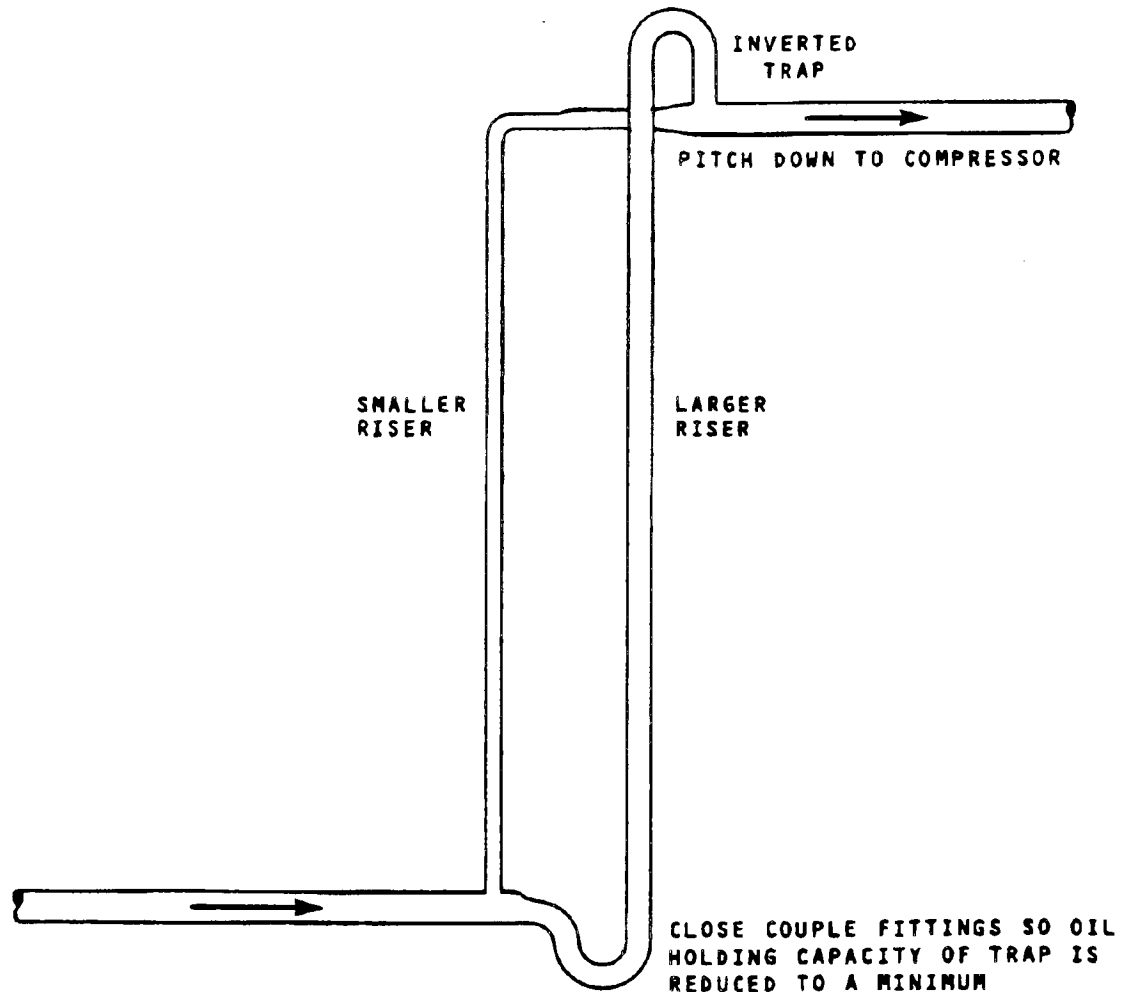


Figure 516-1-6. Suction Line Double Riser

Figure 516-1-6. Suction Line Double Riser

516-1.9.19.3 Suction Line Piping at Evaporator. Evaporators shall be trapped to prevent liquid refrigerant from draining back to the compressor by gravity during the off-cycle. Where multiple evaporators are connected to a common suction line, connections shall be made with inverted traps to prevent drainage from one evaporator from affecting the expansion valve bulb control of another evaporator. Where a suction riser is taken directly upward from an evaporator, a short horizontal section of tubing and a trap shall be provided ahead of the riser so that a suitable mounting for the thermal expansion valve bulb is available. The trap serves as a drain area and helps to prevent the accumulation of liquid under the bulb, which could cause erratic expansion valve operation.

If the suction line leaving the evaporator is free draining, or if a reasonable length of horizontal piping precedes the vertical riser, no trap is required unless necessary for oil return. Typical evaporator connections are illustrated in [Figure 516-1-7](#).

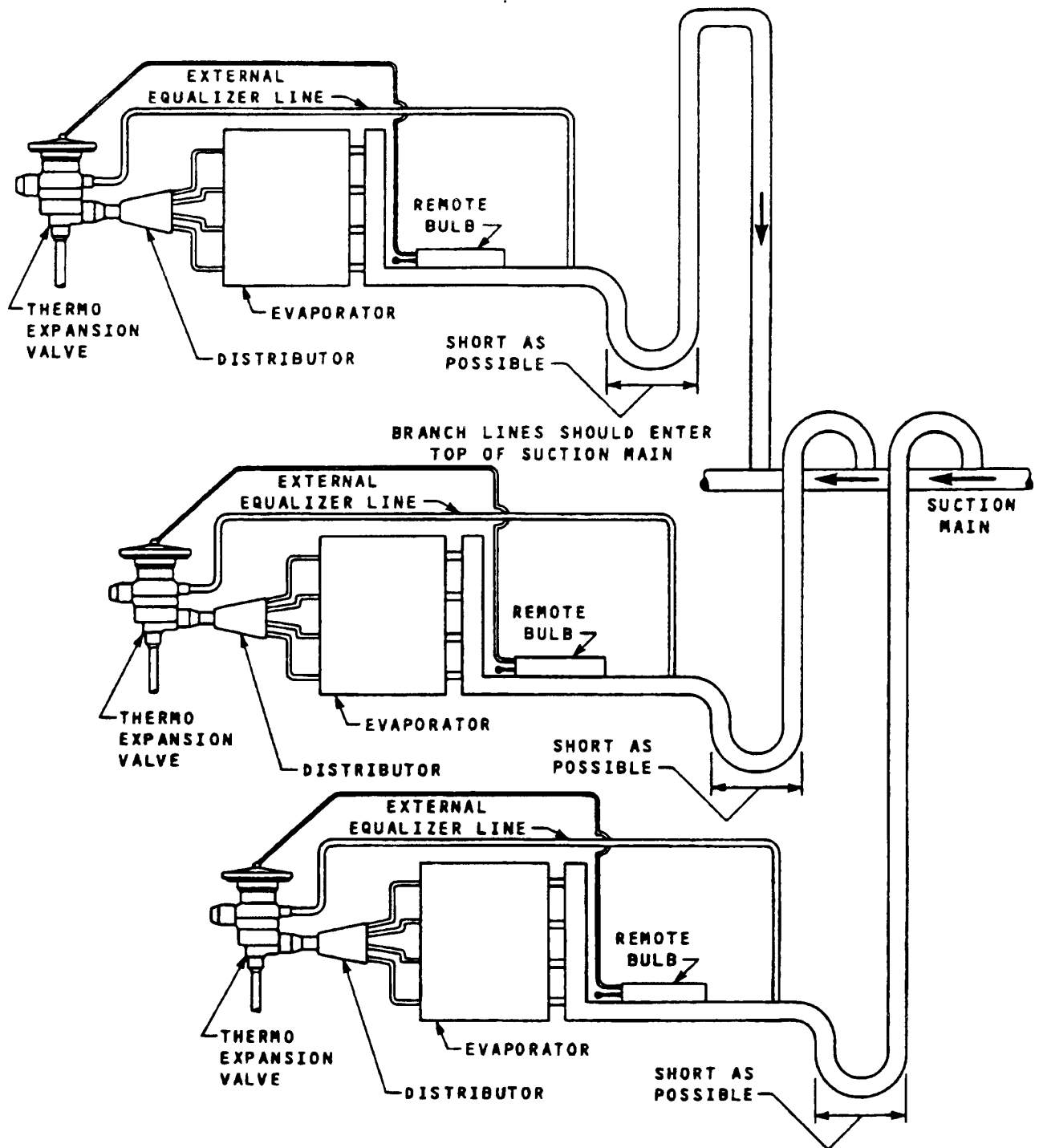


Figure 516-1-7. Schematic of Recommended Suction Piping to a Common Suction Main

516-1.10 SAFETY PRECAUTIONS

516-1.10.1 GENERAL. Safety is a state of mind. It is the attitude with which individuals approach their work. Safety aids are important, as many potential tragedies have been avoided by wearing glasses, goggles, safety shoes, and proper clothing. But even more important is to adopt a mental attitude that emphasizes the safe way of doing things. While halocarbon refrigerants and solvents (also referred to as cleaning agents) are considered less toxic than other refrigerants and solvents, they are treated as toxic gases since they do not support life. Personnel who handle or use halocarbon compounds shall be aware of their hazardous properties. Accidents, sometimes fatal, involving the handling and use of these compounds continue to occur. Hazards connected with the use and handling of halocarbon refrigerants and solvents cannot be overemphasized.

516-1.10.2 HANDLING HALOCARBON REFRIGERANTS AND SOLVENTS. Personnel who use halocarbon compounds shall familiarize themselves with and observe the following safety precautions to prevent injury:

- a. Always wear goggles when handling refrigerants and solvents to avoid getting liquid into the eyes. Liquid refrigerant can cause injury by freezing moisture in the eyes and solvents can cause eye irritation.
- b. If liquid refrigerants or solvents accidentally come in contact with the eyes, avoid rubbing or irritating the eyes and give first aid treatment immediately by promptly irrigating and washing the eyes gently with water at room temperature for 15 minutes. Take the injured person to the medical officer.
- c. If liquid refrigerant with a boiling point below 32°F at normal atmospheric pressure comes in contact with the skin, treat the injury as if the skin were frostbitten or frozen. Avoid prolonged contact with liquid solvents. Solvents dissolve natural oils in the skin and may lead to skin cracking and irritation. Wear rubber gloves if prolonged contact with the hands cannot be otherwise prevented. Immediately remove clothing that becomes wet with solvent.
- d. An open flame, welding, or hot surfaces such as space heaters (Salamanders or other types) will decompose halogen refrigerants and solvents to extremely toxic materials. Purge halogen piping with nitrogen before and while using a torch. If a torch is used with halogens in the line and the halogen is leaking through, halogen acids, which are very irritating to the nose and throat at very low concentrations, will form. It is virtually impossible for a person to voluntarily remain in an atmosphere where these acid vapors are present in high enough concentrations to cause serious harm. The medical department shall observe personnel exposed to significant levels of refrigerant decomposition products for immediate or delayed pulmonary edema.
- e. Ensure that each compartment containing a refrigerating plant has ventilation and exhaust with the exhaust intake duct located about 9 inches off the deck.
- f. If refrigerant is being charged into or being removed from a system, prohibit nonessential persons from being in or entering the space while refrigerant transfer is taking place. Always have two people present (two man rule) when working with refrigerant in an enclosed space. The second person can isolate the leaks and should be able to call for help if required.
- g. While halocarbon solvent in quantities exceeding 200 milliliters (1/2 pint) is being used, at least two people shall be present. Do not leave the area unattended while cleaning is in progress.
- h. Refrigerants and halocarbon solvent vapors used in Navy systems are four to five times heavier than air. In the event of leaks, vapors will drop to the lower level of a compartment, accumulate at the bottom, and fill the compartment, driving out the oxygen, similar to a water leak into a compartment. When entering a compartment, particularly from an overhead hatch that has been secured for some time, and a refrigerant or cleaning solvent leak is suspected, do not be careless. Before entering, do one or more of the following:
 - 1 Exhaust and ventilate the space for several minutes.

- 2 Enter with an oxygen breathing apparatus (OBA).
 - 3 Lower a refrigerant leak detector or halocarbon monitor into the space.
- i. In high concentrations, vapors themselves are toxic. They have an anesthetic effect (causing uncoordination such as stumbling), can affect breathing (shortness of breath) and heartbeat (causing irregular beats and even stoppage), and can cause tremors, convulsions, and death. Exposure can cause headache, rapid heartbeat, lightheadedness, and tingling of fingers and toes. Any one of these symptoms is a warning to leave the area promptly. Exposure to large concentrations of halocarbon compound vapors can be fatal. If a person is overcome because of high concentrations of refrigerant or solvent being present, treat this person as one who has experienced suffocation.

WARNING

If a person is overcome in a space that has or may have a high concentration of refrigerant vapor, remove the person immediately and give artificial respiration if breathing has stopped. NOTE TO PHYSICIAN: Since halocarbons cause cardiac sensitization, the attending physician WILL NOT administer an injection of epinephrine or similar heart stimulant. Cardiac arrhythmia, including ventricular fibrillation, may result. Remove the patient to fresh air immediately and do not allow exercise or exertion.

- j. When cleaning with a halogen solvent (paragraph 516-1.10.5) or using refrigerant, be sure ventilation in the space is adequate to keep the concentration of the halogen solvent or refrigerant below 1,000 parts of halogen per million parts of air. If necessary, use portable blowers. Exhaust ventilation with intake at a low spot (near deck level) is preferable to blowing air into the space. Threshold Limit Value (TLV) refers to the average airborne concentration of substances for an 8-hour workday or 40-hour week, to which nearly all workers may be repeatedly exposed day after day without adverse effect. As an example, a concentration of 1,000 parts per million (ppm) will be reached by evaporation of approximately 150 grams (less than 6 ounces by weight) of liquid refrigerant in a 10 x 10 x 10-foot space.

CAUTION

Although all of the refrigerants listed here have a TLV of 1,000 parts of refrigerant per million parts of air, the initial anesthetic effects of R-113 (trichlorotrifluoroethane) can be experienced at much lower levels than those of other refrigerants.

- k. Do not allow used refrigerant oil to stand in an open container. Used refrigerant oil is contaminated with refrigerant. The refrigerant will evaporate out of the oil and contaminate the ship's atmosphere.
- l. Ensure that personnel who work with refrigeration systems and may be exposed to halocarbon refrigerants are screened by the cognizant medical authority for a history of medical conditions such as cardiovascular disease that might place the person at increased risk.
- m. When solvent is being transferred by hose or pipe from a remote location, establish telephone communication between the pumping station and the space involved.
- n. Place an emergency self-contained breathing apparatus in the space for each person there to permit escape if an accidental spill occurs. Each person shall have received instruction and practice in the use of the particular self-contained breathing apparatus in the space. If a spill occurs, a high concentration of solvent vapor

may rapidly fill the space and dilute the air there. Breathing this diluted, contaminated air can result in rapid (10 to 15 seconds) loss of consciousness. It is, therefore, necessary to stop breathing until the self-contained breathing apparatus has been put on and is supplying air. The Navy's Emergency Escape Breathing Device (EEBD) may be used for emergency escape aboard ship.

- o. Suspend all hot work in the space before using halocarbon solvent or charging or draining refrigerant.

CAUTION

Do not pressurize a refrigerant system with air. At pressures above atmospheric and with air concentrations greater than 60 percent by volume, refrigerants HCFC-22 (R-22) and HFC-134a can form combustible mixtures.

- p. Before filling a system with refrigerant or solvent, carefully check the flushing system and the refrigerating plant for leaks. A pressure drop test with nitrogen will reveal leaks in the system. Test temporary piping and R-12, R-22, and R-134a plants with 75 psig for 15 minutes. The pressure for R-114 plants shall not exceed 50 psig and the pressure for R-11 plants shall not exceed 15 psig as these are their design test pressures. Test pressure for R-124 plants shall not exceed 100 psig. Test all joints for leakage using soapsuds (paragraph [516-1.10.7.10](#)).
- q. Where available, use a halide monitor with alarm or equivalent instrument to continuously monitor the atmosphere in the space where a halocarbon solvent is used. Do not allow the concentration to exceed 1,000 parts of solvent per million parts of air. If the alarm sounds, leave the space immediately and notify damage control central. It will be necessary to use a supplied-air respirator (air-line respirator) or self-contained breathing apparatus operated in pressure-demand mode to return safely to the space to locate the source of vapors in the air.
- r. Post a caution sign in the area where halocarbon solvent is being used for cleaning and at all entrances to the area. The sign should read: CAUTION: NO OPEN FLAMES. DO NOT ENTER WITHOUT TESTING THE AIR FOR HALOCARBONS. Sign letters should be at least 1 inch high.
- s. Nitrogen is a nontoxic inert gas. However, nitrogen can displace air, and in small, closed, or confined spaces enough oxygen may be displaced by nitrogen to cause suffocation and death. Vent the gas to the outside. If it cannot be vented to the outside and there is a chance of suffocation, use an oxygen monitor with alarm to continuously monitor the area.
- t. Establish and document the proficiency of emergency rescue procedures to ensure personnel can be safely removed from potentially hazardous exposure.

516-1.10.3 HANDLING REFRIGERANT CYLINDERS AND DRUMS. Observe the following precautions when handling refrigerant cylinders or drums:

- a. Never drop cylinders or drums or permit them to strike each other violently.
- b. Never use a lifting magnet or a sling (rope or chain) when handling cylinders or drums. A crane may be used when a safe cradle or platform is provided to hold cylinders or drums.
- c. Keep caps provided for cylinder valve protection on cylinders except when cylinders are in use. Never use the protective cap for lifting cylinders.
- d. Whenever refrigerant is discharged from a cylinder or drum, weigh the cylinder or drum and record the weight of the remaining refrigerant. Record the loss in the refrigerant usage log.

- e. Never attempt to mix refrigerants or gases in a cylinder or drum.
- f. When a cylinder or drum is emptied, immediately close the cylinder valve or drum cap to prevent entrance of air, moisture, or dirt.
- g. Never use cylinders or drums for rollers, supports, or any purpose other than to carry refrigerant.
- h. Never tamper with the safety devices in valves, cylinders, or drums.
- i. Open cylinder valves slowly. Only use wrenches designed to open cylinder valves.
- j. Make sure that the threads on regulators or other connections are the same as those on cylinder outlets or drum connections. Never force connections that do not fit.
- k. Open drums slowly and watch out for outgassing.
- l. Do not use regulators and pressure gauges provided for use with a particular gas on cylinders containing different gases.
- m. Never attempt to repair or alter cylinders, drums, or cylinder valves.
- n. Do not carry throwaway (disposable) refrigerant cylinders on board Navy ships. Refrigerant storage and handling are to be in accordance with **NSTM Chapter 550, Industrial Gases; Generating, Handling, and Storage**.

516-1.10.3.1 Special Precautions In Using Cylinders. Observe the following additional precautions when using cylinders:

- a. If it becomes necessary to warm a cylinder, use a bucket of warm water, not hot water. These cylinders have fusible plugs that melt at about 157°F and soften at a lower temperature. Never use a torch or open flame to warm cylinder.

CAUTION

Lubricating oil is light. If a refrigerant is diluted with oil it will occupy a greater liquid volume than pure refrigerant. This could lead to dangerous overfilling of cylinders.

- b. If it is necessary to withdraw refrigerant from a refrigerating plant into cylinders, take care not to overcharge. Overcharging could burst the cylinder due to liquid expansion. Navy type cylinders are identified in [Table 516-1-8](#).
- c. Do not refill cylinders to their rated water weight because oil may be mixed with refrigerant. Refill cylinders to only 80 percent of the rated water weight (capacity) indicated in [Table 516-1-8](#). The weight of the recovered refrigerant may change as industry gains more experience with recovered refrigerant contaminants.

Table 516-1-8. REFRIGERANT CYLINDERS

		Capacity (lb)			
Diameter (inches)	Length (inches)	Refrigerant		Water	Recovered Refrigerant
12-1/4	36	R-12	145	122	97
		R-22	125		
		R-114	150		

Table 516-1-8. REFRIGERANT CYLINDERS - Continued

		Capacity (lb)			
Diameter (inches)	Length (inches)	Refrigerant		Water	Recovered Refrigerant
		R-134a	122		
10	49	R-114	165	122	97
8-3/16	27	R-12	45	42	34
		R-22	40		
		R-114	50		
		R-134a	42		
6-3/4	11	R-12	10	8.5	7
		R-22	10		
		R-114	10		

516-1.10.3.2 Storage of Compressed Gas Cylinders. Observe the following precautions when storing the compressed gas cylinders:

- Cylinders may be stowed on weather decks protected from direct sunlight or in compartments designed for compressed gas cylinder stowage. Locate cylinders so that the cylinder temperature does not exceed 130°F.
- Stow cylinders with valve end up in racks fitted with metal collars.
- The stowage area shall be as remote as possible from navigation, fire control, and gun stations and located to involve least possible danger from mechanical injury, gun blast, missile blast, heat, or open fire.
- Do not permit a direct flame or jet of steam to come in contact with any part of a compressed gas cylinder.

516-1.10.4 SAFETY IN REFRIGERATED SPACES. Be aware of the following safety precautions when entering refrigerated spaces to load or unload provisions:

- The respiration (ripening or decomposition) of stored fruits and vegetables generates carbon dioxide (CO₂) and other gases, which could be dangerous to personnel entering a compartment to unload the produce. Six-to-eight percent CO₂ causes palpitation of the heart. Daily entrance into a small ship stores compartment may not be a problem. However, periodically ventilate a large cargo fruit and vegetable compartment that may be closed for several days, or ventilate before entering.
- Ensure that you cannot be locked in when entering a refrigerated compartment. Older ships have audible alarms. Newer ships have a simple means to disengage the lock mechanism or a means to remove a hasp from the inside. If a tool is needed for this safety precaution, ensure that it is in the compartment.

516-1.10.5 CLEANING WITH HALOCARBON COMPOUNDS. Particular attention is called to hazards associated with trichlorotrifluoroethane (paragraph 516-1.10.2). This halocarbon is used in large quantities for cleaning refrigeration, hydraulic, air, and oxygen systems, and as a solvent for removing oil and grease from machinery. Trichlorotrifluoroethane is supplied commercially in several grades of purity under such names as Freon TF Solvent, PCA, Freon Precision Cleaning Agent, Freon 113 Refrigerant and Genetron 113. Pure trichlorotrifluoroethane is a heavy, colorless liquid at room temperature. It has a low boiling point (approximately 116°F at atmospheric pressure) and evaporates at room temperature. It has an odor similar to a dry-cleaning fluid like tetrachloroethylene. Trichlorotrifluoroethane vapor is several times heavier than air and tends to collect in low places. The solvent is chemically and thermally stable, so it does not burn or explode. Its air mixtures are not capable of

propagating a flame. Treat trichlorotrifluoroethane as a toxic solvent. Production of trichlorotrifluoroethane ended December 31, 1995. It is being replaced with a variety of alternate aqueous, semi-aqueous, and hydrocarbon cleaning compounds.

516-1.10.5.1 Wipe Solvent Alternatives. Methyl Chloroform (1, 1, 1 Trichloroethane) and CFC-113 (trichlorotrifluoroethane) have been used widely as general and precision manual cleaning (wipe) solvents in the past. With the production cessation of these two chlorinated solvents, wipe solvent users must immediately identify alternatives.

516-1.10.5.1.1 Light Soil Removal. The optimum solution for ODS solvent replacement is to completely eliminate a solvent or cleaner in a cleaning process. This may be possible through use of a dry, lint-free cloth (CCC-C-46, Class 7) to wipe parts clean.

- a. If the soil cannot be removed through the use of a cloth wipe, then an aqueous-based cleaner may be used with a cloth wipe. To ensure complete removal of residue left by the aqueous cleaner, a water rinse may be necessary with a final cloth dry. NAVAIR recommends the use of MIL-C-85570 Type II, **Aircraft Exterior General Use Cleaning Compound**, in this application.
- b. NSN's for some aqueous-based wipe solvents:
 - MIL-C-85570, Type II 1 gal. 6850-01-239-0571
 - MIL-C-85570, Type II 15 gal. 6850-01-248-9828
 - MIL-C-87937, Type II 1 gal. 6850-01-390-7827
 - MIL-C-87937, Type II 5 gal. 6850-01-339-5227
 - JAD Chemical MA-102 5 gal. 6850-01-378-0425

516-1.10.5.1.2 Heavy Soils or Precision Wipe. If soils are too heavy for removal by the two methods above, or if the aqueous cleaner leaves behind an unacceptable residue, then a low vapor pressure (LVP) organic solvent may be required. These LVP organic solvents are used extensively as wipe solvents in the aerospace industry. These solvents are volatile organic compounds (VOC's), but due to their low vapor pressures and slower evaporation rates they may be exempt from certain air regulations and produce lower air emissions, especially if coupled with a cloth bagging and management program.

- a. LVP solvents are generally composed of aliphatic petroleum hydrocarbons, terpenes, esters, or organic blends with vapor pressures below 5 mmHg at 20°C (68°F). Normally these solvents are applied with a solvent-soaked cloth, followed by a surface wipe with a clean cloth. In some cases a second clean cloth wipe may be required to remove residual solvent to speed drying.
- b. NSN's for some LVP organic wipe solvents:
 - Dynamold DS-104 1 gal. 7930-01-367-1000
 - Dynamold DS-104 5 gal. 7930-01-367-0986
 - Dynamold DS-108 1 gal. 7930-01-367-0995
 - Dynamold DS-108 5 gal. 7930-01-367-0996
 - Ecolink Prepsolve 1 gal. 6850-01-394-0162
 - Ecolink Prepsolve 6 gal. 6850-01-394-0160
 - *Ecolink Positron 1 gal. 6850-01-411-8815
 - *Ecolink Positron 6 gal. 6850-01-412-0026

- *Ecolink Positron 55 gal. 6850-01-412-0028
- *PT Tech. PF-145HP 1 gal. 6850-01-378-0044
- *PT Tech. PF-145HP 5 gal. 6850-01-377-9710
- *EPA 2000 5 gal. 6850-01-359-9217
- *Teksol EP 1 gal. 6850-01-378-0581
- *Teksol EP 5 gal. 6850-01-378-0583

NOTE

LVP solvents may craze acrylics and polycarbonates. Unlike chlorinated solvents, LVP solvents are flammable. Flash points range from 105°F to 145°F.

516-1.10.6 ADMINISTRATIVE SAFETY PRECAUTIONS. In addition to the above safety precautions the following administrative procedures are suggested:

1. Notify the ship's Officer of the Deck and Engineering Duty Officer when flushing, cleaning, or refrigerant pressure test operations are ready to begin. It is recommended that a gas-free engineer review and approve procedures and operations being considered.
2. A systems petty officer may also be designated to track contractor work on a daily basis.
3. If leaks in excess of 100 milliliters (1/4 pint) develop during cleaning and flushing operations, everyone shall leave the space immediately and report the incident to the quarterdeck and damage control central.

516-1.10.7 LEAK DETECTORS. Leak detectors can be divided into two broad categories: portable leak detectors and area monitors. Portable leak detectors are used to check individual joints or components of a refrigerating system for leaks and are described in the following paragraphs. Area monitors are used to check the level of refrigerant vapor present in compartments containing refrigerating equipment and are describe in paragraph 516-1.10.8. An area monitor will respond when a major leak has occurred within a given space. The leak is then traced down with a portable leak detector. Criteria for categorization of portable leak detectors and area monitors include sensitivity, detection limits, and selectivity.

516-1.10.7.1 Detector Sensitivity. Sensitivity is defined as the amount of input material necessary to generate a certain change in output signal. For leak detection, the input material is the vapor concentration being measured and the output is the reading or display device. Detectors with high sensitivity require very little material to generate a large change in output signal, while detectors with low sensitivity require larger amounts of material to change the output signal. A detector with high sensitivity may be able to accurately discriminate concentration levels of 1 or 2 parts per million (ppm) of vapor, while a low sensitivity detector may only be able to discriminate in increments of 20 ppm or higher. The sensitivity of a leak detector is determined by a number of factors, the most important being the method of detection and the material being detected. A leak detector that demonstrates high sensitivity for R-12 may be relatively insensitive to R-134a.

516-1.10.7.2 Detector Limits. The detection limit of a leak detector is defined as the minimum amount of material a unit can sense that gives a signal at least two times the background noise level. Detection limits are measured in ounces per year (oz/yr) for portable leak detectors. Since sensitivity can vary greatly with different compounds, the detector must be matched to the intended application. For example, a detector with a detection

limit of 0.25 oz/yr of R-12 may not be as sensitive to R-134a, and a detector made specifically for R-134a may be too sensitive for R-12 leak pinpointing. Some units allow the operator to choose various sensitivity settings to match the refrigerant under investigation.

516-1.10.7.3 Detector Selectivity. Selectivity is defined as the ability to detect only the refrigerant of interest without interference from other compounds that may be present in the area. Using selectivity as a criteria, leak detector can be placed into one of three categories: nonselective, halogen-selective, or compound specific. As the specificity of the monitor increases, so does the complexity and cost. Nonselective detectors are those that will detect any type of emission or vapor present, regardless of its chemical composition. Typical detectors in this category are based on electrical ionization, thermal conductivity, ultrasonics, or metal-oxide semiconductors. These detectors are usually simple to use, very rugged, inexpensive, and portable leak pinpointing applications. They lack selectivity, however, and are limited to sensitivity. Detection limits of nonselective detectors for R-134a range from 50 to 100 ppm. Halogen-selective detectors use a specialized sensor that allows the monitor to detect compounds containing fluorine, chlorine, bromine, and iodine without interference from other species. The major advantage of such detectors is a reduction in the number of false alarms caused by the presence of a compound in the area other than a refrigerant. These detectors are typically easy to use, feature higher sensitivity than the nonselective detectors (detection limits less than 0.05 oz/yr), and are very durable. Compound-specific detectors are capable of detecting the presence of a single species without interference from other compounds. They typically are infrared-based (IR) and have minimum detection limits around 1 ppm, depending on the compound being detected. There are a group of IR detectors that have detection limits of approximately 10 ppm. These detectors typically are less costly and complex than those with lower detection limits.

516-1.10.7.4 Leak Detection Procedures. The information in the following sections applies to the general use of leak detection procedures. The actual procedure for leak-testing a refrigeration plant is outlined under the various refrigerating plants. Correcting refrigerant leakage, no matter how small the problem, is one of the most important functions in operating a plant.

516-1.10.7.5 Halide Leak Detector. The best method of finding leaks is to use a halide leak detector. Halide refers to compounds that contain a halogen. Halogens are a group of elements that includes fluorine, chlorine, and bromine. Since halocarbon refrigerants contain one or more halogens, the detector is able to indicate the presence of refrigerant or a refrigerant leak.

516-1.10.7.5.1 Color Additives. Advertised colored additives for the refrigerant, which supposedly allow visual detection of leaks by noting the smudge of dye color on a pipe or fitting, are not approved and should not be used. Some of these trace materials can cause oil to gum and some are taken out of solution by dehydrators.

516-1.10.7.5.2 Fluorescent Dye. Fluorescent dye leak detection systems are approved for all CFC, HCFC, and HFC shipboard plants. These leak detection systems are based on a dye additive which will fluoresce a bright yellow/green or white color when exposed to ultraviolet (UV) light. The dye is injected in with a plant's refrigerant charge and/or lubricating oil charge. Once inside the plant, the dark concentrated dye is diluted by the plant's refrigerant oil, which thus achieves a fluorescence property. The dye additive is carried throughout the plant by the oil and the oil/dye mixture circulates with the refrigerant in the plant. Leakage can be observed by inspecting the plant with a portable UV lamp. The oil/dye mixture tends to pool in areas where refrigerant and oil leaks occur, so that even a trace amount from an intermittent leak can be observed.

516-1.10.7.5.3 Electronic refrigerant detectors are also able to determine gas leakage but are limited by the following shortcomings: long survey time, impractical for operator to cover every square inch of piping, inability to pinpoint leaks in high refrigerant gas backgrounds, inability to pinpoint leaks in drafty environments, and

inability to find intermittent leaks. The fluorescent dye leak detection system is able to overcome many of these shortcomings, but may not detect every gas leak. Use both systems to thoroughly detect refrigerant leakage.

516-1.10.7.6 Electronic Halogen Leak Detector. The electronic halogen leak detector is the most sensitive and widely used halogen leak detector. Some instruments draw a sample of air and their operation depends on the variation in current flow due to ionization of decomposed refrigerant between two oppositely charged platinum electrodes. Such an instrument can be used to detect any halogen refrigerants used in Navy refrigeration and air-conditioning systems. It is not recommended for use in atmospheres containing explosives or flammable vapors. Some vapors, such as alcohol, solvents, and carbon monoxide, may interfere with the test. A portable battery-operated detector for field use is capable of sensing R-12 leaks as small as 1/2 ounce per year ([Figure 516-1-8](#)). The detector may include a small reference refrigerant bottle leaking at the rate of 1/2 ounce per year, for calibration. If the refrigerant contamination background is very high, ventilation is required before very small leaks can be detected. When a leak is found, its presence is indicated by a signal. Every ship with a central refrigerating plant should have one of these important detectors.

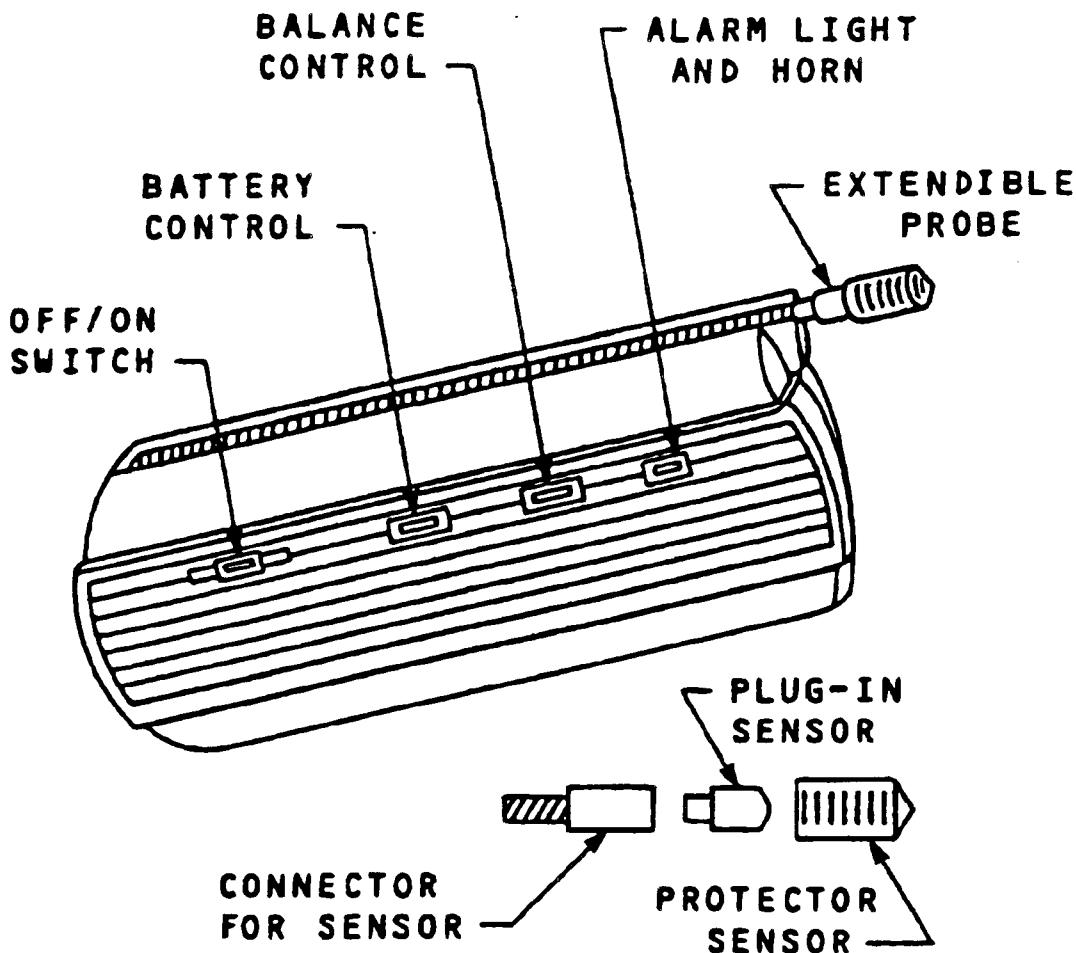


Figure 516-1-8. Yokogawa H10-N Portable Leak Detector

516-1.10.7.7 Halide Torch. The halide torch has been used for many years as a fast, reliable method of detecting chlorofluorocarbon (CFC) refrigerant leaks. It is not as sensitive as the electronic halide leak detector; it is suitable for detecting only CFC's. The torch consists of a fuel source (acetylene or propane), a special burner containing a copper element enclosed in a metal shield with a window for observation, and a sniffer or exploring hose. The fuel feeds a small flame in the burner that heats the copper element. The flame in the burner pulls

a slight vacuum on the sniffer hose. When the sniffer hose is passed near a leak, the refrigerant is drawn into the hose and injected into the burner below the copper element. If CFC refrigerant vapors are present, they will be decomposed by the catalytic action of the copper plate and the color of the flame will change to bluish-green. Increasing amounts of refrigerant will change the color from bright green to violet tinged with red. When testing for leaks with a torch, always watch the flame for the slightest change in color. With experience, very small leaks can be detected. The hand-held, acetylene torch stock number is 1H4940-00-223-8468 and the propane torch stock number is 9H4940-00-756-1207. Although these torches can be used in port on submarines, the acetylene and propane can not be stored on the ship. These torches shall not be used where explosives are present, or in an atmosphere containing flammable vapors.

516-1.10.7.8 Method of Leak Detection. In searching for leaks with a halide leak detector observe the following procedures:

1. Hold the exploring probe close to the joint being tested to prevent dilution of the sample by stray air currents.
2. Move the end of the exploring probe slowly and completely around each joint. There is a definite time lag between the instant air enters the exploring hose until it reaches the reactor plate. Leak testing cannot be safely hurried.
3. If the signal is noted at any time, repeat the test in the same vicinity until the source of the refrigerant is determined. Remember that halocarbon refrigerant gas is heavier than air, so leaks may be detected just below the actual source. After a leak has been detected by the halide detector, use soap bubbles, if necessary, to find the exact point of the leak.
4. After a system has been put in operation, the lubricating oil circulates with the refrigerant in the system and may collect on the exterior of piping joints where a leak exists, thereby indicating the approximate location of system leaks. Carefully remove this oil before the halide leak detector is used to determine the exact location of the leakage.
5. Always follow a definite order in leak testing so that no joints will be missed.
6. Even the smallest leak is not to be considered negligible. However insignificant a leak may seem, it will eventually empty the system of its charge to a point where faulty operation will occur. The extra time spent in testing all threaded, flared, soldered, welded, and gasketed joints will be justified.
7. Never recharge the system until all leaks are discovered and definitely repaired. Upon locating one leak, do not assume that it alone is responsible for the difficulty. Thoroughly retest the complete installation.

516-1.10.7.9 Additional Precautions. In searching for leaks with a halide torch, observe the precautions given for use of the electronic leak detector as well as the following additional precautions:

- a. Ensure the copper reactor plate is in place. Without this plate there is no reaction.
- b. Adjust the flame low enough so that it does not extend appreciably beyond the end of the burner. A small flame is much more sensitive than a large flame. If it is difficult to light the torch when it is adjusted to produce the necessary small flame, block the end of the exploring hose until the flame ignites, then gradually open.
- c. If the flame continues to burn a white or yellow color, the exploring tube is partially blocked with dirt and should be cleaned.
- d. Check to see that air is being drawn into the exploring tube by holding the end of the tube to the ear from time to time.

- e. If a green tinge of flame is noted at any time, repeat the test in the same vicinity until the source of the refrigerant is determined. After a leak has been detected by the halide torch, use soap bubbles if necessary to find the exact point of the leak.
- f. Do not use the torch in an atmosphere known to be heavily contaminated with refrigerant as this will tend to foul it. Clean the copper reactor plate occasionally.

516-1.10.7.10 Use of Soapsuds in Leak Detection. A halide torch will detect very small refrigerant leaks. However, the halide torch is so sensitive that if there are very large leaks in the system, the atmosphere around the apparatus will become so contaminated as to make it impossible to locate the exact source of the leak using the torch. This condition is likely to prevail when the equipment is located in a small or poorly ventilated room or compartment. Under such conditions, the halide leak detector is of little value in finding the exact location of the leak and soapsuds are used. To prepare soapsuds for testing, use a soap and water solution of about the consistency of liquid hand soap, which will lather freely, and work up a lather on a brush. A shaving brush is often helpful in applying the lather. A few drops of glycerin added to the solution will cause the lather to remain wet longer. When applying the soapsuds, paint the soap lather completely around the joint. Then examine the joint thoroughly for bubbles. When the joint is located in the system such that part of it is not visible, use a small mirror. It will sometimes take a full minute or more for bubbles to appear at a small leak. Cover questionable spots with lather and reexamine.

516-1.10.7.11 Oil Testing for Leaks. Never use oil to test for refrigerant leaks because of the capacity of oil for absorbing the refrigerant. If a small leak exists where oil has been applied, refrigerant will be absorbed by the oil and there may be no indication of a leak until after the oil is saturated with the refrigerant. Even after the leak has been stopped, a false leak indication may result when the leaky joint previously tested with oil is retested using the halide torch. This is caused by the refrigerant being released from the oil.

516-1.10.8 AREA HALOCARBON MONITORS. Area halocarbon monitors continuously monitor and indicate the halocarbon levels in the spaces where installed. The monitors provide audible and visual alarms to warn personnel when a major refrigerant leak occurs. Detection limits are measured in parts per million (ppm) for area monitoring. Unlike portable leak detectors, area monitors must work continuously and are thus exposed to more potential interfering substances. Because of the larger number of potential compounds seen and a wider range of concentrations over time, selectivity is more important for area monitors than for portable leak detectors. Using selectivity as a criterion, area halocarbon monitors, like portable leak detectors, can be categorized as nonselective, halogen-selective, or compound-specific. Nonselective detectors are of limited use for area monitoring, since they are also limited in sensitivity. Halogen-selective monitors are higher in selectivity than nonselective detectors, with detection limits typically less than 5 ppm when used as area monitors. This type of monitor is best suited for use in moderately clean equipment rooms where only one refrigerant must be monitored. Its lack of response to nonhalogenated compounds allows its use in storage areas or areas where other (nonhalogenated) compounds may be present. Compound-specific halogenmonitors, with minimum detection limits of around 1 ppm, work well as area monitors but are more complex than the less selective types.

516-1.10.8.1 Where Installed. The halocarbon monitors shall be installed in compartments with refrigerant charged equipment except for the following:

- a. Main machinery rooms and Auxiliary Machinery Rooms (AMRs as originally designed, not redesigned spaces).
- b. Those compartments having a ventilation rate change of two minutes or less for the lowest fan speed and

served by ventilation systems that have a damage control (DC) classification of either "W" or circle "W." One third of the exhaust quantity shall be taken from terminals located nine inches above the deck and near the refrigerant equipment.

- c. Those compartments having a stand-alone self-contained refrigerant charged equipment (e.g., ice machine, galley equipment, drinking water coolers, self-contained air-conditioning units, etc.) with a charge of no greater than 20 pounds.

516-1.10.8.2 Set Points. Installed halocarbon monitors are able to detect low levels of refrigerant in the space. However, their purpose is to alert personnel of equipment derangement that results in ambient refrigerant levels that are hazardous to personnel. Typically, they are set to warn of a dangerous situation in a space at a concentration of 500 ppm of refrigerant in the atmosphere, and to alarm at a concentration of 800 ppm to alert personnel to leave the space and not to enter the space without proper breathing apparatus.

516-1.10.9 Refrigerant Charging. Refrigerant may be charged into a system as a vapor or a liquid depending on the status of the refrigerant system and the location of entry into the system.

CAUTION

DO NOT BREAK VACUUM WITH LIQUID REFRIGERANT

516-1.10.9.1 When a system is under a vacuum, such as after a dehydration and evacuation process, charge with vapor only, until a pressure equivalent to 38 °F is obtained. (R-11 and R-114 is 0 psig, R-12 and R-134a is 35 psig, R-22 is 66 psig, and R-236fa is 3 psig.) Charging with liquid refrigerant will cause a sudden reduction of temperature due to the rapid drop in pressure and boiling of refrigerant. Any water on the non-refrigerant side of heat exchanger tubes will freeze and may result in distortion and leakage of the tubes.

516-1.11 SHIPBOARD REFRIGERANT LEAK REPAIR AND RECORD KEEPING

516-1.11.1 All AC&R systems aboard Navy and MSC ships with an installed charge of 50 pounds or more shall adopt the following performance goals:

- a. Ensure that the annualized leakage rate from shipboard chilled water air conditioning plants does not exceed 15% of the total installed charge.
- b. Ensure that the annualized leakage rate from ship stores and cargo refrigeration systems does not exceed 35% of the total installed charge.

516-1.11.2 Methods by which to measure and monitor refrigerant leakage. [Figure 516-1-9](#) and [Figure 516-1-10](#) are provided to assist ship's force in complying with these requirements. These forms are provided for guidance only and may be revised or substituted to suit individual needs. The rate at which refrigerant is leaking from shipboard air-conditioning and refrigeration equipment can be estimated using the following procedure:

1. [Figure 516-1-9](#) is a day-to-day Service/Maintenance Report Log that can be used to document all service and maintenance conducted on air-conditioning and refrigeration systems. The log is used to keep track of a system's refrigerant consumption and leakage rate.

2. Identify total installed charge. The total installed charge of the system may be obtained from the system technical manual, Fleet Technical Support Centers, or the In-service Engineering Agent.
3. Identify maximum allowable annual leakage rate. Using paragraphs [516-1.11.1.a](#) and [516-1.11.1.b](#), determine whether the maximum allowable annual leakage rate for the system is 15% or 35%.
4. Accidental discharge and removal. Between refrigerant chargings, it is possible that refrigerant has been removed or recovered from a system or an accidental discharge or venting occurred. These events should not be considered when estimating system leakage; but failure to record and account for refrigerant removal or accidental discharge will cause the technician to calculate higher-than-actual leakage rates.
5. Net leakage. The net leakage of a system refers to the system's net refrigerant leakage or net refrigerant consumption. The net leakage is often calculated each time refrigerant is added to a system and covers the period of time since refrigerant was last added to the system. The net leakage can be calculated as follows: Net leakage (lbs) Since Last Charging = (Refrigerant Added (lbs) Since Last Charging) - (Refrigerant Removed (lbs) Since Last Charging) - (Losses Due To Accidental Discharge or Venting (lbs) Since Last Charging).
6. Monthly leakage rate. If the monthly refrigerant leakage ([Figure 516-1-9](#), chart I) exceeds allowable limits ([Figure 516-1-9](#), chart II), leak test the plant and repair all leaks.

RECORD MONTHLY REFRIGERANT LEAKAGE

SHIP _____ YEAR _____

MAX ALLOWABLE LEAKAGE LB/MO	SEE NOTE 2	SEE NOTE 2	SEE NOTE 2	SEE NOTE 2	SEE NOTE 2
MONTH	A/C #1	A/C #2	A/C #3	A/C #4	A/C #5
JANUARY					
FEBRUARY					
MARCH					
APRIL					
MAY					
JUNE					
JULY					
AUGUST					
SEPTEMBER					
OCTOBER					
NOVEMBER					
DECEMBER					
TOTAL					

CHART II

Notes:

1. Obtain refrigerant charge for each A/C unit from technical manual _____ lbs (A*)
2. Calculate allowable monthly leakage rate for each A/C unit as follows:

$$\text{Maximum monthly leakage rate (see note 1)} = \frac{(A*) \times (0.15)}{12} = \text{_____ lbs}$$

Figure 516-1-9. Service/Maintenance Report Log Form (chart II)

RECORD MONTHLY REFRIGERANT LEAKAGE

SHIP _____ YEAR _____

MAX ALLOWABLE LEAKAGE LB/MO	SEE NOTE 2	SEE NOTE 2	SEE NOTE 2	SEE NOTE 2	SEE NOTE 2
MONTH	REEFER #1	REEFER #2	REEFER #3	REEFER #4	REEFER #5
JANUARY					
FEBRUARY					
MARCH					
APRIL					
MAY					
JUNE					
JULY					
AUGUST					
SEPTEMBER					
OCTOBER					
NOVEMBER					
DECEMBER					
TOTAL					

CHART II

Notes:

1. Obtain refrigerant charge for refrigeration system from system manual _____ lbs (B*)
2. Calculate allowable monthly leakage rate for each refrigeration unit as follows:

$$\text{Maximum monthly leakage rate (see note 1)} = \frac{(B*) \times (0.35)}{12} = \text{_____ lbs}$$

Figure 516-1-9. Service/Maintenance Report Log Form (chart II)

Accidental or Unintentional Venting Report

Date _____

Location _____

Refrigeration Unit _____

Type of Refrigerant Vented _____ Approx. How Many Pounds Were Vented _____

Description of Accidental Venting Incident _____

What was the Cause of the Release? _____

What Precautions Have Been Taken to Prevent this from Happening Again? _____

Technician Name/Rank or Grade _____ Certification Number _____

Engineering Officer Signature _____ Date _____

Engineering Officer Printed Name and Rank _____

Maintain for Record Purposes for 3 Years

Figure 516-1-10. Accidental or Unintentional Venting Report Form

SECTION 2.

REFRIGERATION SYSTEM APPLICATIONS

516-2.1 APPLICATIONS ABOARD NAVAL SHIPS

516-2.1.1 INTRODUCTION. Various applications of refrigeration systems used aboard naval ships include the following:

- a. Refrigerated ship stores
- b. Refrigerated cargo
- c. Air conditioning
- d. Process water cooling
- e. Drinking water cooling
- f. Self-contained refrigeration equipment.

516-2.1.2 REFRIGERATED SHIP STORES PLANTS. Refrigerated ship stores plants preserve the food consumed by ship's force. Insulated compartments for cold storage spaces are usually the walk-in type. The equipment for cooling these spaces is selected to maintain the following compartment temperatures as required by NAVMED P5010-1 (Rev 1991):

- a. For ships designed before 1950:
 - 1 Meat compartment - 15°F
 - 2 Fruit and vegetable compartment - 40°F
 - 3 Butter and egg compartment - 32°F
 - 4 Vestibule - 45°F
- b. For ships designed after 1950:
 - 1 Freeze box - 0° F or lower
 - 2 Dairy Products box - 32 - 34° F
 - 3 Chilled Bulk Storage - 33 - 36° F
 - 4 Thaw box - 36 - 38° F
 - 5 Reach-in Refrigerator - 34 - 40° F

516-2.1.2.1 Ship Stores Plant Design. Originally, most ships had ice tanks for making block ice. These were connected to the ship stores refrigeration system. Tanks held a brine solution in which cans of fresh water were inserted to make the block ice. This method of making ice has been discontinued in Navy ships because of possible unsanitary conditions in harvesting the ice. Currently, automatic ice-making machines provide ice for various shipboard uses. On certain ships, adjacent insulated spaces are provided for storage of photographic supplies at a temperature of 50°F with a relative humidity of 50 percent. The addition of other services to the refrigerated ship stores plant is not encouraged because it tends to aggravate the maintenance problem, with the possibility of a serious casualty to this important plant.

NOTE

Many early ships have been modified to maintain 0°F freeze and 33°F chill temperatures.

516-2.1.2.2 Ship Stores Plant Arrangement. [Figure 516-2-1](#) shows a piping diagram of a refrigeration system with reciprocating compressors used for ship stores. Note that two cross-connected, compressor-condenser sets, normally called condensing units, are being used in this example. The design of this plant is such that a load equal to approximately one-half of the total pulldown load is handled by one unit and the balance of the load by the second unit. The refrigerant piping system is valved so that each compressor can be operated on its own refrigerant load. NEVER operate compressors in parallel. Due to ship pitch and roll, one compressor could lose oil to the second operating compressor and cause a failure. There is a threefold reason for using at least two condensing units:

- a. To provide sufficient refrigeration to lower product temperatures (known as pulldown condition) to the design room temperatures.
- b. When this condition is satisfied, to run one unit on the total refrigeration load (normal condition) and permit the securing of the other unit to be used as an emergency standby.
- c. To permit alternate operation of units. Other plants may use three, four, or more units depending on load and design requirements. Ship stores systems are designed for a pulldown condition of not more than 2 days of continuous operation under extreme conditions. Future installations will use 3 days as a design figure for pulldown in ship stores plants.

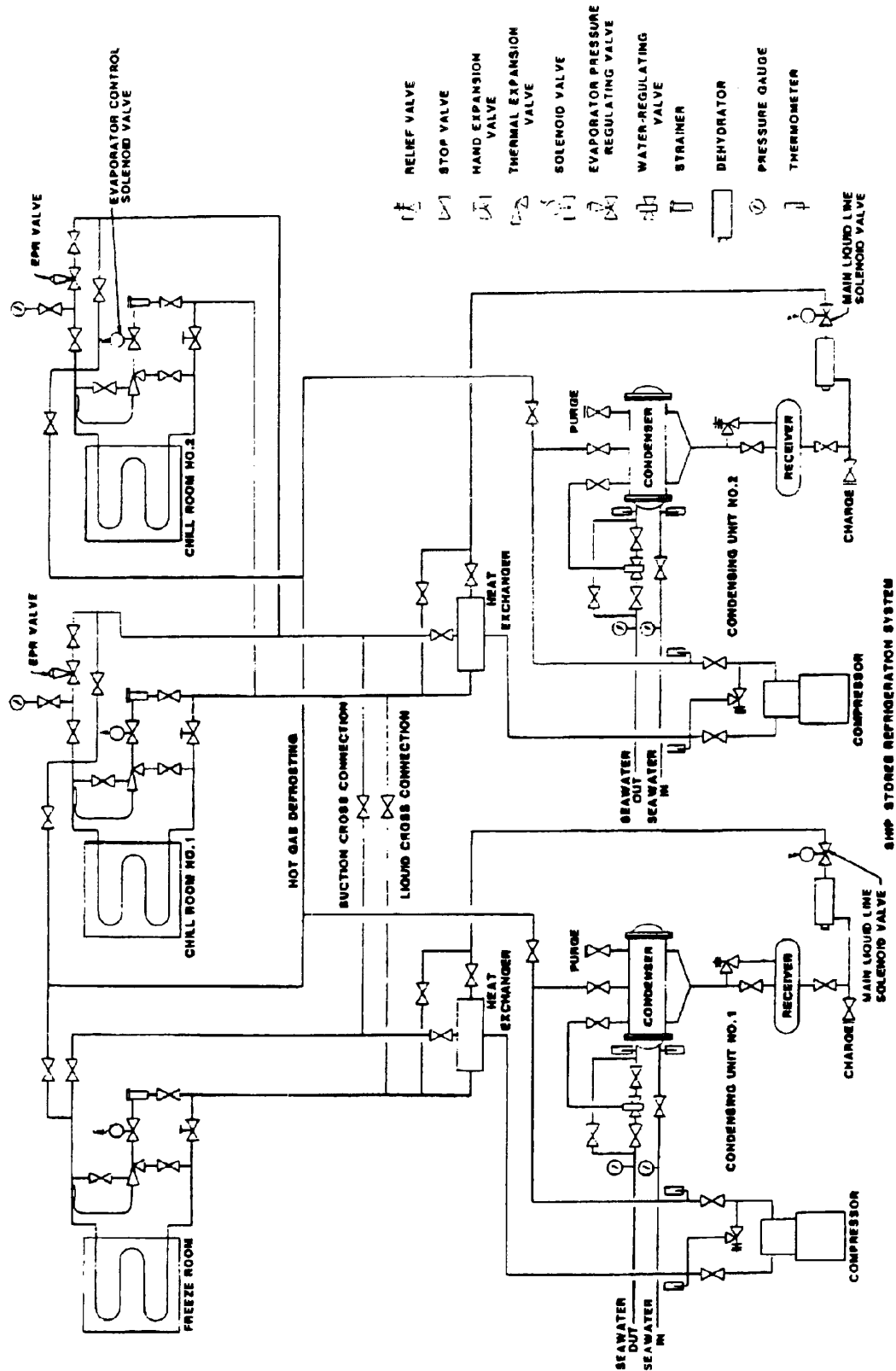


Figure 516-2-1. Diagrammatic Refrigeration System

516-2.1.2.3 Ship Stores Plant Components. In spaces that are maintained at below 32°F, provision is made for defrosting accumulated ice on cooling coils. This is done for maximum cooling coil surface efficiency. Where wall coils with gravity airflow are used, defrosting is accomplished by piping hot refrigerant gas from the compressor unit into the cooling coil to melt the surface frost. Where cooling coils with forced air circulation are used, defrosting is accomplished using built-in electric heating elements. The electric defrosting cycle is usually initiated automatically by a built-in timer. In either cooling coil system the melted frost or ice is collected in troughs located below the coils and is then piped outside the space. Troughs contain electric heating cables to remain ice-free. The drain piping within the freezer compartment is also heated with electric heating cable. Each refrigerated storage space is provided with forced air circulation. This forced air circulation prevents stratification or layering of undisturbed air in the refrigerated area, which would result in wide differences in the temperature of air at deck level compared to the overhead air temperature. Air circulation is accomplished through use of special refrigerator wall-mounted propeller type fans, overhead fans, or vaneaxial fans with ductwork, depending on the size of the space. Temperature within any space is controlled by a thermostat that actuates a control (solenoid valve) in the refrigerant line to start or stop the flow of refrigerant as required. Variation in refrigeration load affects the suction pressure that automatically varies capacity. If cooling is no longer required in the spaces, closing solenoid valves in the system will stop the compressor. In addition, safety controls are provided to protect the compressor. The details of these controls are covered in other sections of this chapter.

516-2.1.3 REFRIGERATED CARGO PLANTS. Refrigerated cargo plants are provided on auxiliary ships to permit the shipment of perishable food intended for forces afloat or advanced base areas. The use of refrigeration in such spaces is similar to that of ship stores, except that equipment and spaces are larger and more complex. Usually, 30 to 60 percent of the total refrigerated volume is designated for freeze temperatures of 0° to -5°F for present ship designs and -10°F for future ship designs. The balance of the ship is designed for chilled spaces of 33°F to 36°F, with flexibility built into the equipment to permit some spaces to be converted to freeze compartments. Similar to refrigerating plants for ship stores, refrigerated cargo plants are installed in multiple compressor arrangement with compressor units cross-connected in the refrigerant piping. Cross-connections are valved so each compressor can operate on its own refrigerant load or take up the load of an adjacent compressor if it fails. Plants range from 1/2 ton up to 18 tons at -20°F suction temperature for refrigeration cold storage applications.

516-2.1.3.1 Cargo Plant Arrangement. The schematic shown in [Figure 516-2-1](#) is generally adaptable to cargo refrigeration. The design of equipment for cargo plants is based on a calculated pulldown condition for freeze spaces of 5 days and a 3-day temperature pulldown time for chilled spaces. The refrigerating equipment is usually zoned, in that freeze spaces are connected to their own group of condensing units, and higher temperature chilled spaces are on a second group of units. Cross-connection of equipment is provided to permit flexibility of operation as independent systems.

516-2.1.3.2 System Operation. Positive air distribution is included in cargo applications to eliminate temperature stagnation. The latest installations use the forced air circulating cooling coil, which is installed in an air recirculating distribution system. The cooled air is forced into the refrigerated compartment, discharged around the perimeter across the overhead, and down the walls toward the deck, causing a blanket of refrigerated air to surround the cargo. The air is returned then under gratings, between cargo packages, and back to the cooling coil. The coil, with its vaneaxial fan, is installed in a plenum space adjoining the refrigerated space it serves.

516-2.1.3.3 Ventilation. Fruits and vegetables give off carbon dioxide and other gases where they are stored. To prevent an accumulation of these gases, which could be dangerous to personnel entering the compartment to unload the food, these compartments are ventilated. A separate supply and exhaust system, with the capacity to ventilate one compartment at a time is provided. Ventilation involves bringing in warm and moist air from the

outside. This air imposes a considerable load on the refrigeration equipment. For this reason, the system has been designed so that the maximum time allowed to operate the fan system in any one compartment or box is 20 minutes at any one time.

516-2.1.3.4 Cargo Plant Components. Refrigerated cargo spaces at temperatures below 32°F are defrosted using either hot gas or hot seawater. Where the installation is extensive and each compartment uses a forced air circulating cooling coil in a plenum space, hot seawater is the preferred method. The hot seawater causes the frost accumulated on the coils to melt and be carried away by the drains. Fans are shut off during this process so that the heat is not carried into the storage area. Electric defrosting may be accomplishing using heating elements built into the coils. Up to this time, Navy ships have not used this method for defrosting cargo refrigeration cooling coils; however, future designs may use this method. To monitor compartment temperatures, distant-reading indicating dial thermometers are installed. In addition, large refrigerated cargo ships are provided with an electronic selective indicating instrument installed in refrigeration machinery rooms to indicate temperature in each refrigeration cargo space. This allows operating personnel to determine and log compartment temperatures without entering the spaces.

516-2.1.4 AIR-CONDITIONING PLANTS. Air-conditioning plants are installed in naval ships to cool certain spaces where operation of equipment, personnel efficiency, health, or safety, could be adversely affected by high temperature or high humidity. Typical spaces are:

- a. Ammunition storage and handling rooms, in which temperatures are kept below the critical level to retain maximum effectiveness of the ammunition
- b. Electronic equipment and control spaces, wherein personnel and equipment generate sufficient heat so that provision shall be made for its removal if satisfactory conditions for both equipment and personnel are to be maintained.
- c. Hospital areas, to facilitate recovery and to improve sanitary working conditions for hospital patients and attendants
- d. Living, messing, and office spaces, for improved combat effectiveness and efficiency.

516-2.1.4.1 General. Air-conditioning equipment on board naval ships is generally the mechanical type using a reciprocating, a centrifugal, or in one case, a helical screw compressor. Lithium-bromide absorption air-conditioning plants are currently installed in several classes of submarines. Steam jet plants are only installed on one ship. Air-conditioning plants are cross-connected in the chilled water piping and not in the refrigerant piping. Air-conditioning plants using reciprocating compressors are installed in multiples up to 80 tons at not less than 35°F suction temperature. Where higher loads are involved, centrifugal plants are used. Plants with centrifugal compressors start at a capacity of 110 tons. Main refrigerating and air-conditioning plants with reciprocating compressors use an open type compressor, that is, one with a separate motor and compressor. The advantage of open type compressors is easier maintenance if the motor fails. Hermetic reciprocating compressors are used in packaged self-contained units. Centrifugal compressor plants may be either open or hermetic.

516-2.1.4.2 Air-Conditioning Plant Arrangement. Air-conditioning plants can be either direct or indirect. In a direct system the refrigerant is circulated through cooling coils that are located in, or adjacent to, the spaces to be cooled. In the indirect system, refrigerant is circulated to a heat exchanger or water chiller that cools fresh water. The cooled fresh water is then circulated to cooling coils in remote areas of the ship.

516-2.1.4.3 Indirect System. Where the system is large and the spaces to be air-conditioned are located throughout the ship, an indirect system is generally installed. The indirect system has an advantage in that the refrigerant piping is much shorter and confined in one space, limiting any refrigerant leak problems. In an indirect system, water is cooled to a design temperature of 44°F by the primary refrigerant through a water chiller located within the refrigeration machinery room. The chilled water is then circulated through space cooling coils in a parallel flow path and back to the chiller. In passing through the cooling coil the water picks up heat from the space and returns it to the chiller for recooling. Water leaving the chiller is maintained at a constant temperature by controls that actuate the refrigeration machinery. For safety, a control is included to prevent freezing of the water in the chiller. The temperature of the conditioned space is regulated by a thermostatically operated on-off solenoid valve which controls the flow of chilled water through the cooling coils. The quantity of chilled water flowing through the cooling coil is controlled by an orifice. Never remove this orifice with the intent of obtaining more cooling. The opposite effect can occur with an added detrimental effect on the adjacent coils, which would receive reduced chilled water flow. [Figure 516-2-2](#) shows an indirect reciprocating air-conditioning plant. The direct type is similar except that instead of the chiller, one or more finned-type direct expansion cooling coil are used. The direct type air-conditioning installation is now seldom used to meet Navy shipboard air cooling requirements except for special applications.

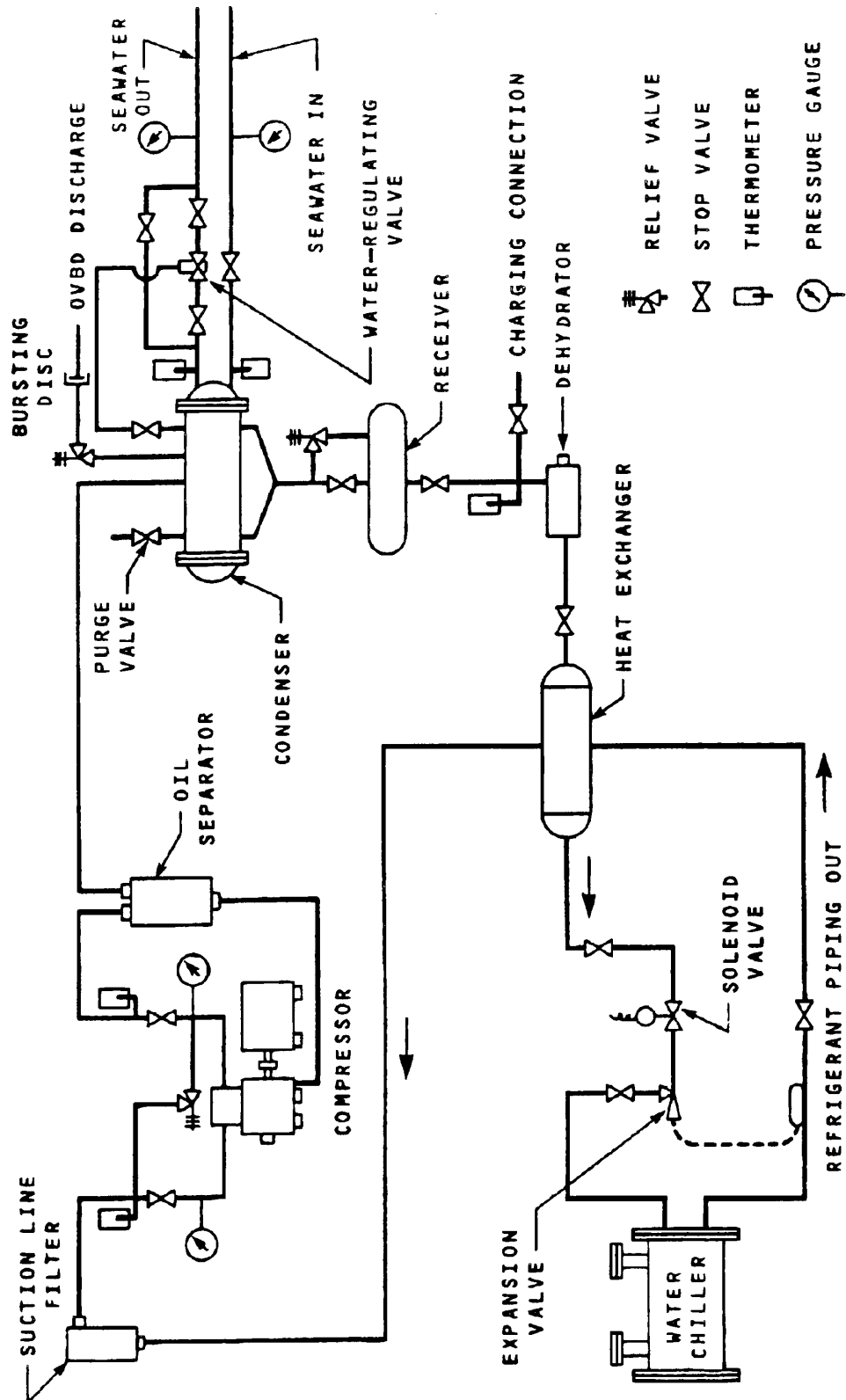


Figure 516-2-2. Diagrammatic Chilled Water Refrigeration System

516-2.1.5 PROCESS WATER COOLING. Process water cooling systems are installed on larger ships where chilled fresh water or chilled seawater is required for photographic purposes. The systems are essentially the same as those used with chilled water air-conditioning plants except that the water is consumed and makeup is provided.

516-2.1.6 DRINKING WATER COOLING. All drinking water is not cooled by self-contained units. On some ships in areas accessible to chilled water, the drinking water is cooled by the air-conditioning chilled water using a small heat exchanger between the air-conditioning chilled water and the drinking water. Provision is made in the piping from the heat exchanger for attachment of a drinking bubbler. This is practical because continuous air conditioning is required on many ships, even in cold weather.

516-2.1.7 SELF-CONTAINED REFRIGERATION EQUIPMENT. Self-contained refrigeration equipment is a refrigerating system within a cabinet or housing that performs a specific function or service. Such equipment is sometimes referred to as package units. Self-contained refrigeration equipment used on Navy ships consists of the following:

- a. Reach-in refrigerators
- b. Frozen food cabinets
- c. Combination refrigerator and frozen food cabinets
- d. Drinking water coolers
- e. Ice-making machines
- f. Air-conditioning units
- g. Soft ice cream freezers
- h. Canned juice dispensers
- i. Dehumidifiers
- j. Soft drink vending machines
- k. Refrigerated cold food counters
- l. Milk or other beverage dispensing units.

516-2.1.7.1 General. Naval shipboard self-contained refrigeration equipment is similar to its counterparts used ashore except for certain added requirements, such as the ability to withstand ship pitch, roll, vibration, and shock, and to operate continuously in high ambient temperatures. Each piece of self-contained equipment has a condensing unit with either an air or water-cooled condenser. The refrigeration cycle in self-contained equipment is essentially the same cycle as described previously. The type of refrigerant and temperature control used and the location and design of various parts and accessories will vary depending on the particular application and manufacturer. The compressor used is generally a hermetic or serviceable hermetic type.

516-2.1.7.2 Self-Contained Refrigerant System. R-134a, and other non-chlorofluorocarbons (CFC's), are used in self-contained equipment in refrigerating applications; some ice-making machines, ice cream machines, freezers, and self-contained air-conditioners use R-22 or R-404A. The refrigerant charge in most reach-in refrigerators, freezers, drinking water coolers, and similar applications is measured in ounces. In larger equipment such as ice cube machines, soft ice cream freezers, and air conditioners, the refrigerant charge will amount to a few pounds. Because of the relatively small internal volume of the piping system and refrigerant-containing compo-

nents, the refrigerant charge is critical and a slight over- or under- charge will adversely affect the functioning of the equipment. Where a capillary tube is used as the refrigerant flow control device, maintain the exact refrigerant charge for proper equipment operation. The correct refrigerant charge for self-contained equipment is shown on the equipment nameplate and in the applicable technical manual.

516-2.1.7.3 Flow Control Devices. The simplest refrigerant flow control device is the capillary tube. It is used only where hermetic or semihermetic compressors are used and where a constant refrigerating effect (cooling capacity) is acceptable. The capillary tube meters a specific quantity of refrigerant into the evaporator when there is a pressure differential in the system; that is, when the compressor is operating. The capillary is not responsive to a varying refrigerating load. The inside diameter and length of the capillary tube is selected by the equipment manufacturer to provide the proper refrigerant flow for the intended load application. A thermostatic expansion valve can also be used as a refrigerant flow control in self-contained equipment. An expansion valve modulates the refrigerant flow in response to the heat load on the evaporator. An expansion valve is generally used where load conditions vary, such as in ice cream freezers and dispensers and air conditioners. An expansion valve is always used when there is a receiver in the refrigerant system.

516-2.1.7.4 Refrigerant Receiver. A refrigerant receiver shall be provided when open compressors are used. A receiver is also provided when an expansion valve is used for refrigerant flow control. Use a receiver where the refrigerant charge is sufficient to warrant storage of the charge when the refrigerant system is pumped down for repairs. A receiver has either a fusible plug or a relief valve to protect it from overtemperature or overpressure conditions.

516-2.1.7.5 Air- or Water-Cooled Condensers. Air-cooled condensers may be used on all self-contained refrigerating equipment. In actual practice, where excessive ventilation is required to remove the quantity of heat rejected from the condenser into a space, water-cooled condensers are used. Air-cooled condensers are generally fin and tube type with a fan moving the air across the condenser. Occasionally, a static condenser is used on small beverage dispensers. Water-cooled condensers come in various configurations, as follows:

- a. Shell and coil, where the refrigerant passes through a spiral tube inside of a shell containing the cooling water
- b. Shell and tube, which are small versions of the condensers used in ship stores refrigeration and air-conditioning plants
- c. Tube-in-tube, where the refrigerant tube is inside a water tube. Tube-in-tube condensers may be either concentric tubes in various configurations or parallel tubes connected to headers at either end.

516-2.1.7.6 Condenser Cleaning. Shell and coil and concentric tube-in-tube condensers shall be acid-cleaned. Shell and tube and tube-in-tube condensers with parallel tubes may be mechanically cleaned. Where air-cooled condensers are used, allow sufficient space (usually 3 to 4 inches) around equipment sides where condenser cooling air enters and is discharged from the equipment.

516-2.1.7.7 Evaporators. Evaporators used in self-contained equipment vary in configuration and design depending on the function of the equipment. They may be finned tube, serpentine tube, round drum, or shaped to form ice cubes or other configurations as required to perform a specific function. Regardless of its configuration or shape, an evaporator is designed to remove heat from the air or the product being stored or processed.

516-2.1.7.8 Equipment Controls. Self-contained equipment is controlled in many ways depending on the equipment application. The simplest arrangement used in reach-in refrigerators, freezers, and beverage dispensers con-

sists of a capillary tube to control refrigerant flow, an adjustable thermostat to regulate the temperature, and a thermostatic device to prevent overheating of the compressor. Other types of self-contained equipment use various combinations of controls, including expansion valves, high- and low-pressure switches, water failure switches, thermostats, solenoid valves, evaporator pressure regulators, motor controllers, relays, and electrical overload devices, as required to accomplish the specific function of the equipment and to protect the equipment in the event of malfunctions, high temperature, and pressure conditions.

516-2.1.7.9 Modular Refrigerators, Freezers, and Cold Food Counters. This type of refrigeration equipment is intended to circumvent the requirement to cut access openings or enlarge passageways in vessels to accommodate conventionally constructed shipboard refrigeration units. Self contained modular refrigeration equipment can be disassembled before being brought on board and reassembled at the site of installation.

516-2.1.7.9.1 Modular Refrigeration Systems. The refrigeration system is furnished fully assembled and operational. It has been previously charged and tested, with all controls properly adjusted. The system is capable of being partially disassembled and reassembled, at the time of installation in the vessel, without the need of an additional refrigerant charge or control adjustments. The condensing unit can be removed from the condensing unit compartment for ease in moving the cabinet base section and for repairs or maintenance actions.

516-2.1.7.9.2 Modular Refrigerant Couplings. The refrigerant lines are connected by self sealing refrigerant couplings. These couplings are specifically designed for refrigeration applications and are used in sets (liquid and suction lines). There are a minimum of two sets in a system; larger systems may have additional sets. The refrigerant couplings allow for future system opening at the coupling without its failure.

516-2.1.8 POWER SUPPLY. Where an alternating current (ac) electric power supply is available, semihermetic or hermetic compressors are used in self-contained equipment. Hermetic compressors are available from a nominal 1/8 horsepower (hp) and up and semihermetic compressors are available from a nominal 1/4 hp and up. Full hermetic compressors are always used in applications where the load requires a compressor less than 1/4 hp. Hermetic compressors are also used in most other self-contained equipment applications since they weigh less, take up less space, and cost less than semihermetic compressors of the same capacity. Semihermetic compressors are most often used in the heavier load applications such as in air conditioners and soft ice cream machines. Semihermetic compressors are also called serviceable hermetic compressors since some parts and components can be repaired or replaced during normal service or maintenance functions. Fractional-horsepower hermetic and semihermetic compressors are normally used with a 115-volt, single-phase power supply. Integral-horsepower hermetic and semihermetic compressors are normally used with a 440-volt, 3-phase power supply. Where a direct current (dc) power supply is available, open compressors with dc motors are used in self-contained equipment. It is impractical to use open compressors in small applications, such as beverage dispensers, dehumidifiers, and ice-making machines, because of space, weight, and cost considerations. Reach-in refrigerators, freezers, drinking water coolers, ice cream machines, and air conditioners can be made with open compressors. Direct current compressor motors are used with either a 115- or 230-volt power supply. Note that dc refrigeration equipment is not in production, difficult to obtain, and high in cost. Where a ship has a dc power supply, it is best to furnish dc-ac motor generator sets rather than use dc refrigeration equipment.

516-2.1.9 NAVY PLANT TYPES. Limit the types of plants used in Navy shipboard applications to reduce logistic support. Plants used in refrigerated ship stores and cargo are generally R-12 or R-134a reciprocating compressor plants or R-134a compressor plants. Air-conditioning plants may have either reciprocating or centrifugal compressors depending on the ship loads. Several submarines have lithium-bromide absorption, one ship has a helical screw compressor, and one submarine has a steam jet air conditioning plant. Package units for various applications have reciprocating compressors with various refrigerants.

SECTION 3.

RECIPROCATING COMPRESSOR PLANTS

516-3.1 INTRODUCTION

516-3.1.1 This section describes shipboard installed refrigerating plants that use reciprocating compressors. [Figure 516-2-2](#) is a schematic refrigerating piping diagram of a Navy-type air-conditioning plant. The diagram shows current components as well as supplemental components being included in newer refrigerating piping system designs. The refrigerated ship stores, refrigerated food cargo, and air-conditioning plants use essentially the same components except for evaporator or cooling coils. All components will be described in the subsequent text. [Figure 516-2-2](#) will be used as the basis for describing R-12 and R-134a refrigeration components. The refrigerant will be traced through the compressor unit, condenser, expansion valve, cooling coil, and back to the compressor unit. Note that virtually all main refrigeration and air-conditioning plants are supplied by either Carrier-Transicold or York International, Inc.

516-3.2 THE COMPRESSOR UNIT

516-3.2.1 DESCRIPTION. Refrigerant vapor is drawn from cooling coils through the suction line by the compressor unit. The compressor unit is an assembly consisting of a compressor, drive, and compressor motor, all mounted on a common steel base. The unit also includes a gauge board and motor controller. These components are sometimes mounted on the compressor unit. However, the practice now is to mount the controller and gauge board separately, off the compressor base, as vibration from the compressor has caused some component malfunction.

516-3.2.2 FUNCTION. The compressor unit is a part of the condensing unit, which in addition to the compressor unit, includes a condenser, receiver, operating controls, piping, and valves to make up a refrigeration plant module. Open-type reciprocating compressors are used for ship stores, cargo refrigerating, and air-conditioning plants. The function of the compressor unit is to draw the refrigerant, which has been evaporated in cooling coils or an evaporator, to increase the refrigerant gas pressure so that the corresponding saturated temperature is higher than the maximum seawater cooling temperature for water-cooled condensers or the maximum air temperature over the condenser for air-cooled condensers.

516-3.2.3 CAPACITY. The capacity of the compressor unit is generally given in tons of refrigeration, assuming certain evaporating and condensing conditions. The capacity of the compressor is not constant but changes with a change in operating conditions. A higher suction pressure, which is a result of a higher evaporating temperature in the cooling coil, will mean a higher density of refrigerant gas entering the compressor than would be entering the compressor at a lower suction pressure. Thus, for each cubic foot of compressor displacement, a larger weight of gas or vapor would flow into the cylinder at the higher suction pressure.

516-3.2.3.1 For example, in referring to [Table 516-1-1](#), column 3, it can be seen that for R-12 at 21.05 psi (20°F saturated temperature), the vapor density under column 7 is 0.89 pound per cubic foot (lb/ft³) whereas, the vapor density at 9.17 psi (0°F saturation temperature) is 0.61 lb/ft³ or 23 percent less weight per cubic foot of compressor displacement. It follows that if a greater weight of refrigerant is pumped, the refrigerating capacity will be higher. It also follows that the higher a compressor speed (rpm), the higher the capacity. Conversely, the capacity will be reduced with a lower suction pressure, in which case a lesser weight of refrigerant vapor is pumped. The head or discharge pressure also affects the compressor capacity; a higher discharge pressure results in a reduced compressor capacity. This reduction occurs because at the higher discharge pressure a greater weight

of high-pressure refrigerant vapor remains in the fixed clearance volume of the compressor cylinder at the end of each compression cycle. This results in a reduction in the weight of low-pressure refrigerant vapor that can be drawn into the cylinder for the following cycle.

516-3.2.4 POWER REQUIREMENTS. The power required by the compressor at a constant discharge pressure is determined by the weight of the refrigerant vapor. The higher the suction pressure, the heavier the weight of refrigerant per stroke. Therefore, more power is required. At a constant discharge pressure the power required varies with the suction pressure. The higher the suction pressure the more power required. Conversely, the lower the suction pressure the less power required. A change in discharge pressure has less of an effect on a compressor than a change in suction pressure. An increase in discharge pressure will reduce the capacity, slightly reduce the power consumption, but will increase the amount of power required per ton of cooling. The increase in pressure causes an added weight of refrigerant to remain in the cylinder. As a result, on the intake stroke, less refrigerant enters the piston. Less refrigerant pumped means less power required. The additional power required as a result of the increase in discharge pressure is more than offset by the lesser quantity of refrigerant pumped, resulting in a net reduction in the power requirement.

516-3.2.5 APPLICATIONS. A compressor can be used for any application, whether low temperature for freezing or high temperature for air conditioning. It would not be strange to find a 12-cylinder compressor for a freeze application rated at 18 tons with a 50-horsepower (hp) motor and the same 12-cylinder compressor for air conditioning rated at 80 tons with a 125-hp motor. When the compressor is associated with a specific motor and speed, and selected to perform within specified limits of operation for a given application, it cannot be used for some other application where the brake horsepower required may exceed the capacity of the motor itself. Other components that have been selected for a specific application, such as condenser, receiver, and interconnecting piping will prove deficient if used for other applications. If a unit is to be used for other than its original selected design, a study as to operating characteristics under the proposed application will be required, plus a study of the individual components making up the condensing unit assembly to determine adequacy under revised operating conditions.

516-3.2.6 COMPRESSOR UNIT MOUNTING. The compressor unit is generally installed and fastened directly to the steel deck of the compressor room. In several instances on initial starting, excessive vibration was experienced that was thought to be due to compressor misalignment. On investigation it was found that the compressor unit deck area was unsupported by a frame member. This caused the deck to vibrate. Adding additional support under the deck cured the problem. The piping to most current compressor units is solidly connected to the compressor. Future compressor installations will include flexible pipe connections at the compressor. Flexible connectors used in refrigeration application are made of corrugated bellows pipe with reinforcing braid. Where structure borne noise is a problem in compressor unit installations, units have been installed on Navy-type vibration isolation mounts. Pipe connections to units on vibration isolation mounts shall be through flexible piping connectors.

516-3.2.7 RECIPROCATING COMPRESSORS. The operation of a reciprocating compressor is common knowledge. The piston on the downward stroke takes a charge of refrigerant, compresses it on the upward stroke, and discharges the high-pressure, high-temperature gas to the condenser. The reciprocating compressor is also known as a positive displacement compressor as compared to a centrifugal compressor, which compresses the refrigerant gas by centrifugal action, such as the spinning of an impeller. Another positive displacement compressor is the helical screw compressor. Early refrigerating compressors used in Navy shipboard application were slow-speed units with a maximum speed of 600 rpm. These units used splash lubrication and were driven by a belted two-speed motor to achieve a one-step capacity reduction. Some of these compressors may still be in use. [Figure 516-3-1](#) shows a typical slow-speed compressor.

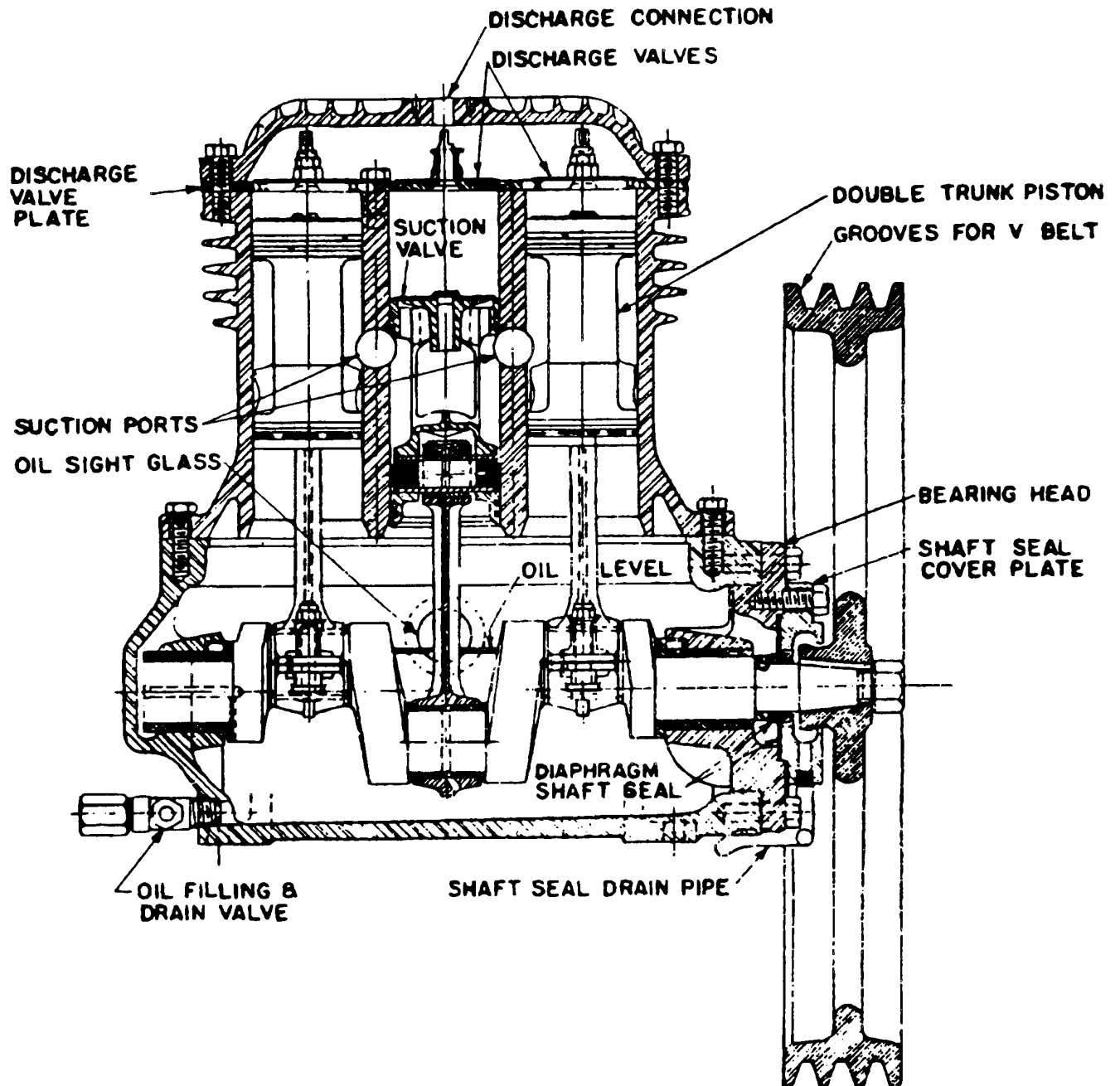


Figure 516-3-1. Typical Slow-Speed Compressor

516-3.2.7.1 Present compressors are high-speed with a forced circulation lubricating system and an automatic capacity control system. While these high-speed compressors are designed for a maximum speed of 1,750 rpm, they may be operated at lower speeds, some as low as 1,150 rpm. Since compressor speed (rpm) is directly proportional to compressor capacity, lower speeds are used to match compressor capacity with the refrigeration or air-conditioning load. [Figure 516-3-2](#) shows a Carrier reciprocating compressor and [Figure 516-3-3](#) shows a York reciprocating compressor.

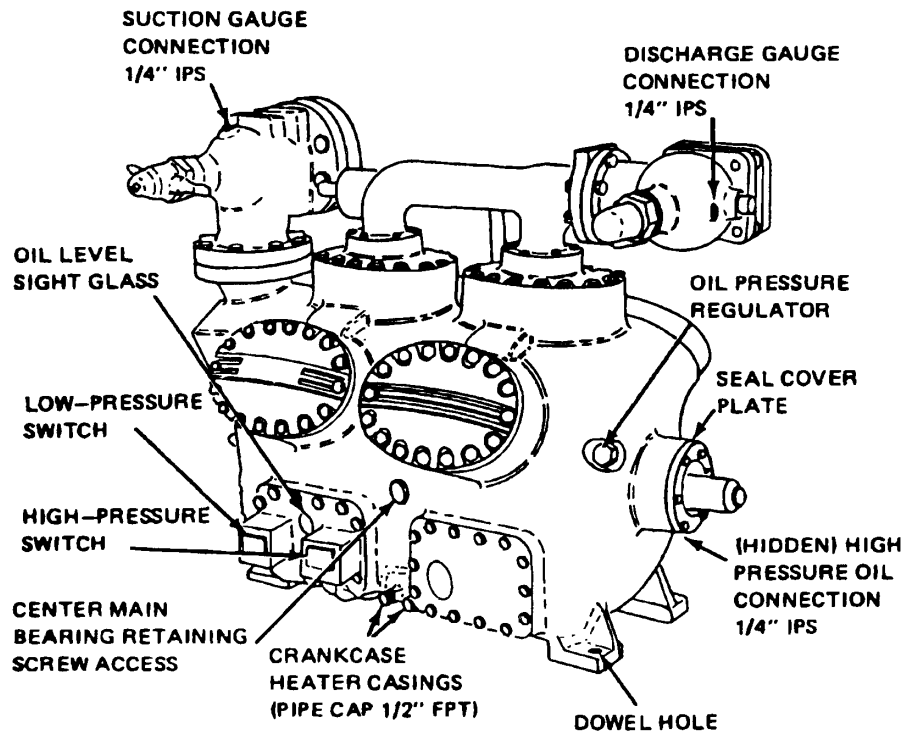
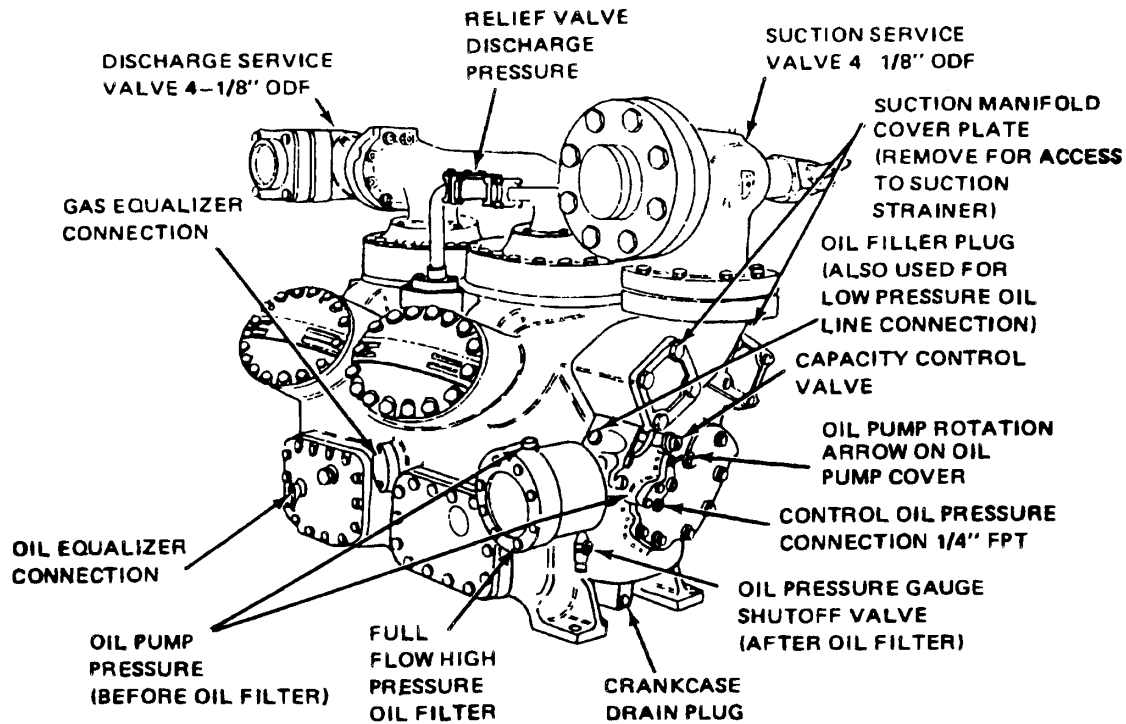


Figure 516-3-2. Carrier High-Speed Reciprocating Compressor

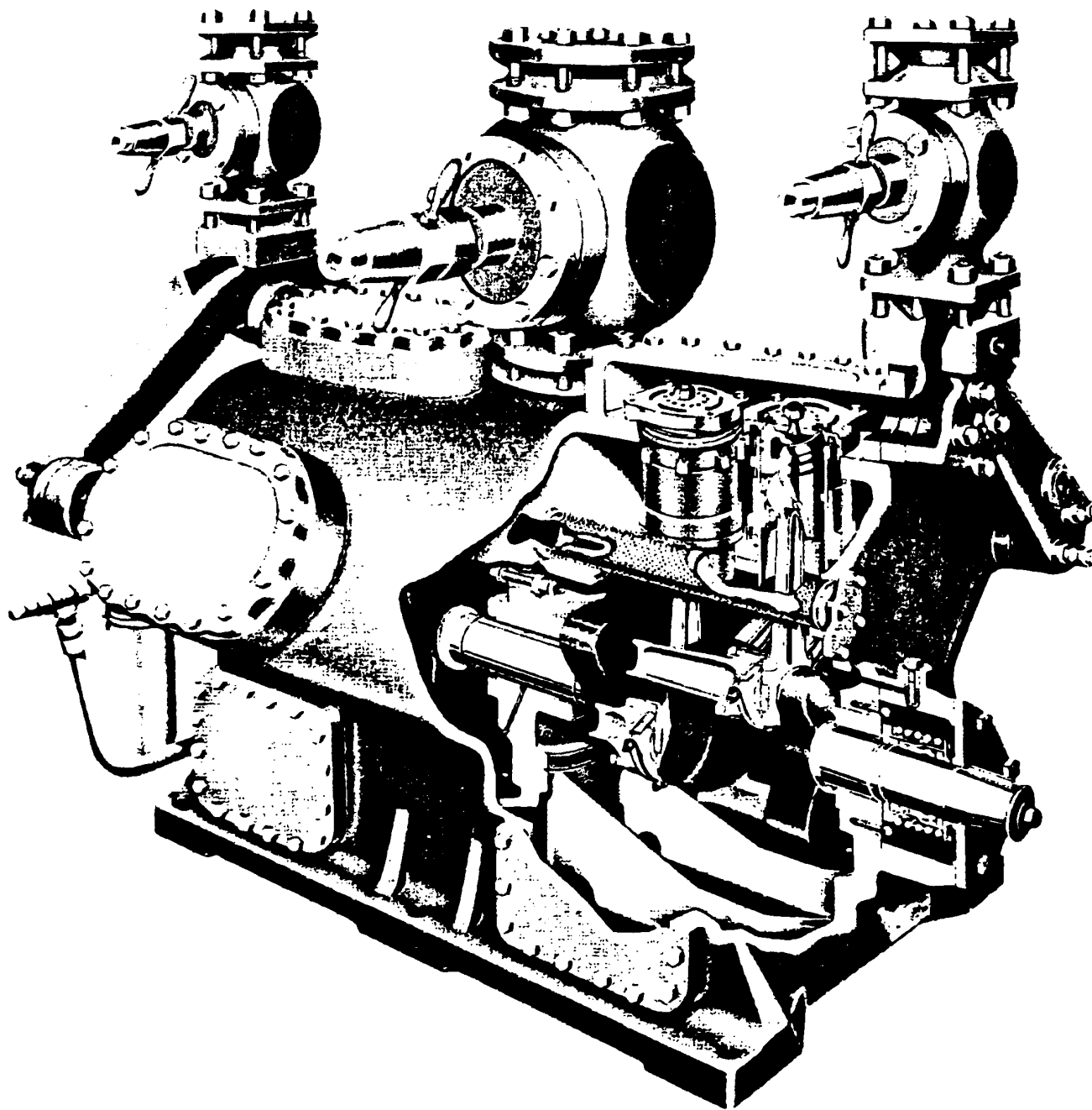


Figure 516-3-3. York High-Speed Reciprocating Compressor

516-3.2.7.2 The reciprocating compressors for refrigeration service found in Navy ships are multicylinder, single-acting, with trunk-type pistons driven directly through a pin and connecting rod from the crankshaft. As indicated, major suppliers of refrigeration equipment are Carrier-Transicold and York International, Inc. Current Navy standard compressors supplied by Carrier are versions of models 5F and 5H. 5F and 5H are commercial designation; 5MF and 5MH are designation for high shock shipboard compressors. The mechanical fittings on the Navy compressors are straight thread "O"-ring fittings. The 5F series has a bore and stroke of 2-1/2 by 2. The 5H series compressor has a bore of 3-1/4 and is available with two different strokes, 2-3/4 (shortstroke, i.e. 5MH40, 60, 80, 120) and 3-7/16 (longstroke, i.e. 5MH46, 66, 86, 126). Current compressors supplied by YORK are versions of the R series with bore and stroke of 3-3/4 by 2-3/4 and the F series, 2-5/8 by 2-1/4. R and F are commercial designations; RN and FN are designation for high shock shipboard compressors. Older YORK compressors in Navy ships are the YN series, 3-3/4 by 3.

516-3.2.7.3 All of these compressors are precision machined refrigerant gas pumps that include many accessories, such as valves, refrigerant strainers, relief valve, capacity control, oil pump, oil filter, and other items, which will be discussed in the following sections. When servicing a compressor, if it is to be opened for maintenance, pump out the refrigerant to a low-positive pressure of approximately 2 psi. The refrigerant may be pumped to a receiver or other parts of the system. Avoid opening a compressor under a vacuum (in a negative pressure).

516-3.2.8 COMPRESSOR SERVICE VALVES. Manually operated refrigerant suction and discharge shutoff valves are installed to isolate the compressor from the piping system. These valves are supplied with tongue-in-groove flanges configured to bolt directly to the compressor body or compressor manifold and to the piping system. Valves are backseating ones with a packed stem and a self-aligning swivel disc containing a fully retained, heat stabilized nylon or lead seat. The backseating feature permits repacking of the stem with pressure in the system. Valve stems are provided with seal caps. Older seal caps on the valve body, with a gasket between the cap and body, provide an additional seal against refrigerant leakage. Older seal caps have a built-in socket wrench for turning the stem to open or close the valve. Whenever it is necessary to turn the disc stem to open or close the valve, loosen the packing gland nut approximately one-half turn, and then retighten after the disc stem has been adjusted. The seal cap gasket shall always be tightly in place on the valve body except when adjusting, opening, or closing the valve.

516-3.2.9 COMPRESSOR SUCTION STRAINER. Refrigerant compressors are equipped with one or two suction strainers located in the compressor body, suction manifold, or suction elbow, depending on the compressor. Periodically clean strainers with solvent. Replace if broken or corroded. Where extensive alterations have been made to a refrigeration system or the system has extensive contaminants, insert a felt filter or sock in the strainer to trap fine foreign contaminants as suction strainers are not made to trap them. Make the filter out of felt material similar to SAE F-1 or ASTM 2475 16R1. Remove the felt filter after about 50 hours. If the system is still dirty, clean the felt filter with an approved cleaning solvent or replace with a new filter and insert for another period. The felt filter shall not be permanently installed, as this reduces compressor capacity due to the high-pressure drop through the filter. New compressors from Carrier may come equipped with a felt filter included in the compressor strainer. Use this for initial operation and then remove. Compressor strainers may be withdrawn from various models as follows:

a. Carrier Compressors:

- 1 On models 5F20, 5F40, 5H40, and 5H46, remove suction and discharge manifold cover on seal end of compressor.
- 2 On model 5F30, remove suction service valve.
- 3 On models 5F60, 5H60, and 5H66, remove suction manifold and withdraw two strainers.

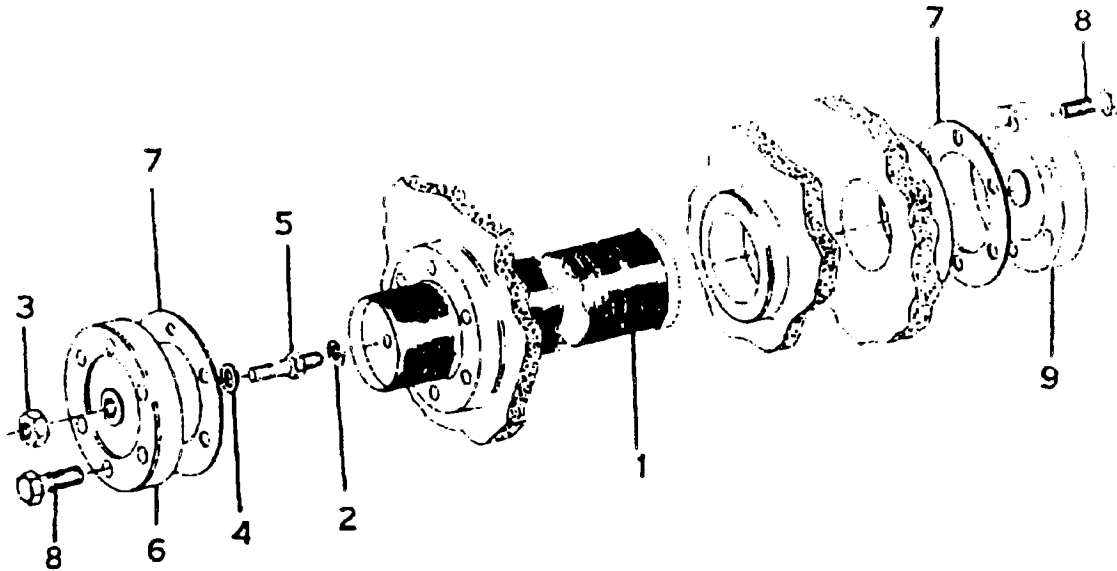
- 4 On models 5H80 and 5H86, remove suction manifold cover.
- 5 On models 5H120 and 5H126, remove one suction manifold plate at a time so as not to disturb position of detachable suction manifold and suction line. Withdraw two strainers. Do not damage suction strainer when replacing. Be sure that the strainer bail is compressed by positioned manifold cover. If bail is too short, squeeze on side and elongate it enough to be compressed by the manifold cover. Position bail between the Z bosses on inside of manifold cover to prevent strainer from turning.

b. York Compressors:

- 1 On the 4-, 6-, and 8-cylinder model R, remove the cover plate at the bottom of the suction elbow and withdraw the strainer screen.
- 2 On the 12-cylinder Model R, remove the two strainers; one on each end of the compressor.
- 3 The 4, 6, and 8 cylinder 3-3/4 by 3 compressors have quantities respectively of: 1, 2, and 2, suction strainer assemblies. On these compressors, the suction strainer can be removed from either the suction end or the discharge end of the compressor. See [Figure 516-3-4](#) for an exploded view of the suction strainer assembly.

NOTE

Whenever possible, remove the suction strainer assembly from the discharge end of the 4, 6, and 8 cylinder compressors.



Item No.	Part Number	York Part No.
1	Screen, Suction Strainer	029-03847
2	Lockwasher, Spring	021-05269
3	Nut, Strainer Cover	021-00466
4	Gasket, Stud	028-00757
5	Stud, Collar	064-00377
6	Cover, Strainer	064-00378
7	Gasket, Strainer Cover	070-03808
8	Screw, Cap	021-01483
9	Cover, Suction End	064-00379

Figure 516-3-4. Suction Strainer York Model G Compressor

- (a) To remove the suction strainer from the discharge end of the compressor:
- (1) Remove the six cap screws which secure the discharge-end strainer cover to the compressor housing. Do not loosen the nut in the center of the cover.
 - (2) Carefully remove the cover. The suction strainer will come with it.
- (b) To remove the suction strainer from the suction end of the compressor.
- (1) Remove the six cap screws which secure the suction-end strainer cover to the compressor housing. Remove the cover and its gasket.

CAUTION

The stud-to-cover gasket MUST be REMOVED before the strainer is removed via the suction end of the compressor. If this CAUTION is ignored, the gasket could be lost inside the compressor suction compartment.

- (2) At the discharge-end cover, remove the nut in the center of the cover. Remove the six cap screws which secure the discharge-end strainer cover. Carefully remove the cover so as not to lose the stud-to-cover gasket and REMOVE this gasket.
- (3) At the suction end of the compressor, the strainer can now be carefully removed from the compressor housing.
- 4 The 12-cylinder 3-3/4 by 3 compressor has four suction strainers. Removal is similar to removing the strainer from the discharge end of the 4-, 6-, and 8-cylinder compressors.
- 5 On the 3-, 6-, and 9-cylinder 2-5/8 by 2-1/4 compressors, remove the suction manifold and suction valve ([Figure 516-3-5](#)).

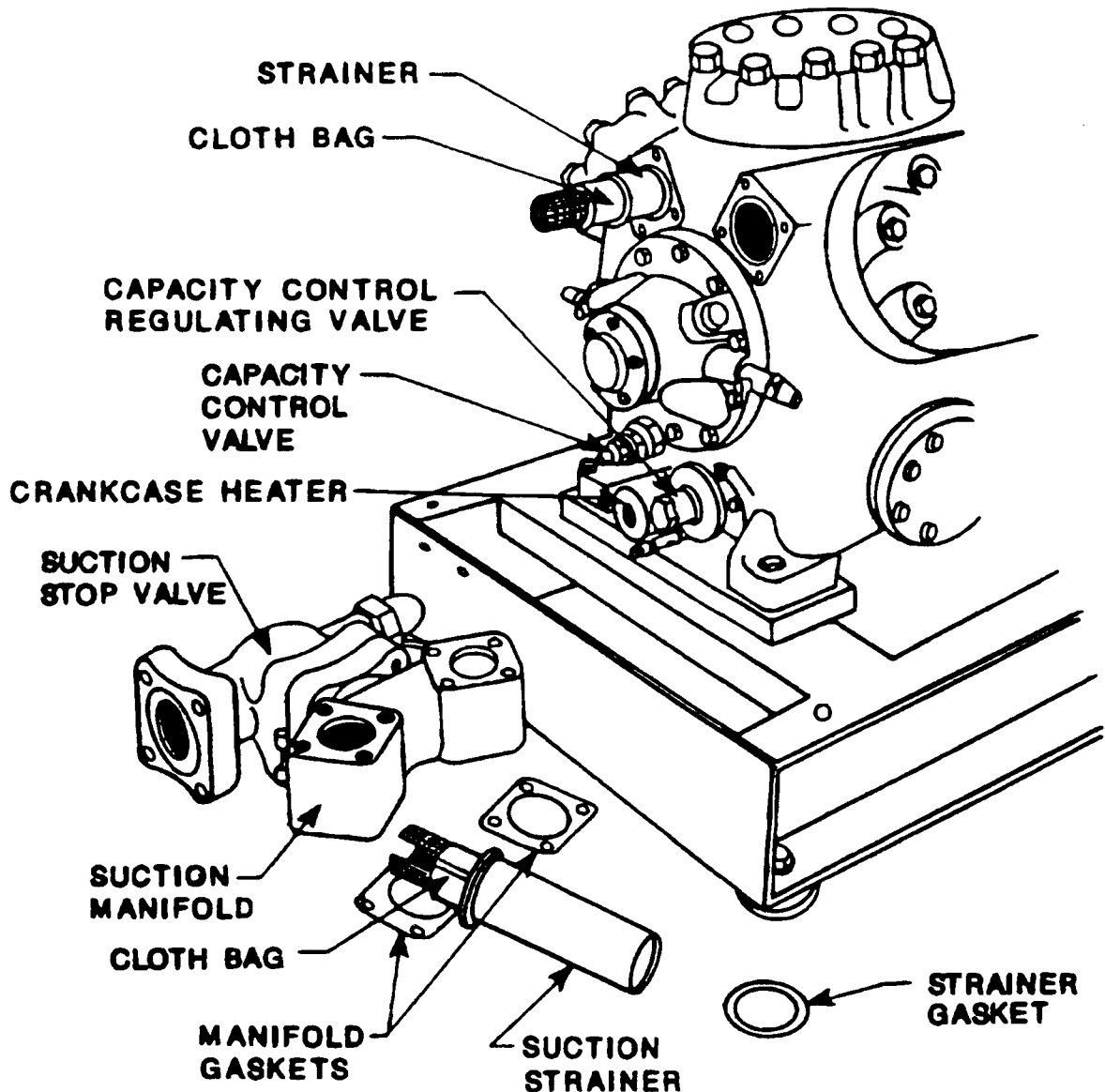


Figure 516-3-5. Removing Suction Strainer 2-5/8 by 2-1/4 York Compressor

516-3.2.10 COMPRESSOR LUBRICATION SYSTEM. Refrigerant compressors are provided with either forced-feed lubrication or splash lubrication. In the latter case, the oil level maintained in the compressor crankcase is relatively high and no oil pump is provided. Splash lubrication is satisfactory for small compressors and for larger slow-speed compressors, where machines are specially designed for this type of lubricating system. Splash lubrication of large high-speed (1,750 rpm) compressors is difficult and unsatisfactory. These compressors are provided with oil pumps and full-pressure lubrication systems. The forced-feed lubrication system generally consists of a gear-type oil pump driven from the crankshaft, sump oil strainer, external oil filter, relief valve, crankcase oil heater, permanent magnets in oil drain, and crankcase sight glass. The lubricating system oil pump serves both for lubrication and as a capacity control system. For details of the various components included, see the plant technical manual. When charging a new plant with oil, strictly add the quantity specified for that plant. In a new plant a small quantity of oil, which is lost in the piping system due to an oil coating forming in the inside of the piping and components, may have to be made up. If an oil separator is part of a plant, the separa-

tor retains a certain quantity of lubricating oil. If a new or a recently overhauled separator is first placed in service, a certain known quantity of oil will remain in the unit. Information on the extra quantity is normally provided by the oil separator manufacturer.

CAUTION

Do not add more refrigerant oil than required. Refrigerant oil is not consumed or used up.

CAUTION

When removing oil be aware that the oil will contain dissolved refrigerant, so that an equal measure removed will be less than the quantity added. Only add oil designed for the specific refrigerating service. DO NOT ADD any other type.

516-3.2.11 COMPRESSOR OIL CHECK. Always check compressor oil before starting a unit. If oil is required, record date and quantity of oil added. If due to some misoperation or malfunction, a low oil level is noted in the sight glass during operation and there are no oil leaks, the oil is in the system. Carefully monitor the compressor until the oil returns. If it is judged necessary to add more oil, the excess quantity should be subsequently removed when the oil returns. A higher than normal oil level causes an excessive quantity of oil to splash on the cylinder walls. This excess oil is then carried on into the piping system. The oil can then accumulate in the system and return as slugs causing possible compressor damage.

516-3.2.12 CRANKCASE OIL HEATERS. Crankcase oil heaters keep the crankcase warm during off-cycles and thus minimize refrigerant absorption in the oil. The heater is energized when the compressor stops and deenergized when the compressor starts. Most of the current compressor units do not include a crankcase heater; new installations will include one, however. If a heater is installed, ensure that the heater is not energized when the compressor is operating as possible seal failure may result. Crankcase oil heaters may be of two types, either immersion or cartridge. The cartridge-type heater is in a well in the crankcase.

516-3.2.13 CARRIER LUBRICATING SYSTEM. The Carrier 5F oil pump assembly is shown in [Figure 516-3-6](#). Note that the oil pump in these compressors is manually reversible by rotating the oil pump cover 180 degrees. An arrow included on the upper part of the cover indicates the rotation. The indicated rotation on the pump cover should correspond with the compressor rotation. If the oil pump is disassembled, be sure that the cover is installed for the proper rotation.

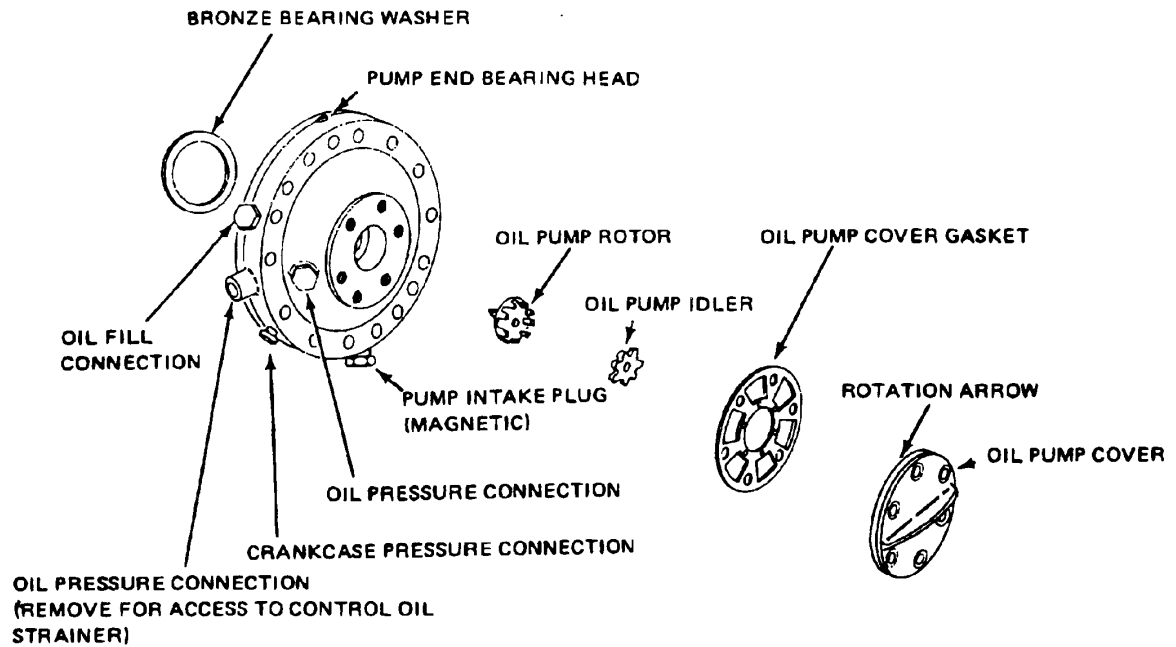


Figure 516-3-6. 5F Carrier Oil Pump Assembly

Figure 516-3-6. 5F Carrier Oil Pump Assembly

516-3.2.13.1 Carrier compressors use two types of oil pumps depending on the unit. The oil pump may be the rotor-idler type or gear-in-gear type. [Figure 516-3-6](#) and [Figure 516-3-7](#) show the two types. [Figure 516-3-7](#) is applicable to 5H120 and 5H126 compressors manufactured in 1969 and later. All other compressors use the 5F oil pump. The following details the servicing of the lubricating system for all the Carrier compressors used in Navy shipboard application:

- a. Rotor-Idler Type Oil Pump (5F Oil Pump, [Figure 516-3-6](#)):

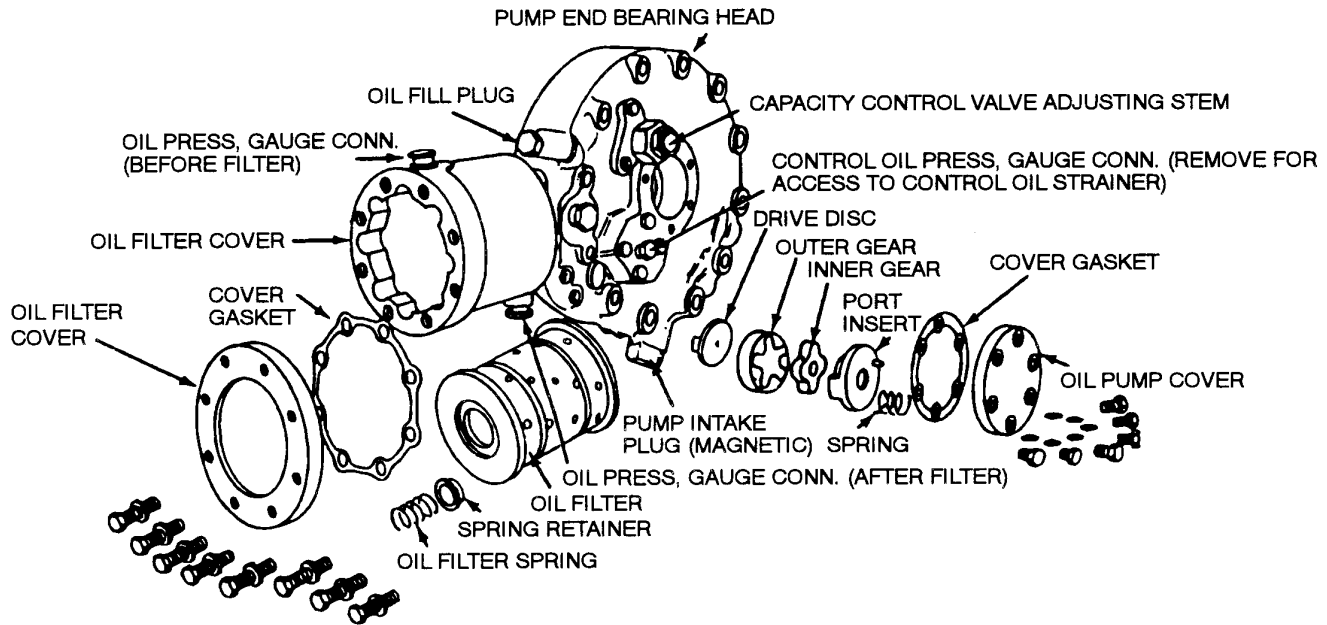


Figure 516-3-7. Oil Pump and Filter Assembly (5MH120, 126)

- 1 Drain the oil below the level of the pump end bearing head. Remove the pump end cover and bearing head. (Remove the complete end bell assembly on models 5H40, 46, 60, 66, 80, and 86). Check the oil pump rotor for end play. Maximum allowable movement of the rotor is 0.0025 inch ([Table 516-3-1](#)). If there is excessive end play, reposition the oil pump bushing in the bearing head as described below.

Table 516-3-1. WEAR LIMITS FOR 5F AND 5H CARRIER COMPRESSORS

Compressor Part	Compressor					
	5F20, 30, 40, 60			5H40, 46, 60, 66, 80, 86, 120, 126		
	Factory Tolerances (in.)		Max. Allowable Wear (in.)	Factory Tolerances (in.)		Max. Allowable Wear (in.)
	Max	Min		Max	Min	
SEAL END						
Main Bearing Diameter	1.6262	1.6250	0.002	2.6278	2.6250	0.001
Journal Bearing	1.6240	1.6233	0.003	2.6235	2.6225	0.002
PUMP END						
Main Bearing Dia. (Assembled)	1.6264	1.6250	0.002	2.2530	2.2502	0.001
Journal Diameter	1.6240	1.6233	0.002	2.249	2.248	0.002
CENTER (5H80, 86, 120, 126)						
Main Bearing Diameter	-	-	-	2.6264	2.6250	0.001
Main Bearing Thickness	-	-	-	-	0.0942	0.001
Journal Diameter	-	-	-	2.6235	2.6225	0.002
CONNECTING ROD						
Bearing Diameter	1.6255	1.6245	0.002	2.2505	2.2495	0.002
Bearing Thickness	-	0.06225	0.001	-	0.06225	0.001
Crankpin Diameter	1.6240	1.6233	0.003	-	2.248	0.002
Seal End Bearing Washer Thk	0.131	0.129	-	0.188	0.186	-
Seal End Thrust Washer Thk	0.157	0.155	-	0.188	0.186	-
Pump End Bearing Washer Thk	0.131	0.129	*	0.188	0.186	*
CYLINDERS						
Bore	2.501	2.500	0.003	3.2515	3.2505	0.003
Piston Dia. (Steel, Std Stroke) (Alum., Long Stroke)	-	2.4980	0.003 See Figure 516-3-21			
Piston Pin Diameter	-	0.7498	0.001	-	0.998	0.001
Piston Pin Busting	0.7500	-	0.001	1.000	-	0.001

Table 516-3-1. WEAR LIMITS FOR 5F AND 5H CARRIER COMPRESSORS - Continued

Compressor Part	Compressor					
	5F20, 30, 40, 60			5H40, 46, 60, 66, 80, 86, 120, 126		
	Factory Tolerances (in.)		Max. Allowable Wear (in.)	Factory Tolerances (in.)		Max. Allowable Wear (in.)
	Max	Min		Max	Min	
CYLINDERS (Contd)						
Piston Ring Eng Gap (compression and oil)	0.009	0.004	0.030	0.017	0.007	0.030
Piston Ring Side Clearance						
Compression Side	0.0015	0.0005	0.003	0.0015	0.0005	0.003
Oil Side	0.012	0.002	-	0.012	0.002	-
OIL PUMP**						
Axial Clearance	0.015	0.0005	0.0025	0.0015	0.0005	0.0025
Drive Shaft Diameter	0.4361	0.4356	0.000	0.4361	0.4356	-
Drive Shaft Bushing Dia. (10)	0.4375	-	0.000	0.4375	0.4370	-
Drive Shaft Dia. (5H120 & 126)	-	-	-	0.6250	0.6240	-
Drive Shaft Busing Diameter ID - 5H120 & 5H126)	-	-	-	0.6270	0.6260	-
SUCTION VALVE						
Suction Valve Disc (depth of wear below face)	-	-	0.005	-	-	0.005
Suction Valve Seat (see Figure 516-3-20 for Dim A***)	-	0.012	-	-	0.012	-
DISCHARGE VALVE						
Discharge Valve Disc depth of wear below face)	-	-	0.005	-	-	0.005

Table 516-3-1. WEAR LIMITS FOR 5F AND 5H CARRIER COMPRESSORS - Continued

Compressor Part	Compressor					
	5F20, 30, 40, 60			5H40, 46, 60, 66, 80, 86, 120, 126		
	Factory Tolerances (in.)		Max. Allowable Wear (in.)	Factory Tolerances (in.)		Max. Allowable Wear (in.)
	Max	Min		Max	Min	
Discharge Valve Seat See Figure 516-3-9 for Dim. B****)	-	0.012	-	-	0.012	-
*5F40 and 5F60: replace thrust bearing washers when end clearance exceeds maximum listed below. Crankshaft End Clearance (in.) 5F20-5F60 0.011 to 0.035 5H40, 46 0.010 to 0.036 5H60, 66 0.011 to 0.037 5H80, 86 0.014 to 0.042 5H120, 166 0.014 to 0.144. **Return assemblies for factory exchange. ***Minimum height of dimension A before replacing cylinder sleeve is 0.010 inch. ****Minimum height of dimension B before replacing valve plate and discharge valve inner seat is 0.010 inch.						

- 2 Turn the rotor. If there is more than a slight drag, remove the pump cover and disassemble the oil pump. Check all parts (Figure 516-3-6) for wear and damage. Inspect the oil pump bushing for scoring. Replace the bushing if scored. If the bearing head is scored, replace the complete bearing head and oil pump assembly.
- 3 Install oil pump bushing. Press the new bushing into the pump end bearing head from the inner side of the head (Figure 516-3-8). Position it so that the bushing oil groove is at the top when the bearing head is installed. The lead (entering) end of the bushing is identified by machined circumferential lines.
- 4 Position oil pump bushing (Figure 516-3-8):
 - (a) Place a 0.001-inch circular shim against the bushing and install the pump (shim should be between bushing and oil pump rotor).
 - (b) Complete assembly of the oil pump.

CAUTION

Be sure the oil pump assembly is flush with the coverplate surface but does not protrude beyond the bearing head surface.

- (c) Seat bushing against the shim by tapping it with a cylindrical positioning tool (field-fabricated, Figure 516-3-8).
- (d) Disassemble the oil pump and remove the shim.
- (e) Reassemble the oil pump and check for binding.
- (f) Install the bearing head on the compressor. Line up the tang on the oil pump rotor shaft with slot in end of the crankshaft. Be sure that the oil pump has proper rotation.
- (g) Refill compressor oil to proper level.

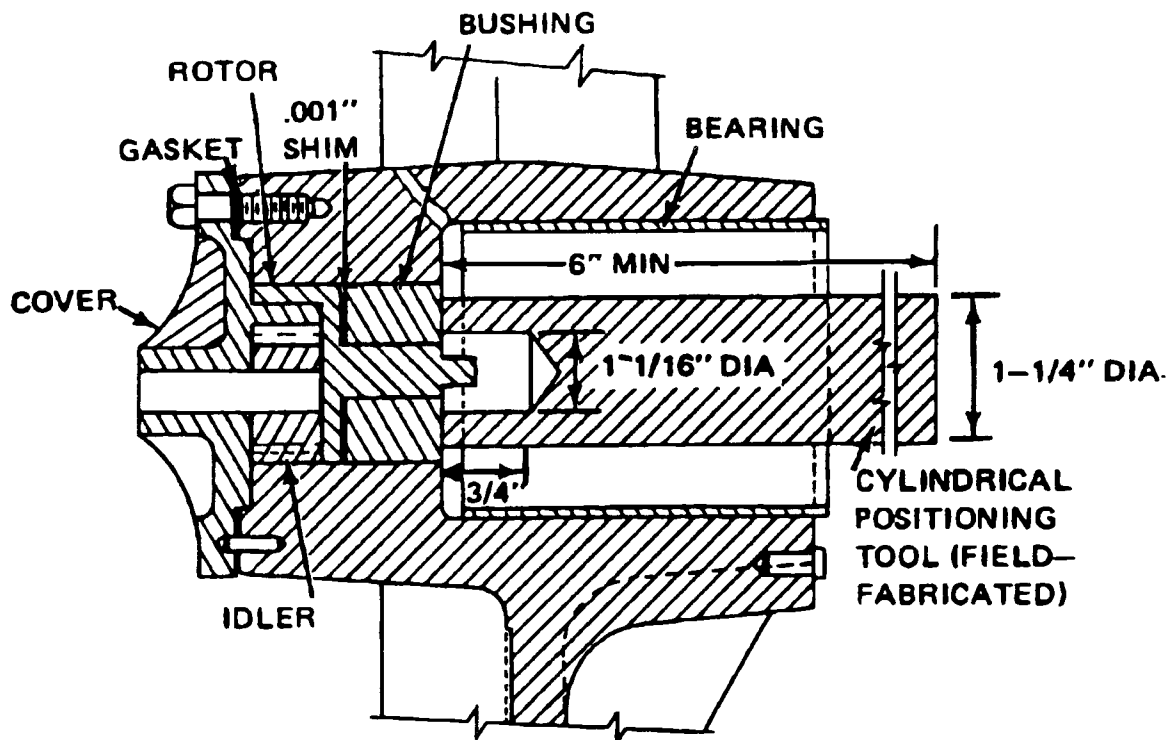
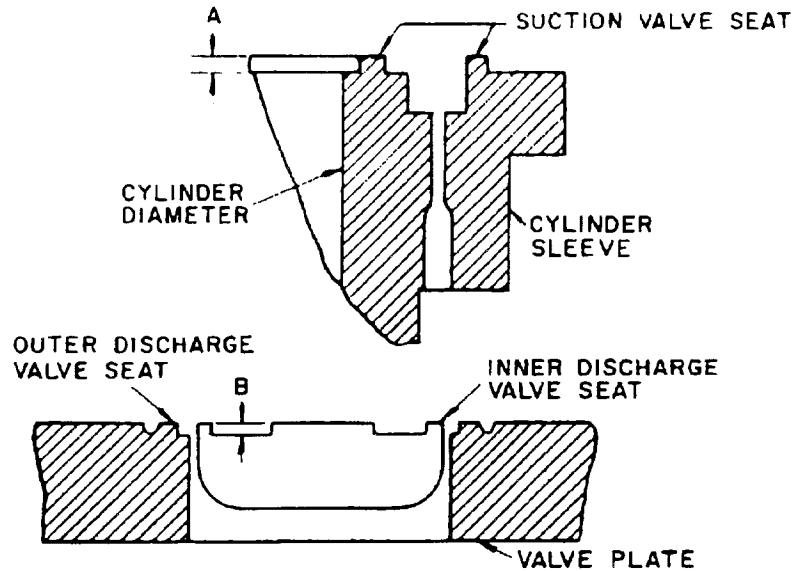


Figure 516-3-8. Setting Oil Pump Bushing



(FOR A AND B SEE Table 516-3-1)

Figure 516-3-9. Suction and Discharge Valve Seat Height

CAUTION

Observe oil pressure when starting compressor. If correct pressure (45 to 55 psi above suction pressure) is not reached in 8 to 12 seconds, stop the compressor and recheck the oil pump.

- b. Gear-in-Gear Type Oil Pump, (Models 5H120 and 126, from 1969 on) (Figure 516-3-7):
 - 1 Remove the bearing head and oil pump cover. Disassemble the oil pump. Check all parts for wear and damage. Inspect the bushing for scoring. Replace the bushing if scored. If the bearing head is scored, replace the complete bearing head and oil pump assembly.
 - 2 Install new oil pump bushing (models 5H120 and 5H126 from 1969 on). Reinstall the oil pump into the bearing head with 1/64-inch shim between the port insert and oil pump cover. Install the oil pump cover without gasket for this operation. Press the new bushing into the bearing head from inner side so that the bushing oil groove is at the top when the bearing head is installed (Figure 516-3-8). The lead (entering) end of the bushing is identified by machined circumferential lines. Press the bushing until the port insert bottoms against the 1/64-inch shim. Remove the pump cover and the shim. Reinstall the pump cover with the gasket and install the assembled bearing head to the compressor.
- c. The oil pressure regulating valve (nonadjustable, Figure 516-3-10) is located on the side of the compressor adjacent to the seal housing. This regulator is important in maintaining correct oil pressure (45 to 55 psi) and satisfactory unloader operation. To check the regulating valve, unscrew the regulator from the crankcase. Use a 5/16-inch Allen wrench on all compressors except model 5H120, which requires a 1/2-inch Allen wrench. Be sure the regulator is not clogged nor the plunger stuck. Check drillings to the regulator for fouling. The non-adjustable oil pressure regulator is interchangeable on all current 5F and 5H compressors except the model 5H120 and 5H126 (these models are equipped with a larger nonadjustable regulator). Early 5F and 5H compressors were equipped with an adjustable oil-pressure regulator. If it is necessary to replace an adjustable regulating valve, replace it with a nonadjustable type.

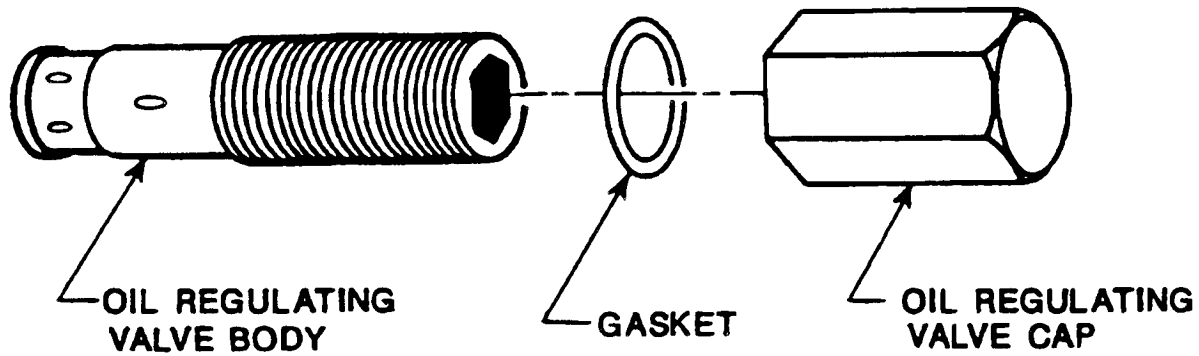


Figure 516-3-10. Oil Pressure Regulating Valve

- d. The oil return check valve (5F20 through 5F60 and 5H40 through 5H86) allows oil to return from the suction manifold to the crankcase. It is a normally open valve and will close when crankcase pressure becomes higher than suction pressure. Two disc-type check valves on 5F20 and 5F30 compressors are located beneath the partition between the suction manifold and the crankcase, one on each side of the compressor. They can be removed through the bottom cover or pump end of the compressor. The leaf-type check valve ([Figure 516-3-11](#)) on 5F40, 5F60; 5H40, 5H46, 5H60, 5H66, 5H80, and 5H86 compressors is accessible through, and located at top center of the hand-hole cover opening. Remove check valves and check to see that the flutter valve or leaf is not sticking and that it seats tightly.

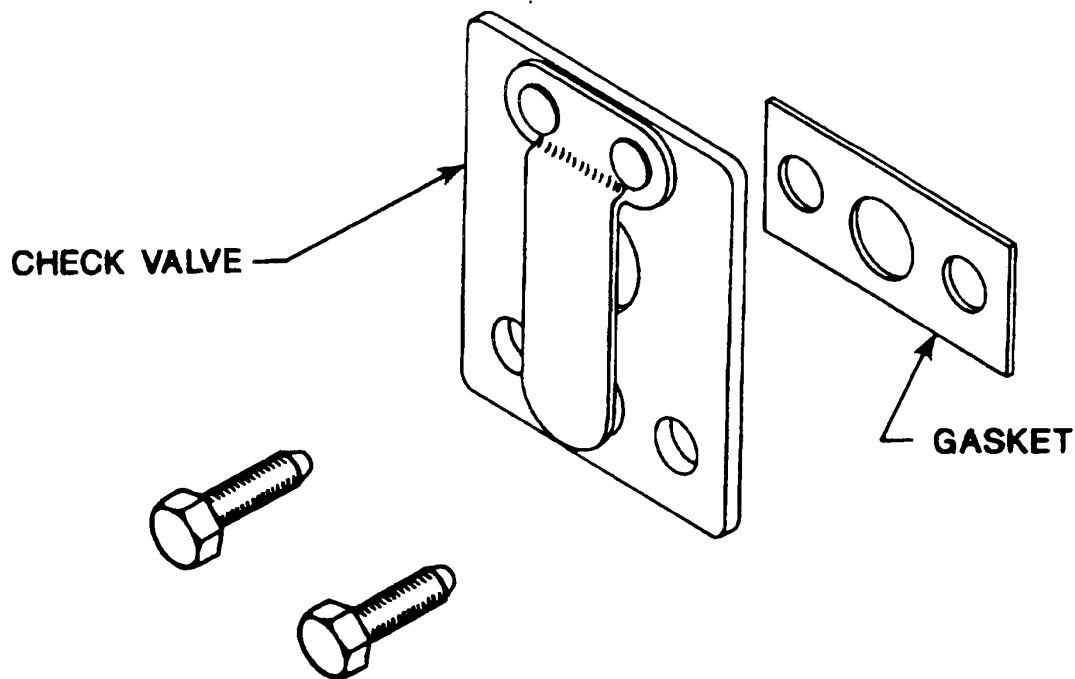


Figure 516-3-11. Leaf-Type Oil Return Check Valves

- e. The centrifugal oil separator on 5H120 and 5H126 compressors is mounted on the crankshaft and provides for oil return to the compressor crankcase. During flooded startup, gas and oil foam can escape from the crankcase only by moving inward through the centrifugal oil separator. Rotating rapidly, the oil is centrifuged out of the foam and thrown back to the crankcase. For oil separator removal and replacement, see paragraph [516-3.2.22.8](#) and [Figure 516-3-50](#).
- f. The oil filter screen in the compressor crankcase is accessible through the hand-hole cover or bottom plate. Remove and inspect it for holes and dirt. Clean it with an approved cleaning solvent and replace.
- g. An accessory oil filter is available and is installed on most 5H compressors. The filter for the 5H40 through 5H86 compressors is a bleed-type, high-pressure throwaway. The filter for the 5H120 and 5H126 compressors is a full-flow replaceable cartridge-type. Replace the filter or cartridge whenever the oil is changed or becomes dirty. Make a yearly check for a clogged filter. Clogging is indicated by a greater than normal difference between oil pressure ahead of the filter and after the filter. When this difference exceeds 5 psi, the filter

requires changing. [Figure 516-3-12](#) shows the throwaway oil filter and [Figure 516-3-7](#) shows the replaceable filter assembly. To replace the throwaway filter proceed as follows:

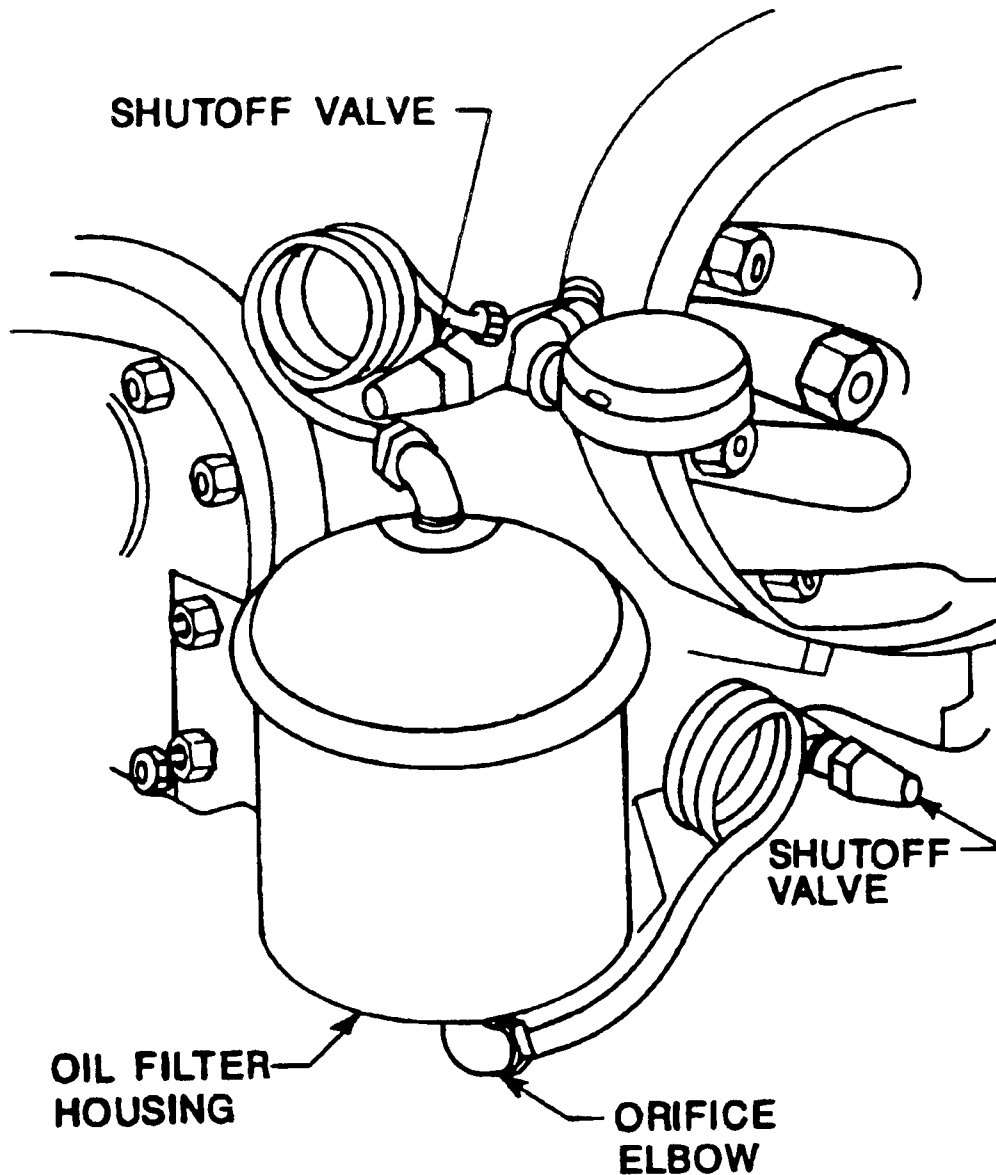


Figure 516-3-12. Carrier Oil Filter Accessory Package

- 1 Close the oil-line shutoff valve on each side of the filter ([Figure 516-3-12](#)).
 - 2 Disconnect the oil lines at the filter connections.
 - 3 Loosen the filter bracket; remove and replace the filter body.
- h. To replace the cartridge in the 5H120 and 5H126 compressors, pump down the compressor and replace the cartridge ([Figure 516-3-7](#)).

516-3.2.14 YORK LUBRICATING SYSTEM. The lubricating systems in the various York compressors are full force-fed to all bearing surfaces and shaft seals by self-reversing gear pumps. Most of the systems include replaceable cartridge-type oil filters.

NOTE

Some of the information presented herein on the various components was obtained from various instruction bulletins issued by York. In some cases the illustrations include the parts list with part numbers. A review of sample technical manuals indicates that part numbers in the manuals may not be the same as noted on the illustrations as York changed their numbering system. In any maintenance action where parts are involved, use the applicable onboard technical manual as the primary guidance.

516-3.2.14.1 York R Series Compressor Lubricating System Oil Pump Assembly. If it is necessary to repair the oil pump in the R series compressor, install a complete new pump assembly. [Figure 516-3-13](#) shows the oil pump. The later R series compressors (3-3/4 by 2-3/4) include an oil cooler. The cooler is externally mounted and cooled by refrigerant flowing through a strainer, solenoid valve, and expansion valve. The solenoid valve is deenergized to stop refrigerant flow to the oil cooler when the compressor stops. A thermostat with the bulb in the oil sump controls the solenoid valve in operation. The thermostat is set to open the solenoid valve at 140°F oil temperature and close the valve at 135°F. To replace the oil pump proceed as follows:

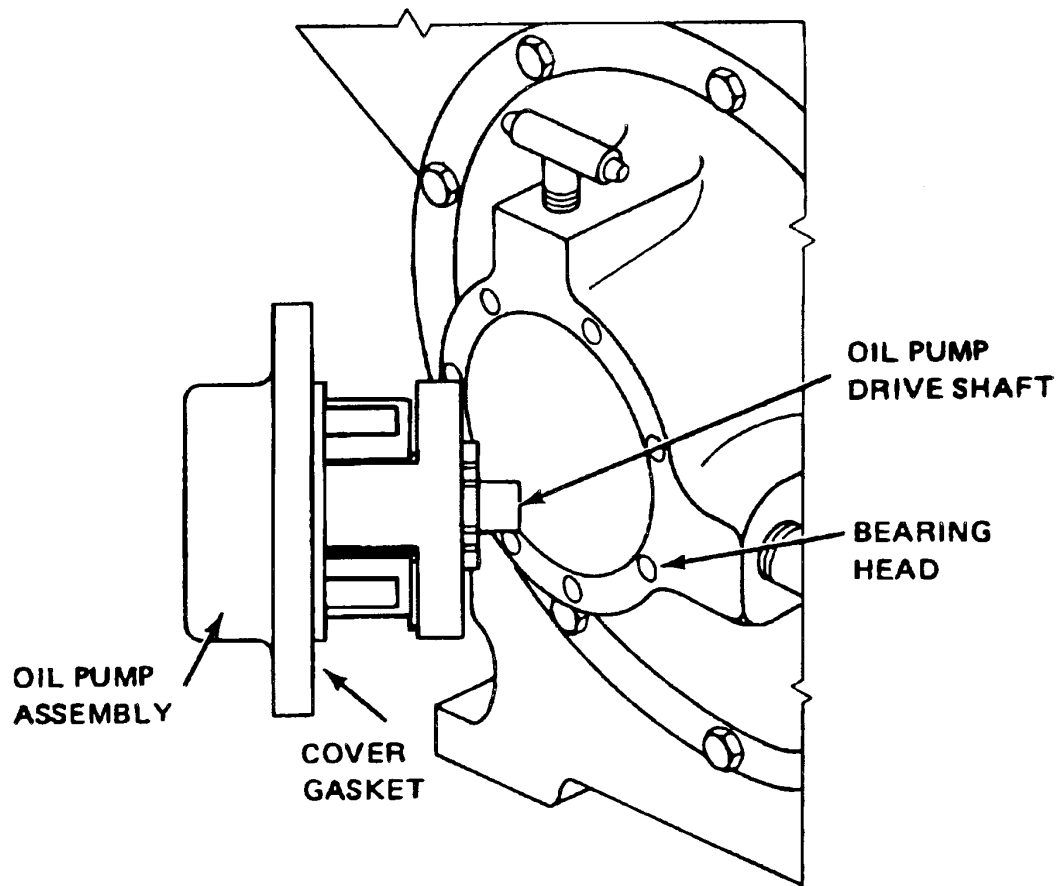


Figure 516-3-13. Removing Oil Pump - York R Style

1. Pump down the system (see paragraph [516-4.1.8](#)). Pull the main disconnect switch and recover the remaining refrigerant.
2. Remove the oil pump cover capscrews and remove the oil pump assembly from the bearing head.
3. Install the new oil pump assembly using a new gasket. Be sure that the flat end of the pump drive shaft engages the slot in the end of the compressor crankshaft and that the match mark on the oil pump cover is at the 1:30 position ([Figure 516-3-14](#)).

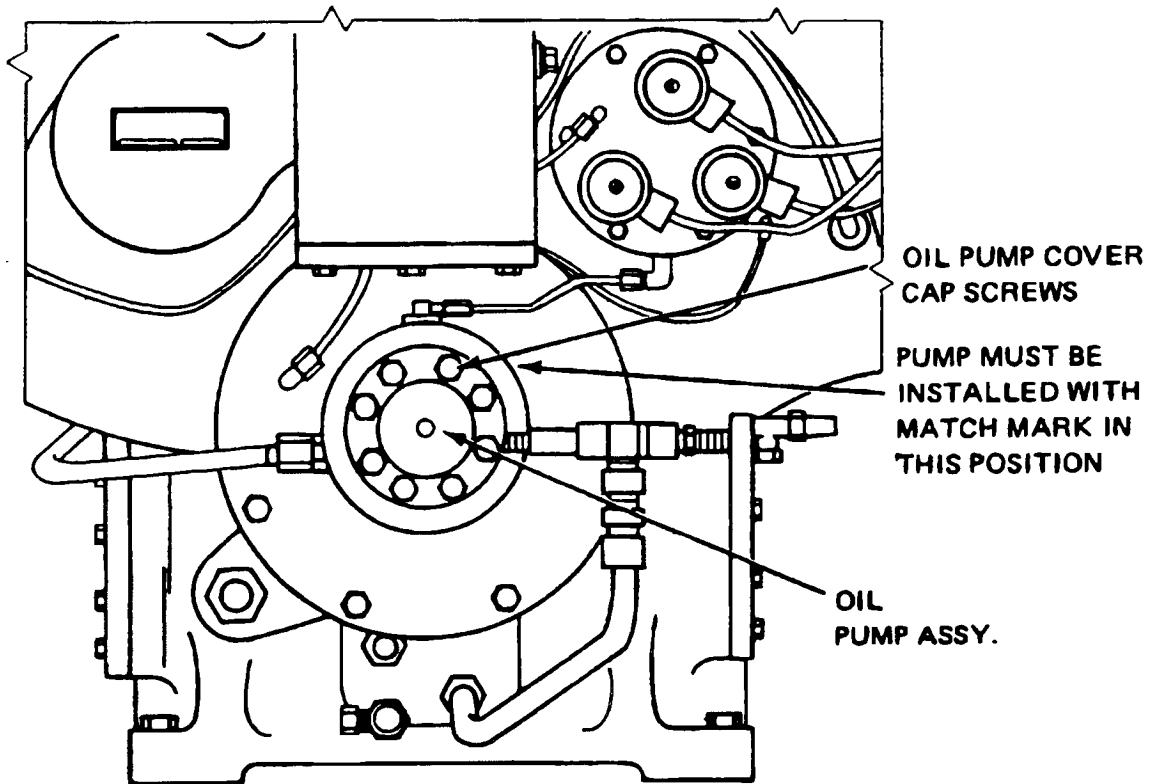


Figure 516-3-14. Oil Pump End of Compressor - York Early R Style

4. Tighten the pump cover capscrews evenly by drawing down opposite and alternate pairs. Tightening torque for the oil pump cover is 15 foot-pounds.

516-3.2.14.2 York G Series Compressor Lubrication. Servicing the G series (3-3/4 by 3) compressors is rather confusing without some background on the design changes applicable to the different designations indicated in the various manuals. Specific information is not available on what design changes are included in each 3-3/4 by 3 compressor installed on the various ships in the fleet. The design history herein should be helpful in maintaining these units. In the technical manuals for these plants, reference is made to Y-49, Y-51, or Y-53 designs to facilitate repair and maintenance. The part numbers are those indicated in bulletins issued by York. A review of some technical bulletins indicates differences among these part numbers and those in the technical manuals and in some cases from manual to manual; be guided by the manual onboard ship applicable to the plant being serviced.

516-3.2.14.3 Design Changes for G Series. In early 1953, to aid in the identification of compressors and selection of replacement parts for them, a compressor number was stamped on the housing after assembly. The location of the compressor number on the various compressors is shown in [Figure 516-3-15](#). The compressors are painted after the number is stamped on the housings, and it may be necessary to carefully examine the number locations and even scrape off the paint to clearly distinguish the numbers. From the compressor number, it is possible to determine the style of the component parts used in that particular compressor. The oil pump for G series compressors having a number of 909 and lower is the Y-49 ([Figure 516-3-16](#)). Y-49 bearing heads are no longer available; therefore, conversion to the Y-53 oil pump and bearing head assembly (64-5892S) is necessary when a Y-49 bearing head is found to be defective. Y-49 oil pump kits (64-5056S) are available for repairing

pump failures when a Y-49 bearing head is not damaged. The parts list for [Figure 516-3-16](#) consists of parts listed in technical manuals; and those parts are indicated here for reference. [Figure 516-3-17](#) shows Y-53 and Y-49 oil pumps with part numbers from a York service bulletin.

516-3.2.14.3.1 Early production of 4-, 6-, and 8-cylinder compressors had a no. 4 (1/16-inch) orifice in the orifice elbow located in the center of the oil header, and fed the wrist pins and crank pins through the main bearing. This orifice was increased to a no. 8 (1/8 inch) to ensure ample lubrication for the wrist pins. Redrill the no. 4 orifice to 1/8 inch on these earlier compressors at the first opportunity. The orifice number is stamped on the side of the elbow.

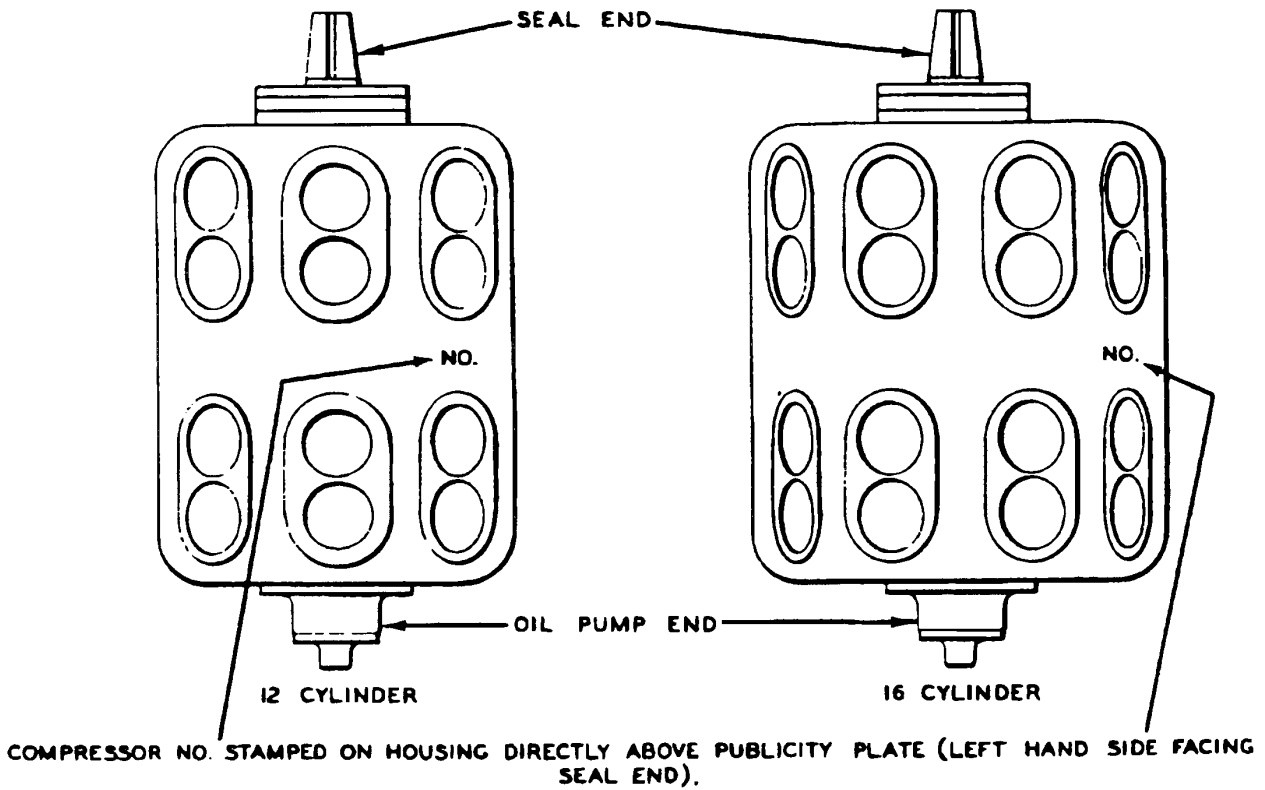
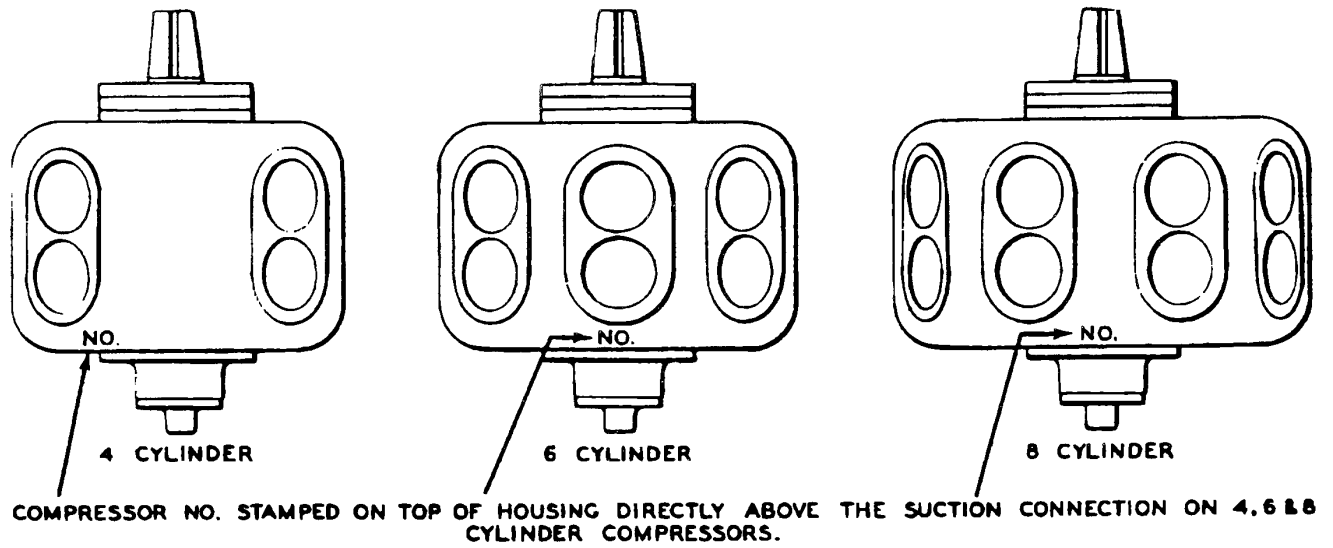
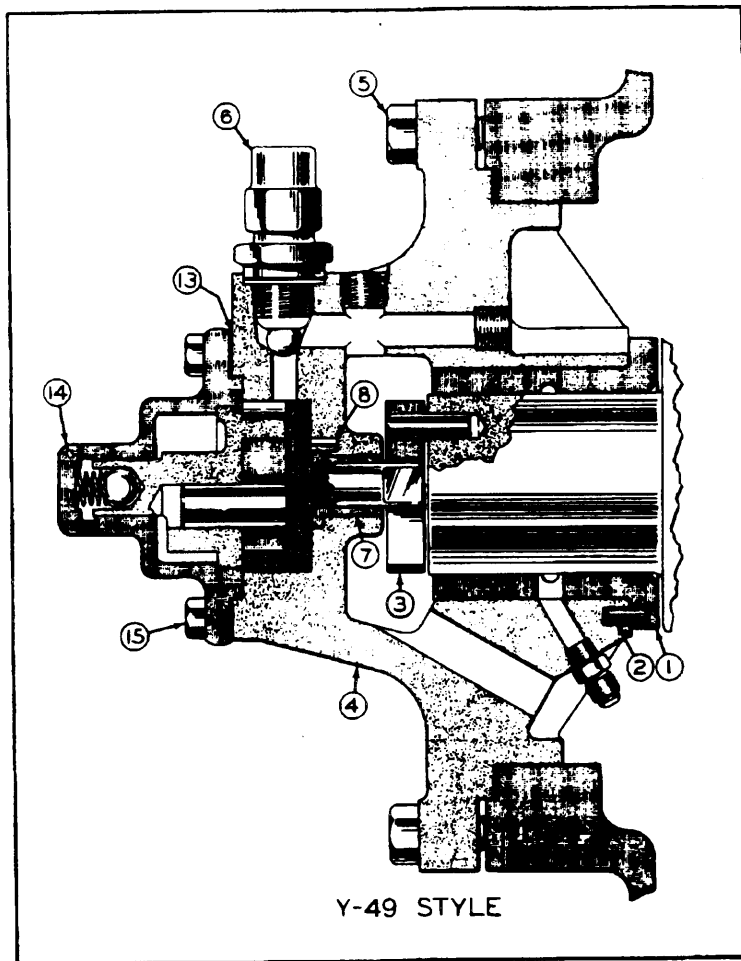
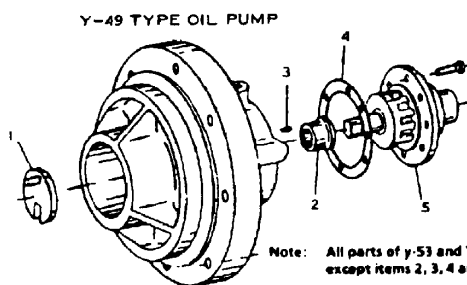
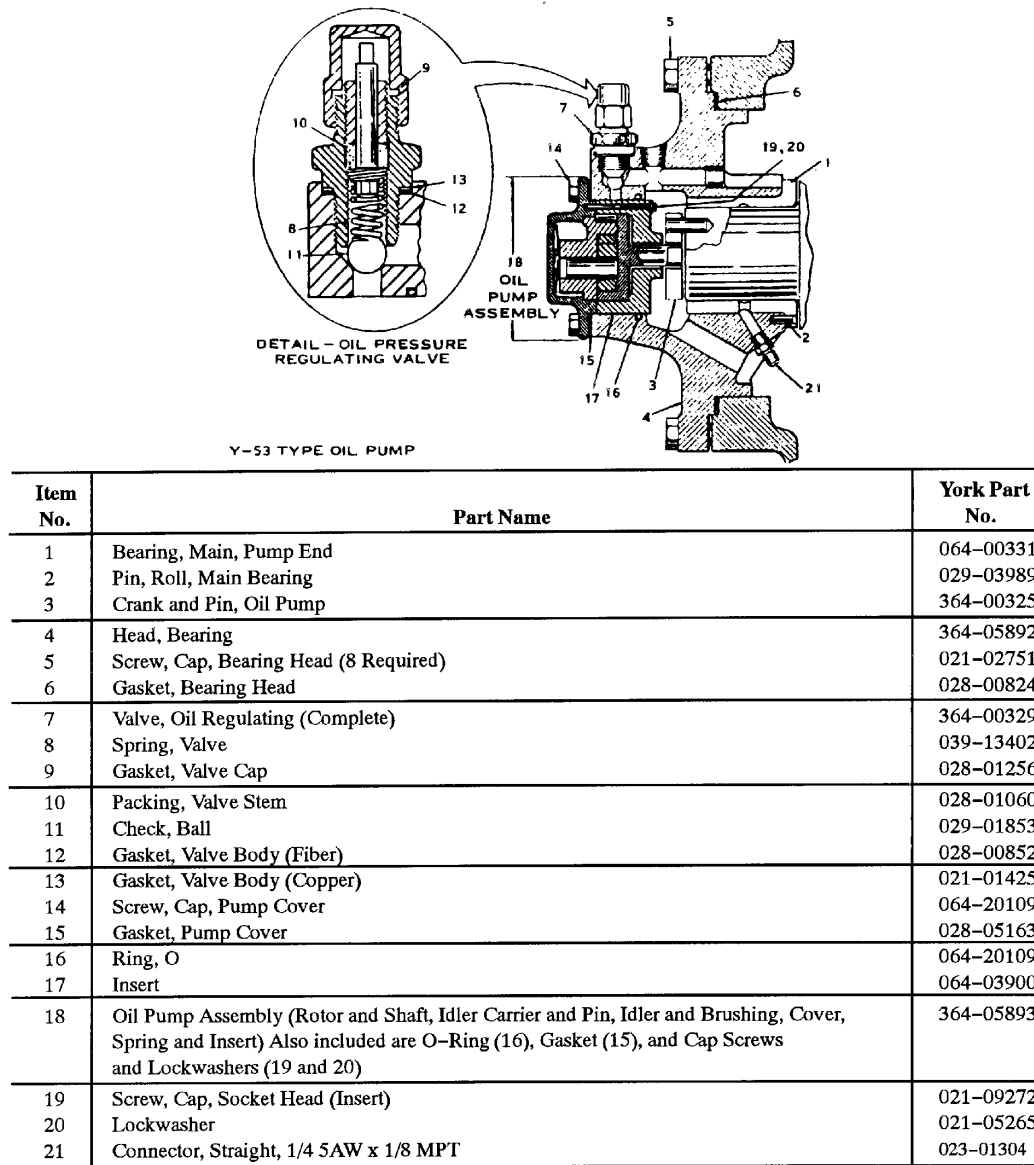


Figure 516-3-15. Location of Compressor Numbers (3-3/4 by 3)



Item No.	Part Number	Y-49 Part No.
1	Main Bearing	64-331PL
2	Main Bearing Pin	29-3989P
3	Oil Pump Drag Crank	64-325SK
4	Main Bearing Head with Plugs and Fitting	-
5	Main Bearing Head Cap Screw	21-2590P
6	Pressure-Regulating Valve	64-329SL
7	Oil Pump Bearing	64-332PK
8	Oil Pump Bearing Pin	29-3991P
13	Oil Pump Gasket	28-474PK
14	Oil Pump	26-3509PM
15	Oil Pump Cap Screw	21-1425P
7, 13 & 14	Oil Pump Kit	64-5056S

Figure 516-3-16. Oil Pump Y-49 York



Item No.	Part Number	York Part No.
1	Crank and Pin, Oil Pump	364-00325
2	Bearing, Oil Pump	064-00332
3	Bearing Pin, Oil Pump	029-03991
4	Gasket, Oil Pump	064-20109
5	Oil Pump	026-03509
1, 2, 4, 5	Oil Pump Kit	364-05056

Note: All parts of Y-53 and Y-49 Oil Pumps are interchangeable except items 2, 3, 4 and 5.

Figure 516-3-17. Oil Pump, Bearing Head, and Oil Pressure Regulating Valve

516-3.2.14.4 Oil Pump for G Series. Reinstall any oil pump removed for inspection or replacement using a full-face fibre gasket, part no. 064-20109, instead of the original (inside the bolt circle) copper-lead coated gasket, 028-00474. The original gasket was discontinued to prevent overtightening of capscrews that could cause the idler gear to seize. Seizure of this gear may cause the pump drive shaft to twist off. In removing all pump relief valves, relieve the pressure on the spring, counting the number of turns so that the relief valve can be replaced at approximately the correct setting. Some modules have a ball in the bearing head seat while in other modules the plunger sets in the bearing head seat and the ball is omitted.

516-3.2.14.5 York 2-5/8 By 2-1/4 Compressor. Servicing the 2-5/8 by 2-1/4 compressor is similar to the G series in that there is more than one design. If it becomes necessary to repair the oil pump, install a complete new pump assembly. To replace the oil pump, pump out the compressor and remove the high-pressure relief valve. See paragraph 516-3.2.14.4 for relief valve removal. Remove pump cover capscrews and pull the oil pump assembly out of the bearing head. Thoroughly clean and dry replacement parts and coat with clean oil. Be sure oil-ways in the bearing head are clean. Assemble replacement pump parts as shown in Figure 516-3-18 and install the assembly in the bearing head.

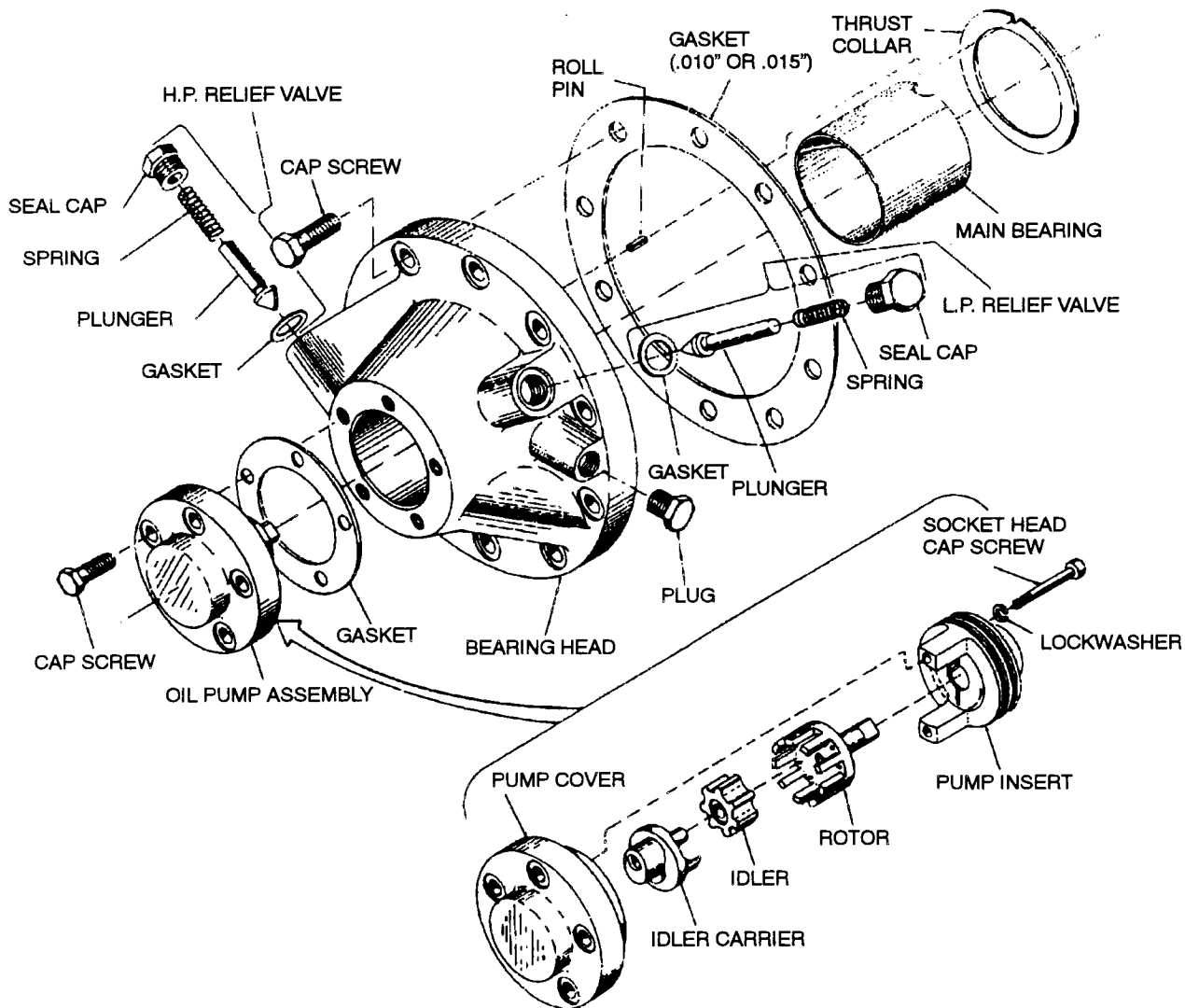


Figure 516-3-18. York - Bearing Head and Oil Pump Assembly

516-3.2.15 CAPACITY CONTROL SYSTEM. Where internal automatic capacity control is not provided in the compressor, capacity variation for off-peak load is generally provided by variable or multispeed operation of the electric motor. In those cases the speed of the motor is selected manually. This type of capacity control is generally found in older, slow-speed (600 rpm) compressor units. Modern high-speed (1,750 rpm) compressor units include an automatic capacity control system.

516-3.2.16 AUTOMATIC CAPACITY CONTROL. Capacity variation for most reciprocating compressor applications in Navy shipboard plants is provided by an oil-pressure operated, automatic capacity control system. The system unloads or cuts cylinders out of operation in accordance with decreases in the refrigeration load requirements of the plant. Unloading of a cylinder is accomplished by holding the suction valve open so that no gas can be compressed (Figure 516-3-19).

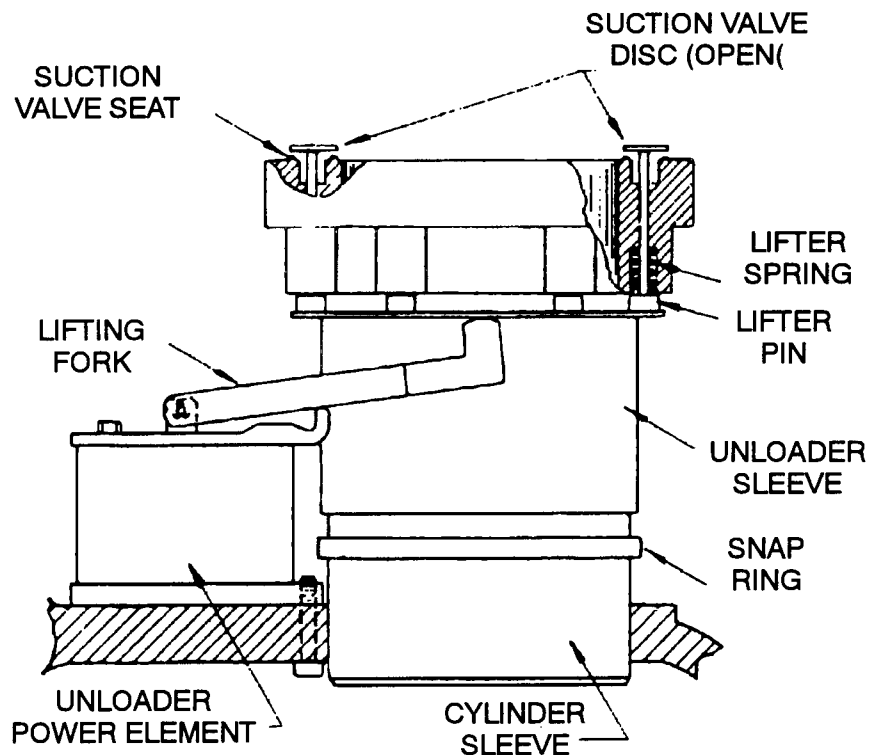


Figure 516-3-19. Typical Suction Valve Lifting Arrangement

516-3.2.16.1 On each compressor, certain banks of cylinders are not equipped with unloaders. This prevents overheating since a definite volume of cool refrigerant gas flows through the compressor at all times during operation, regardless of load condition. Upon starting, since oil pressure is required to load or put cylinders into operation, the compressor will start with all controlled cylinders unloaded and only the nonunloading cylinders start pumping gas. As soon as the compressor comes up to speed and full oil pressure is developed, all cylinders will become operative. After the temperature pull-down period, the refrigeration load imposed on the compressor will decrease and the capacity control system will unload cylinders accordingly. The unloading will result in reduced power consumption.

516-3.2.16.2 In those applications where numerous cooling coils are supplied by one compressor or where a large cooling coil is installed, the capacity control system will prevent the suction pressure from dropping to the low-pressure cutout setting, and thereby prevent stopping the compressor before all cooling requirements are satisfied. Without a capacity control system either short cycling would occur (frequent compressor stopping and

starting while never reaching design temperatures) or the suction pressure cutout switch would have to be set at a needlessly low setting. It is very important that the capacity control be accurately set to take care of specific capacity variations without any compressor short cycling. The specific setting of the capacity control system depends on the design and should be indicated in the plant technical manuals. Many of the older manuals do not state the capacity control settings. If the capacity control is not indicated, set the control by trial and error to ensure that compartment temperatures are maintained and that the compressor does not short-cycle and submit a Technical Manual Deficiency/Evaluation Report (TMDER) on the equipment technical manual.

516-3.2.17 CAPACITY CONTROL OPERATION. In the operation of an automatic capacity control system, compressor oil is pumped through the control oil strainer into the auxiliary step control valve where the oil flow to unloader power elements is controlled in steps by the movement of the auxiliary step piston. As soon as pump oil pressure reaches the power element, the piston rises, the lifting fork pivots, and the suction valve disc is lowered, permitting the suction valve to seat. The system is governed by suction pressure, which actuates the capacity control valve. This is a general description of the type of capacity control system used by Carrier and York in Navy shipboard applications.

516-3.2.17.1 While the principle of operation at work in these two control systems is the same, the details differ. While Carrier uses a lifting fork to move the suction valve disc, York uses a piston or a rod-operated cam. Another York system uses oil pressure switches that close or open solenoid valves in the oil circuit to the unloaders. Each of these will be described in later paragraphs.

516-3.2.18 CARRIER COMPRESSOR CAPACITY CONTROL. Suction pressure increases or decreases according to increases or decreases in the refrigeration load requirements of the plant. When the suction pressure decreases, the crankcase pressure in turn decreases the pressure against the capacity control valve bellows and relieves the tension on the range adjustment spring. The expansion of the range adjustment spring forces the push pins against the capacity control valve spring and moves the needle point away from the valve seat. This increases the control or bleed from the auxiliary step control valve to the crankcase. The resulting decrease in control oil pressure within the auxiliary step control valve allows the piston to be moved by spring action, successively closing the oil ports and preventing compressor oil pump pressure from reaching the unloader power elements. As oil pressure leaves each power element, the suction valve rises, and that cylinder unloads. With an increase in suction pressure, the above process is reversed and the controlled cylinders will load in succession.

516-3.2.18.1 General Capacity Controls. An external cylinder unloading-type of capacity control package is used for 5F20 and 5F30 compressors. An internal capacity control system is standard equipment on the 5F40 and larger compressors. The cylinder unloading mechanism is powered by the compressor force-feed lubricating system. This feature ensures unloading of all controlled cylinders at starting regardless of the position of the capacity control valve, since suction valves will be held in the open position until the lubricating oil pressure reaches its normal operating level. With the exception of the 5F20 and 5F30 sizes, compressors, as furnished, will have the capacity control arranged for capacity reduction in response to suction pressure. An external adjusting stem is provided to set the control point and maintain the desired suction pressure. The control point is adjustable from 0- to 50-psig suction pressure. The differential over the complete range at any temperature level is 6.8 to 7 psig with R-12. The power elements and valve lifting mechanisms are identical on all 5F and 5H compressors. However, for the capacity control, various methods are used to activate the power elements. [Table 516-3-2](#) shows the unloading steps and power requirements at each step, and [Figure 516-3-20](#) shows the cylinder unloading sequence.

Table 516-3-2. CAPACITY CONTROL REDUCTION STEPS - CARRIER

Compr Model	Contr Cyl	Cap Steps (Percent Full Load Cap)									
		100	87-1/2	83-1/3	75	66-2/3	62-1/3	50	37-1/2	33-1/3	25
		100	90	86	80	74	71	60	50	45	38
		Number of Active Cylinders									
5F20	1	2	--	--	--	--	--	1	--	--	--
5F30*	1	3	--	--	--	2	--	--	--	--	--
5F40	3	4	--	--	3	--	--	2	--	--	1
5F60	4	6	--	5	--	4	--	3	--	2	--
5H40	3	4	--	--	3	--	--	2	--	--	1
5H46	3	4	--	--	3	--	--	2	--	--	1
5H60	4	6	--	5	--	4	--	3	--	2	--
5H66	4	6	--	5	--	4	--	3	--	2	--
5H80	6	8	7	--	--	--	5	--	3	--	2
5H86	6	8	7	--	--	--	5	--	3	--	2
5H120	8	12	--	10	--	8	--	6	--	4	--
5H126	8	12	--	10	--	8	--	6	--	4	--
*Two controller cylinders (to 33-1/3 percent) available on request for 5F30.											

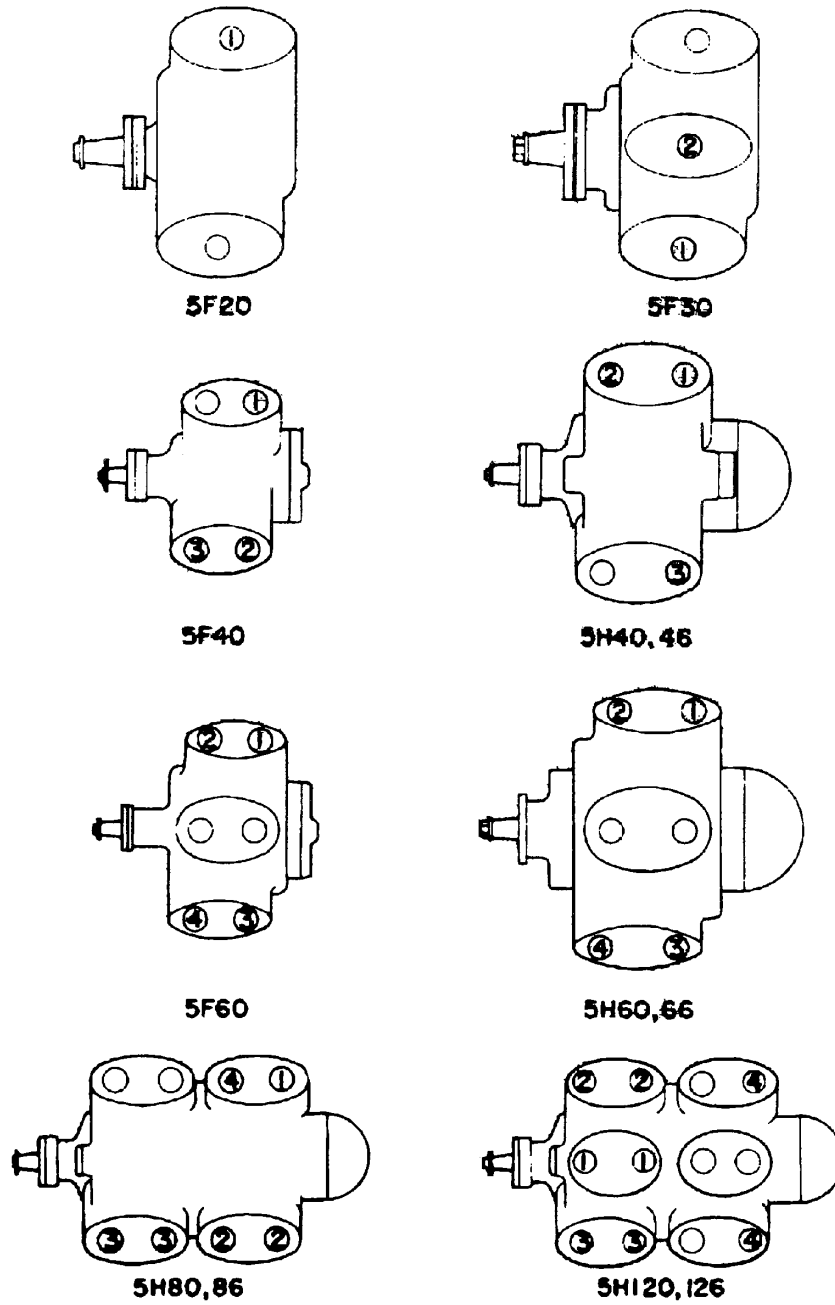


Figure 516-3-20. Cylinder Unloading Sequence - Carrier

516-3.2.18.2 Carrier 5F20 to 5F30 Capacity Control. Refer to [Figure 516-3-21](#). The following are major elements of this capacity control system:

- a. Capacity Control Valve. This valve raises or lowers the oil pressure from the oil pump in response to the refrigerant suction pressure.
- b. Power Element. This element supplies the power necessary to operate the valve-lifting mechanism. It is modulated by the capacity control valve.
- c. Valve-Lifting Mechanism. This mechanism consists of a sleeve and push pin assembly around each controlled cylinder designed to hold the suction valve open or to permit the valve to remain in a normal operating position depending on its actuation by the power element.
- d. Principal of Operation of the System:
 - 1 Loaded Operation. An increase in suction gas pressure, which requires increased compressor capacity, causes the needle valve to close. Therefore, the lubrication oil pressure in the power element increases. Increased oil pressure in the power element moves the power piston upward and the suction valve discs are allowed to seat.
 - 2 Unloaded Operation. A drop in suction pressure causes the needle valve to open. Oil bleeds through the valve to the crankcase decreasing oil pressure in the power element. As oil pressure to the power element drops, the piston moves downward. The lifting fork is pivoted upward, moving lifting pins upward; the suction valve is raised from its seat and the controlled cylinder is unloaded.

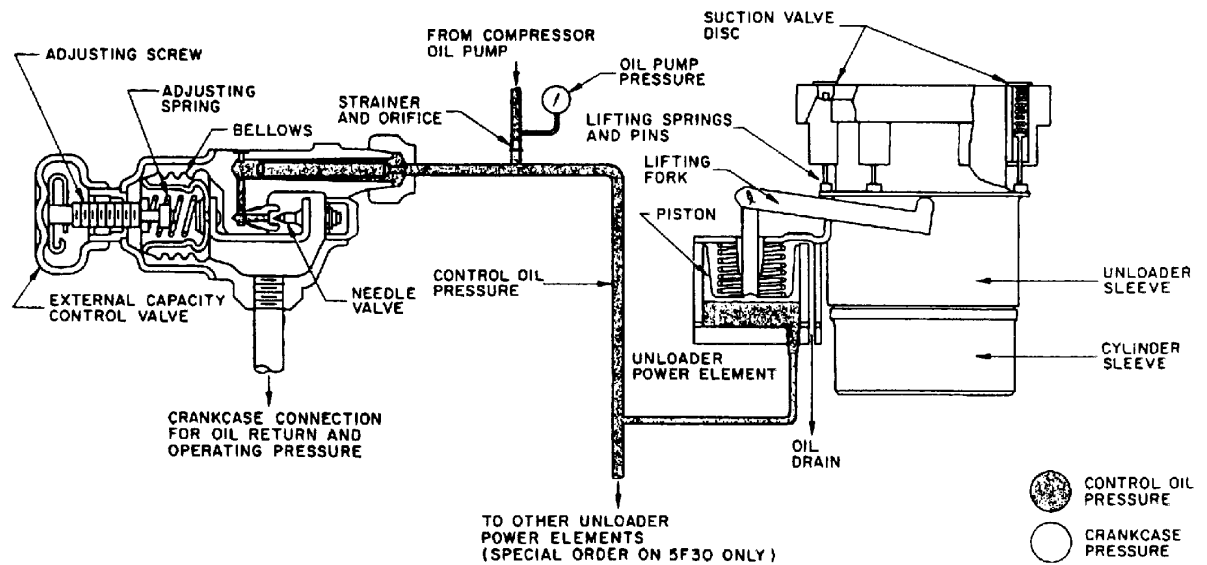


Figure 516-3-21. Capacity Control - 5F20 and 5F30

516-3.2.18.3 Carrier 5F40 to 5H86 Capacity Control. Refer to [Figure 516-3-22](#). The following are major elements of this capacity control system:

- Capacity Control Valve.** This valve raises or lowers control oil pressure to the hydraulic relay piston in response to the refrigerant suction pressure. An increase in suction pressure increases the control oil pressure in the hydraulic relay.
- Hydraulic Relay.** This relay feeds the lubrication oil from the oil pump at full pressure in sequence to one or more power elements. This hydraulic relay is activated by the control oil pressure from the capacity control valve.
- Power Element.** This element supplies the power to operate the valve-lifting mechanism.
- Valve Lifting Mechanism.** This mechanism consists of a sleeve and push pin assembly around each controlled cylinder, designed to hold the suction valve open or to permit the valve to remain in a normal operating position depending on its actuation by the power element.

e. Principles of Operation of the System:

- 1 Loaded Operation. A rise in suction pressure increases pressure against the capacity control valve bellows, compressing the range adjustment spring. Compression of the range adjustment spring allows the valve spring to move push pins and valve needle point toward the valve seat. Flow of control oil to the crankcase through the oil drain is throttled. Control oil pressure rises as oil enters the capacity control circuit through the orifice, in the hydraulic relay, from the compressor oil pump circuit. Increased control oil pressure advances the hydraulic relay piston (against spring), which feeds oil at full pressure to one or more controlled cylinder power elements depending on the position of the control valve. Pump oil pressure in unloader power elements forces the piston upward, pivoting the lifting fork(s) downward. Lifter pins drop allowing suction valve(s) to seat and load cylinder(s).
- 2 Unloading Operation. A drop in suction pressure decreases pressure against the control valve bellows. The range adjustment spring presses against push pins, compressing the valve spring. This moves the needle valve off the seat. Control oil bleeds from the hydraulic relay and control valve to the crankcase, relieving oil pressure on the hydraulic piston. The piston retracts, preventing transmission of pressurized oil to controlled cylinder power element(s), and the oil drains to the crankcase. As oil pump pressure to the power element drops, the piston moves downward. The lifting fork(s) is pivoted upward, moving lifting pins upward; suction valves are raised from their seats and the controlled cylinder(s) is unloaded.

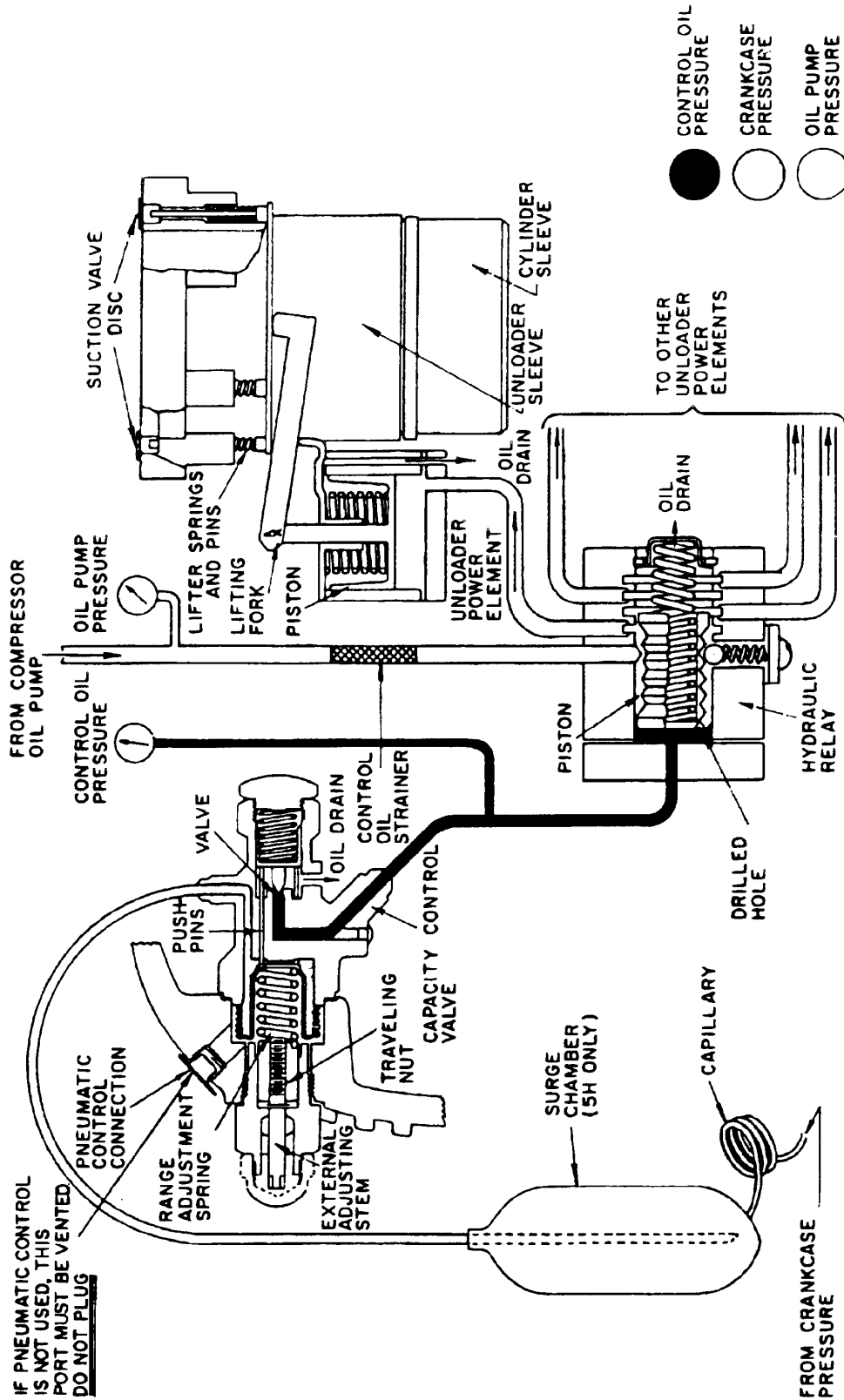


Figure 516-3-22. Capacity Control - 5F40, 5F60, 5H40, 5H46, 5H60, 5H66, 5H80, and 5H86

516-3.2.18.4 Carrier 5H120 and 5H126 Capacity Control. Refer to [Figure 516-3-23](#). The 5H120 and 5H126 capacity control systems are slightly different from those used on 5F40 through 5H86 compressors. Unloaded starting and capacity reduction is obtained by holding open suction valves of a number of cylinders. For capacity control purposes, a suction-pressure-actuated capacity control valve pilots a hydraulic relay that loads or unloads cylinders in pairs. Major differences from 5F40 through 5H86 capacity controls are:

- a. The hydraulic relay design provides a wider pressure differential between cylinder cut-in and cutout points. This hydraulic relay is a small, easily removed cartridge rather than an integral part of the pump end cover.
- b. The surge chamber on the 5H120 and 5H126 compressor is an integral part of the bearing head casting. For principles of operation for 5H120 and 5H126 compressors, see operation of 5F40 through 5H86 compressors.

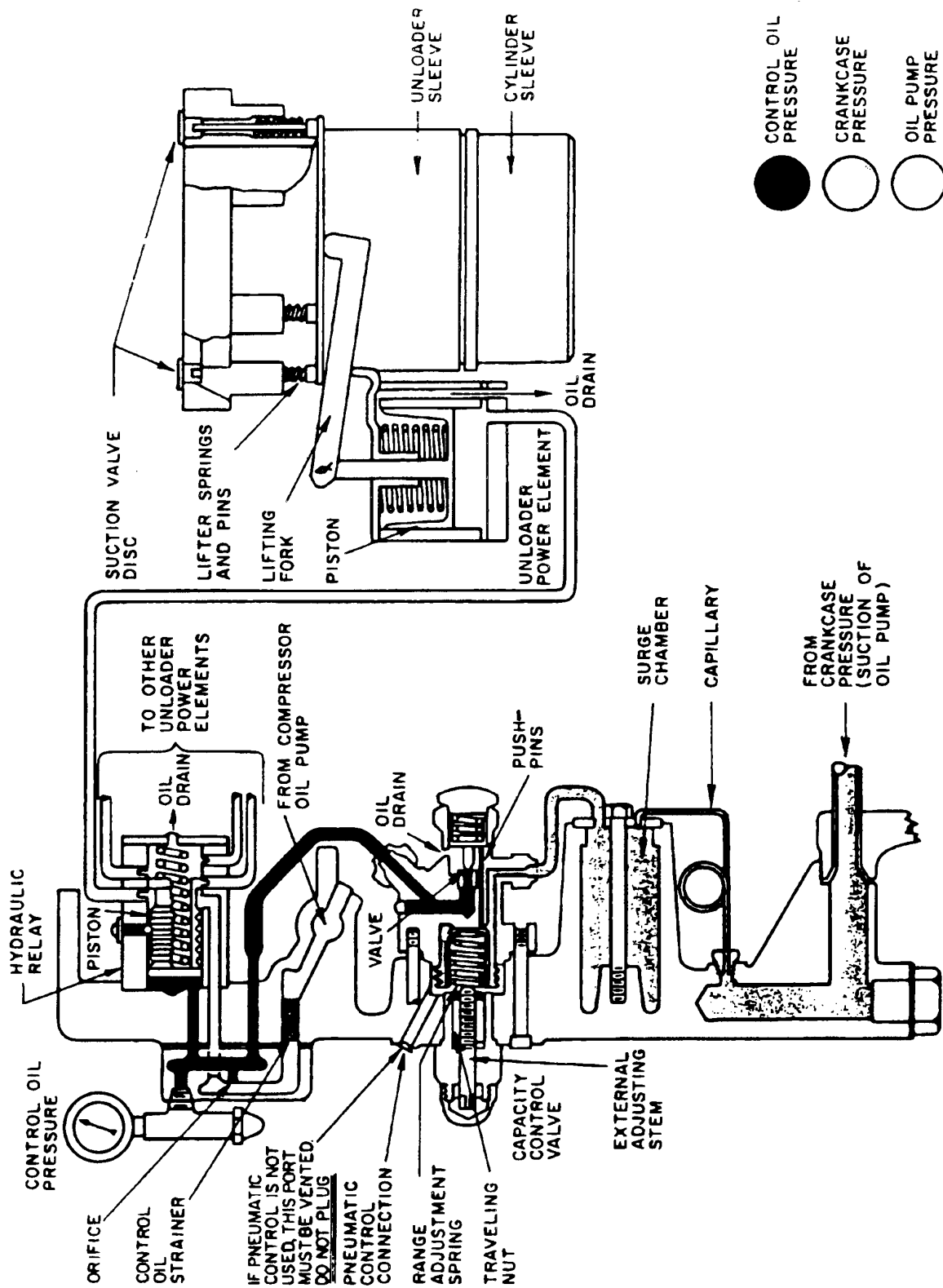
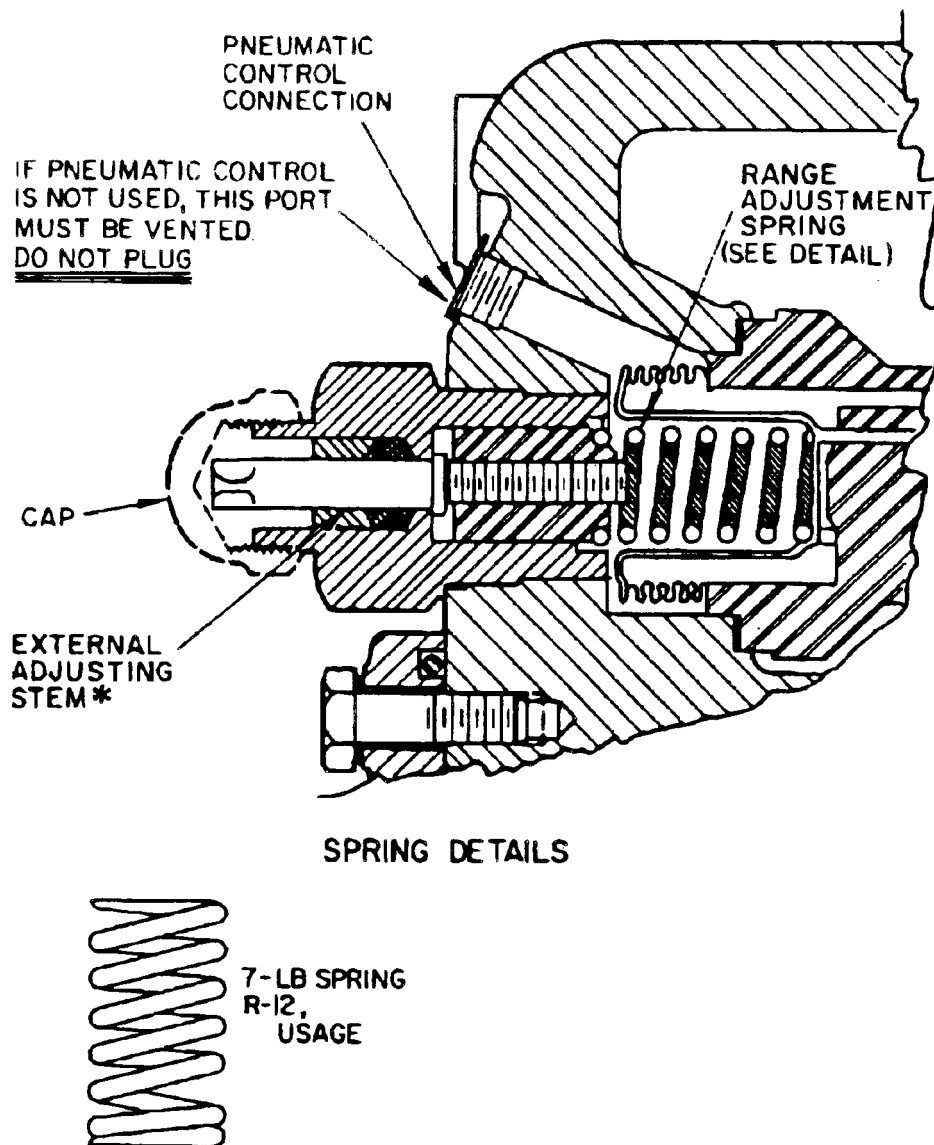


Figure 516-3-23. Capacity Control - 5H120 and 5H126

516-3.2.18.5 Adjustment of Capacity Control. For 5F40 through 5H126 compressors, an external adjusting stem (Figure 516-3-24) sets the control point (suction pressure at which first step of cylinder unloading occurs). For R-12 and R-134a the control point range previously stated is 0 to 50 psi. One full clockwise turn of adjusting stem will raise the control point approximately 6 pounds. Control oil pressure is an indication of cylinder loading condition. Figure 516-3-25 indicates the operating sequence of capacity reduction steps to load and completely unload. Refer to the technical manual for location of the control oil pressure gauge connection and control point indicated by the manufacturer. The control point may vary from plant to plant depending upon the design. Figure 516-3-23 indicates that the pneumatic control connection shall be vented if pneumatic controls are not used. Reciprocating plants in Navy applications do not use pneumatic controls. If a new bearing head is installed see that the dust cover in the pneumatic control connection is removed or vented. Ensure that debris or dripping water does not enter. This applies to the Carrier capacity control valve for reciprocating machines.



*When compressor is received the capacity control adjusting stem will be backseated. (Compressor will be fully loaded under all conditions.)

Figure 516-3-24. Capacity Control Valve - Carrier

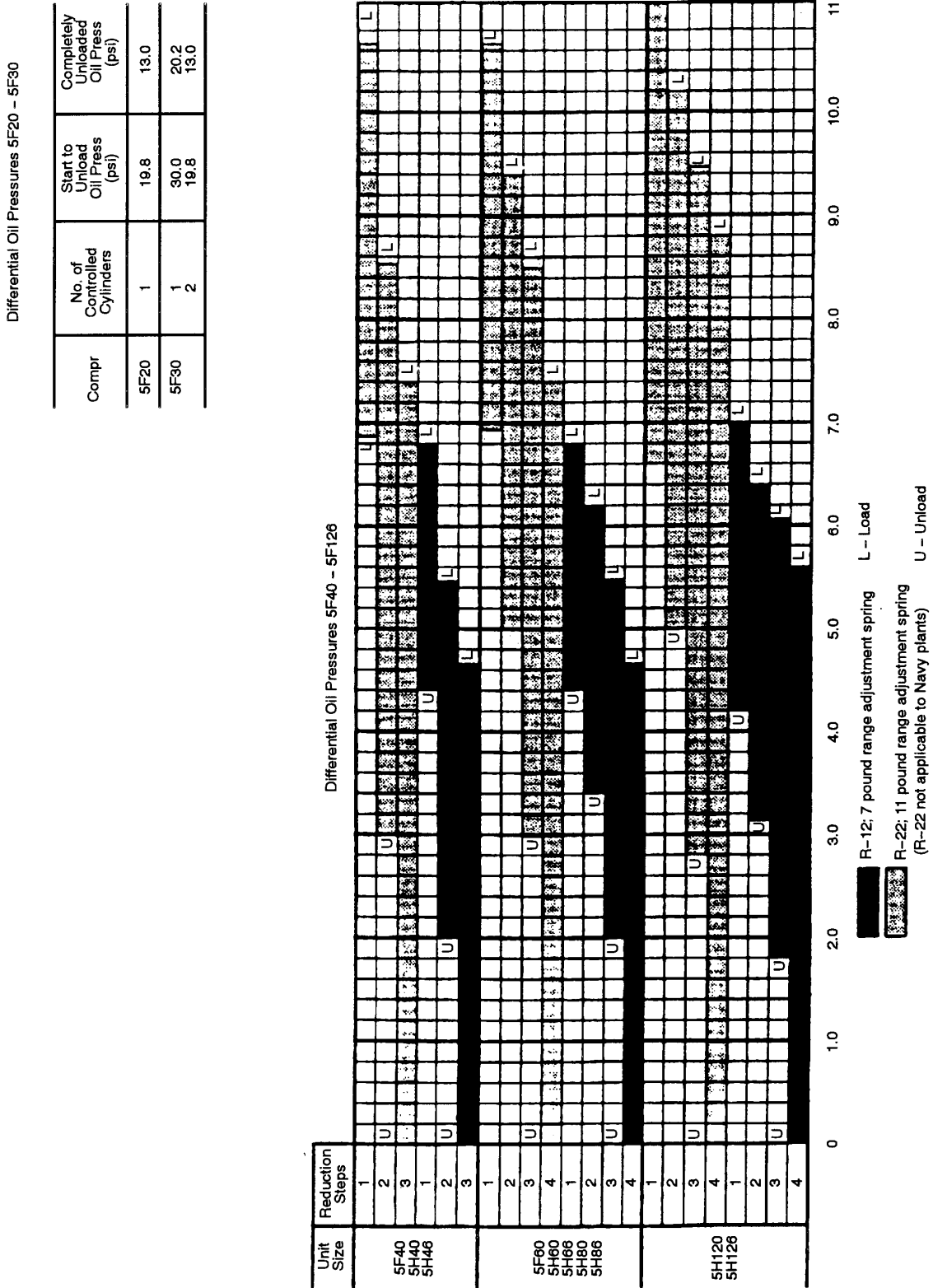


Figure 516-3-25. Operating Sequence of Capacity Reduction Steps - Carrier

516-3.2.18.5.1 To adjust the control point, perform the following steps:

1. Impose an artificial load on the compressor until suction pressure is above the desired control point.
2. Lower the compressor suction pressure to control point pressure by slowly closing the compressor shutoff valve.
3. When at control point pressure, turn the external adjusting stem clockwise until the first step of unloading takes place. This is indicated by changes in the control oil pressure, current draw, and the sound of the compressor.

516-3.2.18.5.2 The control point is now set. Slowly reopen the compressor suction shutoff valve. The compressor will be fully unloaded when suction pressure is 4 psi below control point. For adjustment of the capacity control for 5F20 and 5F30, the control package is furnished as an necessary. When a new accessory package is received, the adjusting stem (Figure 516-3-21) is backseated (fully counterclockwise) and the compressor will be fully loaded under all conditions. Adjust the capacity control setpoint by the same three-step procedure described in paragraph 516-3.2.18.5.1 for 5F40 through 5H126 compressors. For the air-conditioning application setting, the capacity control is difficult. There is very little pressure difference to maneuver between the design chilled water temperature of 44°F (40 psi for R-12) and the freezing point of water of 32°F (30 psi for R-12) and the pressure range of the capacity control between full loaded and unloaded of approximately 7 psi.

516-3.2.18.6 Capacity Control Inspection and Service.

- a. Remove unloader power element:
 - 1 Remove the cylinder head, valve plate, connecting rod, piston, and cylinder sleeve. Remove Allen head capscrews (2) holding the unloader power element in position.
 - 2 Remove the power element (Figure 516-3-26) and disassemble. Check all parts for wear and damage.

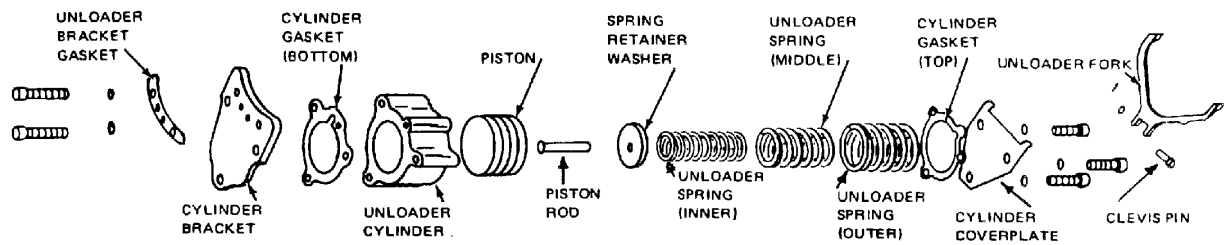
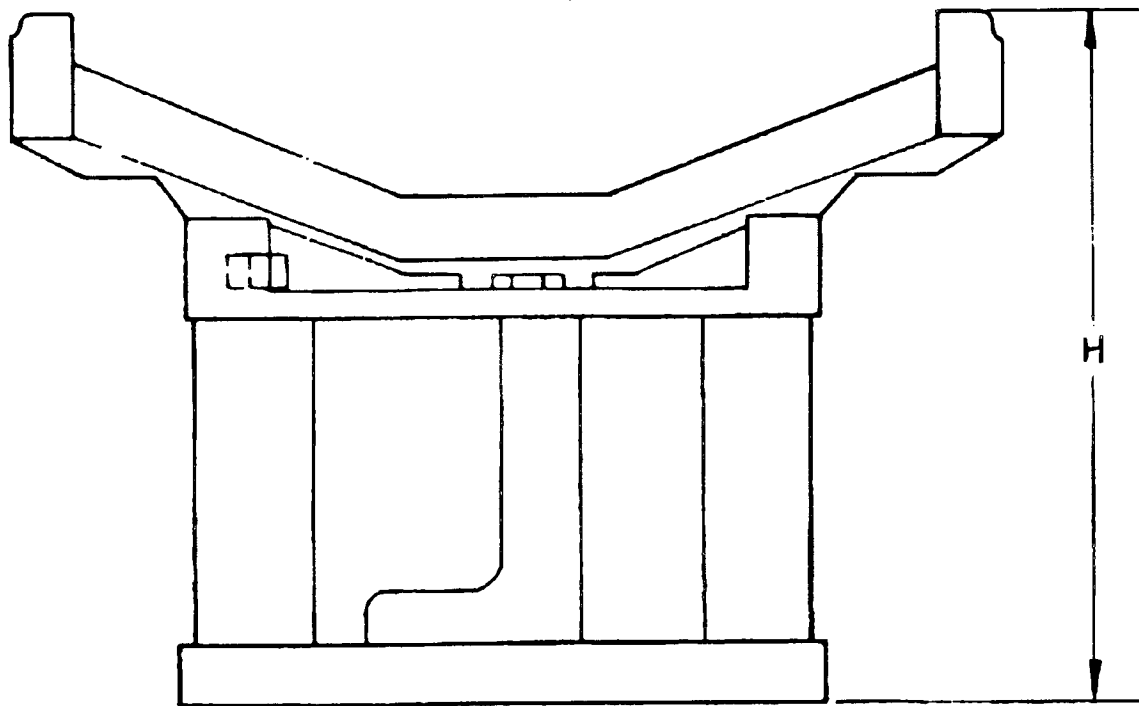


Figure 516-3-26. Unloader Power Elements - Carrier

b. Replace power element:

- 1 Check the unloader fork height (Figure 516-3-27) of the assembled or new power element to ensure it is the correct one for the compressor.



$$(5F) H = 2 \frac{15}{32} + \frac{1}{64} - 0 \quad (5H) H = 3 \frac{7}{16} + \frac{1}{64} - 0$$

Figure 516-3-27. Unloader Fork Height (5F and 5H)

- 2 Attach the power element to the internal suction manifold. Replace the cylinder sleeve piston, connecting rod, valve plate, cylinder head, and handhole cover.
- c. Remove external adjusting stem. Removal of the adjusting stem does not require pumping down the compressor. Loosen the hex nut at the valve stem base and remove the adjusting stem assembly.
- d. Remove capacity control valve and hydraulic relay:
 - 1 Locate the assembly in the handhole cover (Figure 516-3-28) of 5F40 and 5F60 units, in the pump end cover (Figure 516-3-29) of 5H40, 5H46, 5H60, 5H66 5H80, and 5H86 units, and in the pump end bearing head (Figure 516-3-30) of 5H120 and 5H126 units.
 - 2 Remove the capacity control valve and hydraulic relay. Inspect parts for wear, damage, and evidence of leaking or sticking.
 - 3 A new handhole cover, pump end cover, or pump end bearing head with control valve assembly may be installed. However, the capacity control valve (and hydraulic relay on 5H120 and 5H126 units) is available as a separate part item for installation on the original handhole cover, pump end cover, or pump end bearing head.

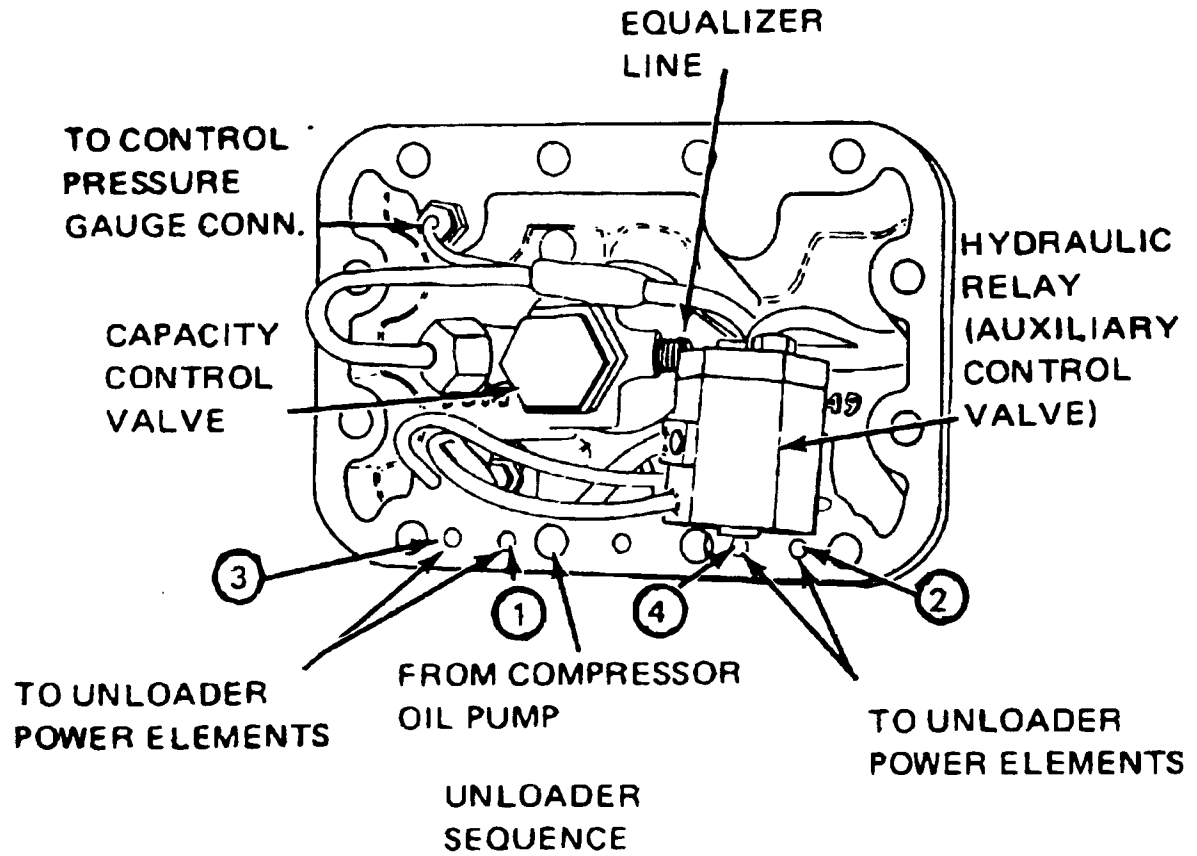


Figure 516-3-28. Compressor Handbook Cover and Assembly (5F40 and 5F60)

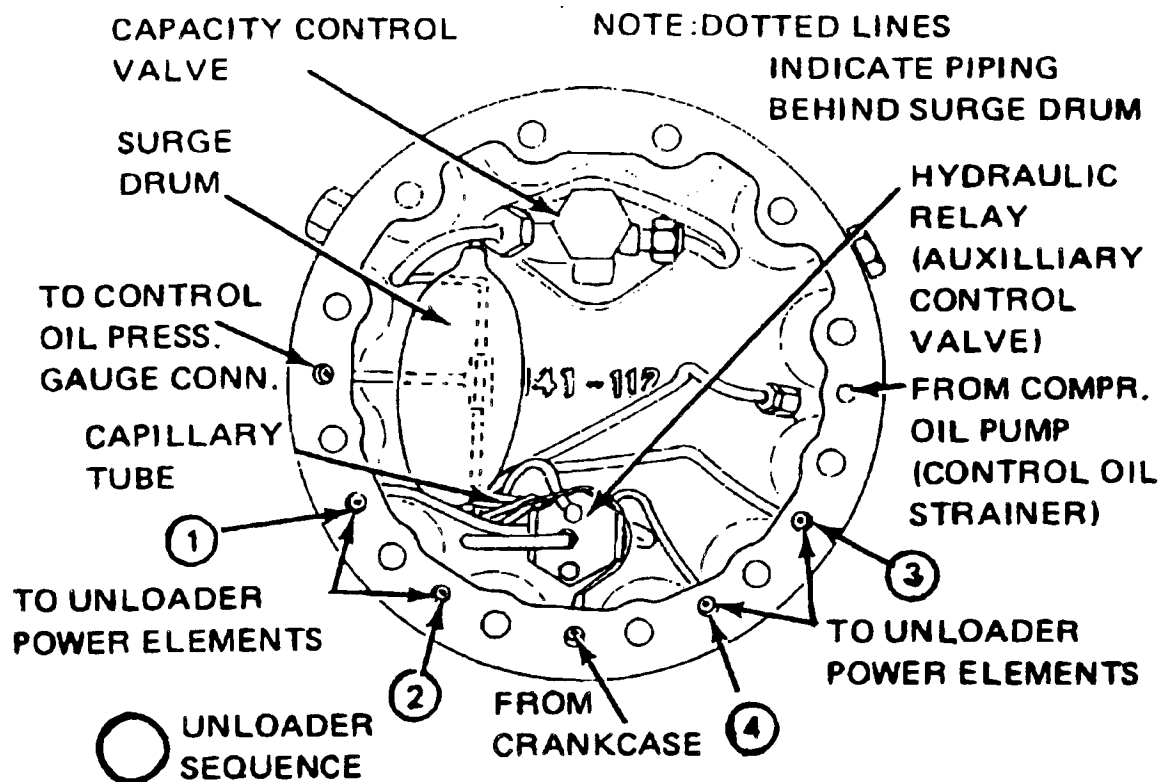


Figure 516-3-29. 5H Pump End Cover and Control Assembly (5H40, 5H46, 5H60, 5H66, 5H80, 5H86)

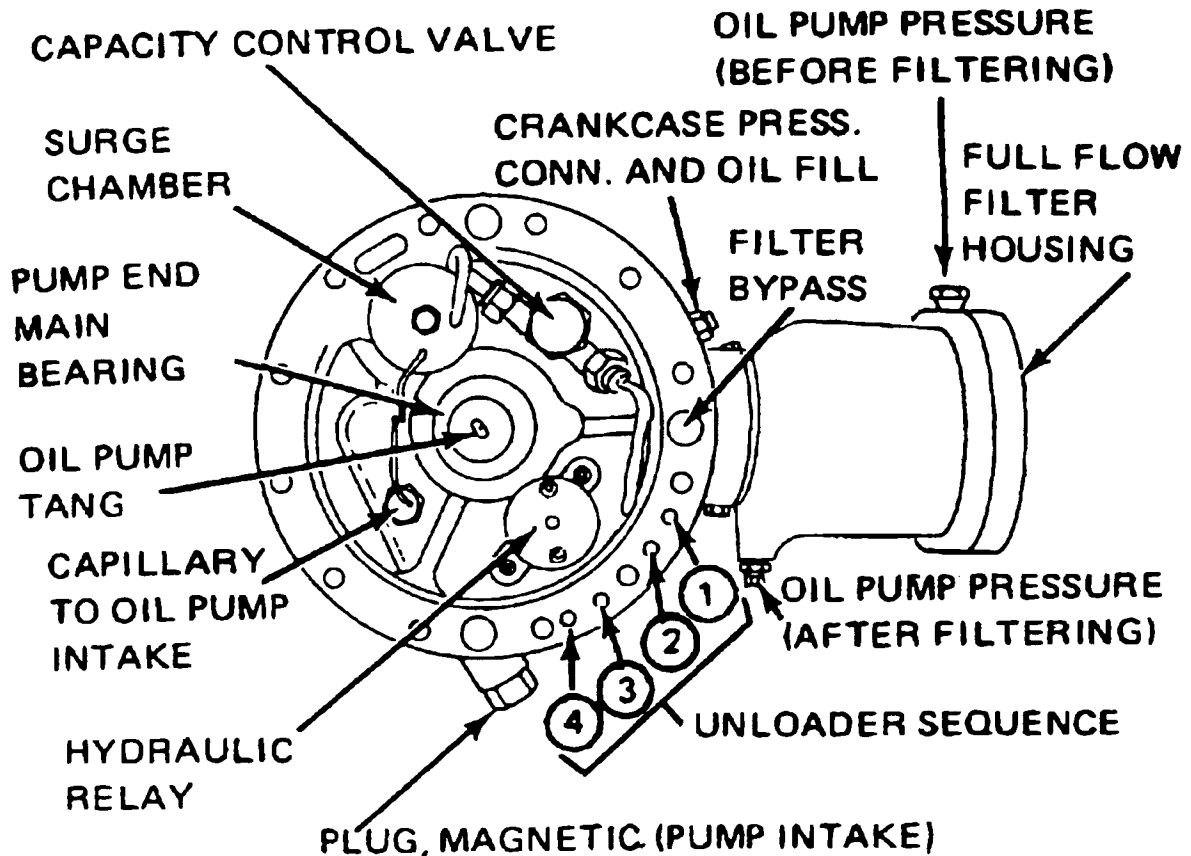


Figure 516-3-30. 5H120 and 5H126 Pump End Bearing Head

- e. Inspect control oil strainer. On 5F compressors the control strainer is on the side of the pump end bearing head (Figure 516-3-6). On 5H120 and 5H126 compressors the strainer is located on the pump end bearing head behind the control oil pressure gauge connection (Figure 516-3-7 and Figure 516-3-23) and in the pump end cover (Figure 516-3-29) on all other 5H compressors.

516-3.2.19 YORK COMPRESSOR CAPACITY CONTROLS. York uses different types of compressor capacity control in the various compressor series depending on when the compressor was introduced. In addition, several changes and improvements were made in their older series of compressors throughout the years. The R series compressors use solenoid valves and pressure switches that activate solenoid valves in sequence. The G series and the 2-5/8 by 2-1/4 series capacity controls are similar to each other but different than the R series type.

516-3.2.19.1 York R Series Capacity Controls. York capacity control for the R compressor (3-3/4 by 2-3/4) is actuated by means of high-pressure oil from the compressor oil pump. The system consists basically of several parts: solenoid valves, mounting plate for solenoid valves, unloader power elements, and pressure switches sensing suction pressure to actuate the solenoid valves. In this compressor, capacity control is obtained by loading or unloading one or more pairs of cylinders. Loading and unloading of cylinders follows a definite sequence (Figure 516-3-31).

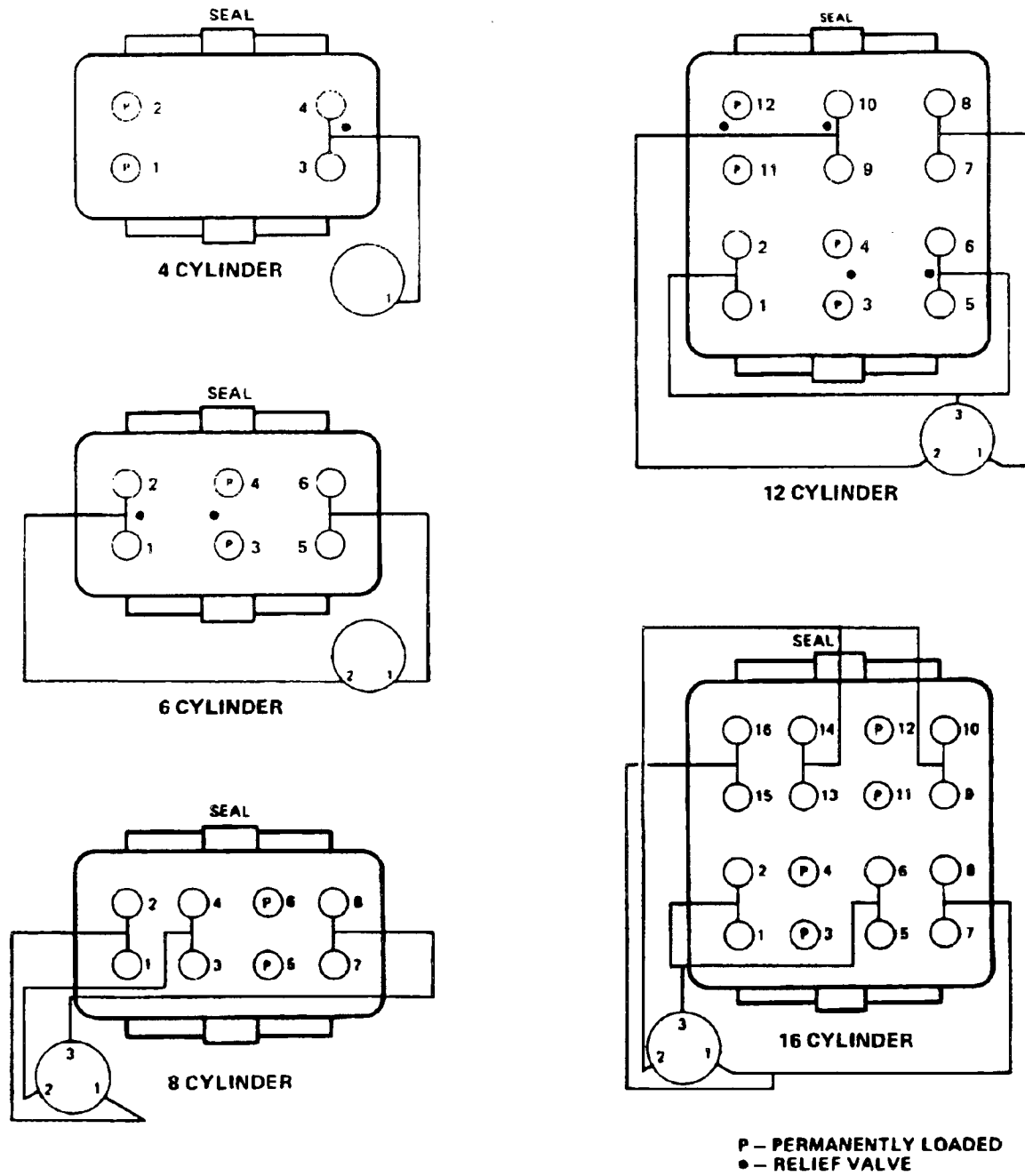


Figure 516-3-31. Solenoid Arrangement and Piping - York R Series

516-3.2.19.1.1 As the compressor comes up to speed and develops oil pressure, unloaded cylinders will be capable of loading in response to the solenoids. A time delay relay is usually included in the controller to ensure that the unloaded cylinders do not load until the motor has reached operating speed. While in operation ([Figure 516-3-32](#)), high-pressure oil from the compressor oil pump flows to the solenoid mounting plate where internal passages distribute it to the individual three-way capacity reduction solenoid valves. If the solenoid valves are not energized, the oil flows to unloader power elements. Unloader power elements are screwed into the compressor housing between the suction gas chamber and top heads. This element consists of a stationary piston and a movable cylinder. The movable cylinder engages a shoulder on the spring-loaded unloader ring that is free to move up and down on the cylinder sleeve. When oil pressure is admitted to the power element, the movable cylinder pushes the unloader sleeve down, allows lift pins to retract, and permits the suction valve to seat and operate normally. The cylinder is now pumping (or loaded).

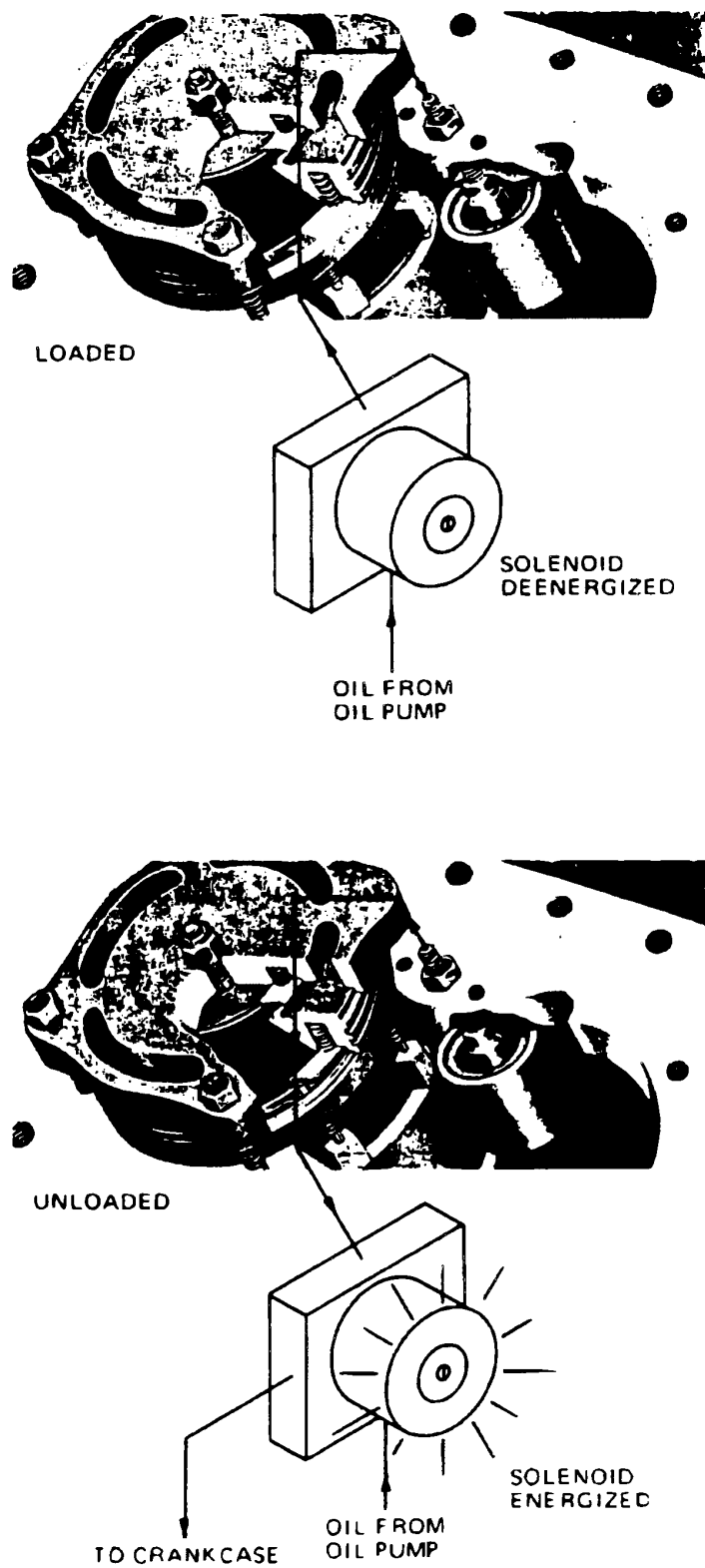
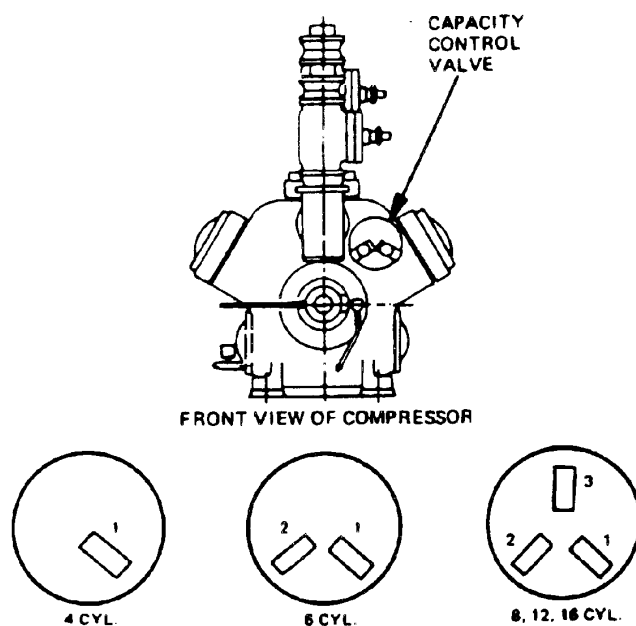


Figure 516-3-32. Solenoid Capacity Control - York R Series

516-3.2.19.1.2 If solenoid valves are energized, the oil pressure to the unloader power element is relieved and the oil flows back to the crankcase. Since there is no oil pressure to the unloader power element, the spring-loaded unloader rings move up, and by means of lift pins, raise the suction valve off its seat. In this position the cylinder is not pumping (is unloaded). The solenoid mounting plate is stamped 1, 2, and 3 adjacent to the solenoid valves ([Figure 516-3-33](#)).



No. Compr. Cyl.	No. Fully Loaded Compr. Cyl.	Min. % Full Load Cap.	Capacity Steps			
			1	2	3	4
			% Full Load Cap.	% Full Load Cap.	% Full Load Cap.	% Full Load Cap.
4	2	50	100	50		
6	2	33-1/3	100	66-2/3	33-1/3	
8	2	25	100	75	50	25
12	4	33-1/3	100	66-2/3	50	33-1/3
16	4	25	100	75	50	25

Figure 516-3-33. Arrangement of Solenoid Valves - York R Series

516-3.2.19.1.3 When wiring the compressor unit, wire capacity control solenoid valves so that solenoid no. 1 is deenergized first, solenoid no. 2 is deenergized second, and solenoid no. 3 is deenergized last. They will then be energized in the reverse order. This will ensure that compressor cylinders load and unload in the proper sequence. In this type of capacity control, the solenoid valve is replaceable.

516-3.2.19.2 York Capacity Control for the G Series (3-3/4 by 3) and 2-5/8 by 2-1/4 Series. Capacity controls for these two compressor series are of the same type. The original design of the capacity control mechanism included a capacity control valve and a separate capacity control regulating valve or power assembly. In later compressors the two controls were combined. Where the capacity control valve and regulating valve are separate, it is possible to manually control the capacity by adjusting a hand-operating stem on the control valve. Both the original and later arrangement of valves will be found on board various ships. Unloading cylinders for each type of compressor are shown in [Figure 516-3-34](#) and [Figure 516-3-35](#). The capacity control valve is located in one of the compressor crankcase cover plates. This valve is actuated by high-pressure oil from the oil pump and its function is to admit or relieve oil pressure to or from the individual mechanism, depending on suction (crankcase) pressure.

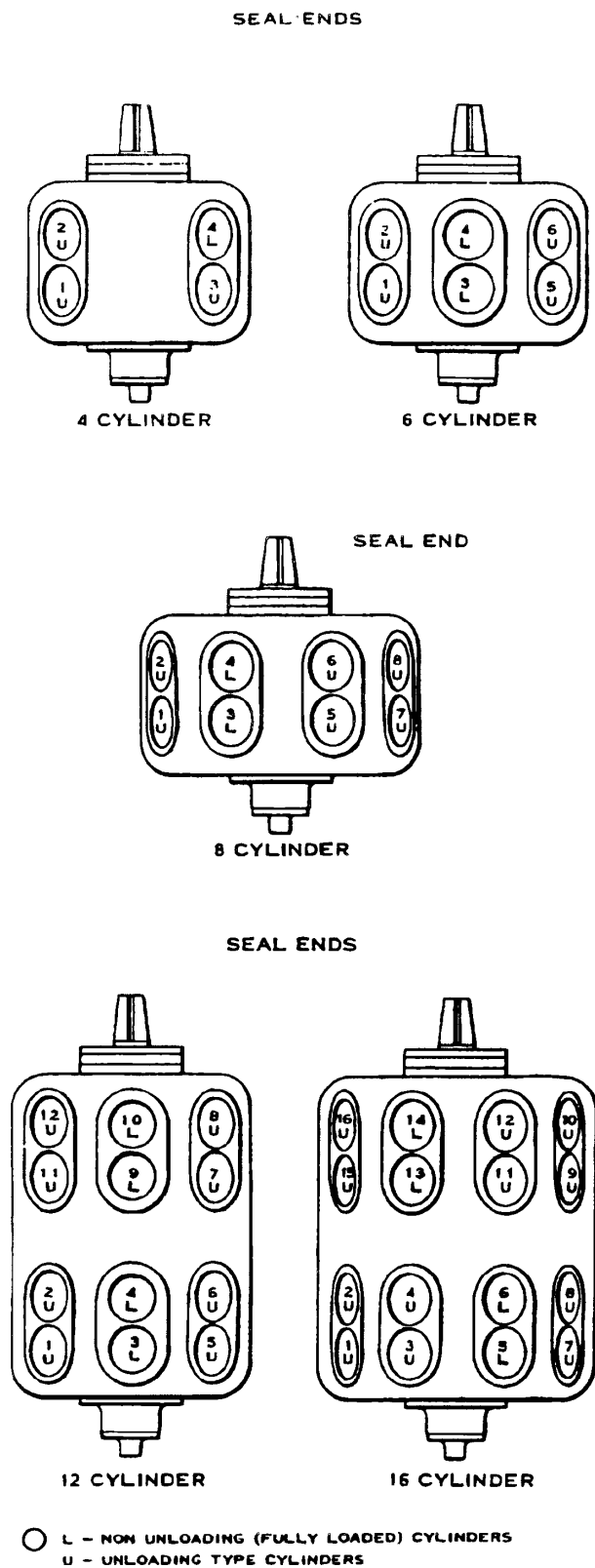


Figure 516-3-34. Loading and Unloading - York (3-3/4 by 3)

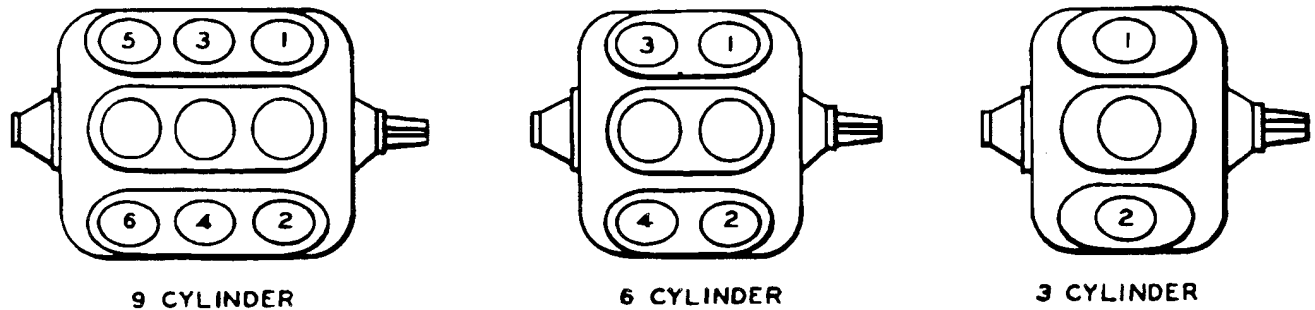
SEQUENCE OF LOADING: 1-2-3-4-5-6**SEQUENCE OF UNLOADING: 6-5-4-3-2-1****ROTATION OF COMPRESSOR: EITHER DIRECTION****SPEED RANGE: 900-1750 RPM****DRIVE: DIRECT OR BELT**

Figure 516-3-35. Unloading Sequence - York Series (2-5/8 by 2-1/4)

516-3.2.19.2.1 All piping between the capacity control valve and the individual unloader power elements is located within the compressor crankcase. The capacity control regulating valve is also located in the compressor crankcase cover plate. This valve is actuated by a change in balance between crankcase pressure on one side of the diaphragm, and the tension on the adjustable spring on the opposing side of the diaphragm. Increased crankcase pressure closes the valve and decreased crankcase pressure opens the valve. The function of this valve is to regulate the oil pressure that actuates the capacity control valve. The action of the regulating valve permits the capacity control valve to automatically load or unload the cylinder through an unloader power element as the crankcase (suction) pressure increases or decreases. Unloading is accomplished by lifting and holding the suction valve off its seat. The regulating valve has an adjusting screw to adjust spring pressure.

516-3.2.19.3 Automatic Operation-Separate Control and Regulating Valve. [Figure 516-3-36](#) illustrates capacity control system operation. When the compressor is at rest, all cylinders equipped with unloader power elements will be unloaded and will remain unloaded until the compressor is started and the oil pump discharge reaches normal operating pressure.

NOTE

The hand-operating stem of the capacity control valve is equipped with a graduated indicator collar ([Figure 516-3-36](#)). For automatic operation, BE SURE THIS STEM IS TURNED COUNTER- CLOCKWISE AS FAR AS IT WILL GO. In this position, the letter A stamped on the collar will line up with the groove cut into the capacity control valve body.

516-3.2.19.3.1 Refer to [Figure 516-3-36](#). If an R-12 system is being started under full-load conditions with the regulating valve adjusted to begin unloading at a crankcase (suction) pressure of 40 psig, the cylinders equipped with unloaders would remain unloaded until the oil pump discharge reaches normal operating pressure. Then high-pressure oil from the pump enters chamber A of the capacity control valve and passes through the orifice in the top of the piston into chamber B, forcing the piston to the end of its stroke against spring A. When the capac-

ity control valve piston is forced to the opposite end of its travel from that shown in [Figure 516-3-36](#), each of the circular grooves which form chamber A is put in communication with its respective unloader connection. This admits high-pressure oil to all unloaders, forcing movable cylinders of unloader power elements down and loading cylinders by permitting suction valves to seat and to operate normally.

516-3.2.19.3.2 During operation, the oil flow from chamber B to the crankcase is governed by the regulating valve. The actual position of the piston in the capacity control valve is determined by the oil pressure in chamber B, since the force exerted on top of the piston by oil pressure is essentially in balance with the force exerted by spring A, unless the piston is against the stop at either end of its travel. Exact balance between spring A and the oil pressure does not exist because of spring B, which pushes a ball against circular grooves in the outside surface of the capacity control valve piston, causing the piston to move with a stepped motion. This ensures that the piston will not shift position until there is a positive change in oil pressure within chamber B, preventing unnecessary cycling of the capacity control system. Spring B, with its steel ball, also locates the piston in the capacity control valve so that the connection to individual unloaders is either fully opened or fully closed. As the crankcase (suction) pressure pulls down slightly below the setting of the regulating valve, the regulator opens and relieves the oil pressure from chamber B to the crankcase. This permits spring A to push the capacity control valve piston one step toward chamber B, uncovering the unloader connection nearest the end of the valve and relieving the oil pressure to the power element. As the pressure to the power element is relieved, the power element spring forces the movable cylinder and unloader sleeve up, raising the suction valve off its seat by means of lift pins as shown in [Figure 516-3-36](#) or [Figure 516-3-37](#).

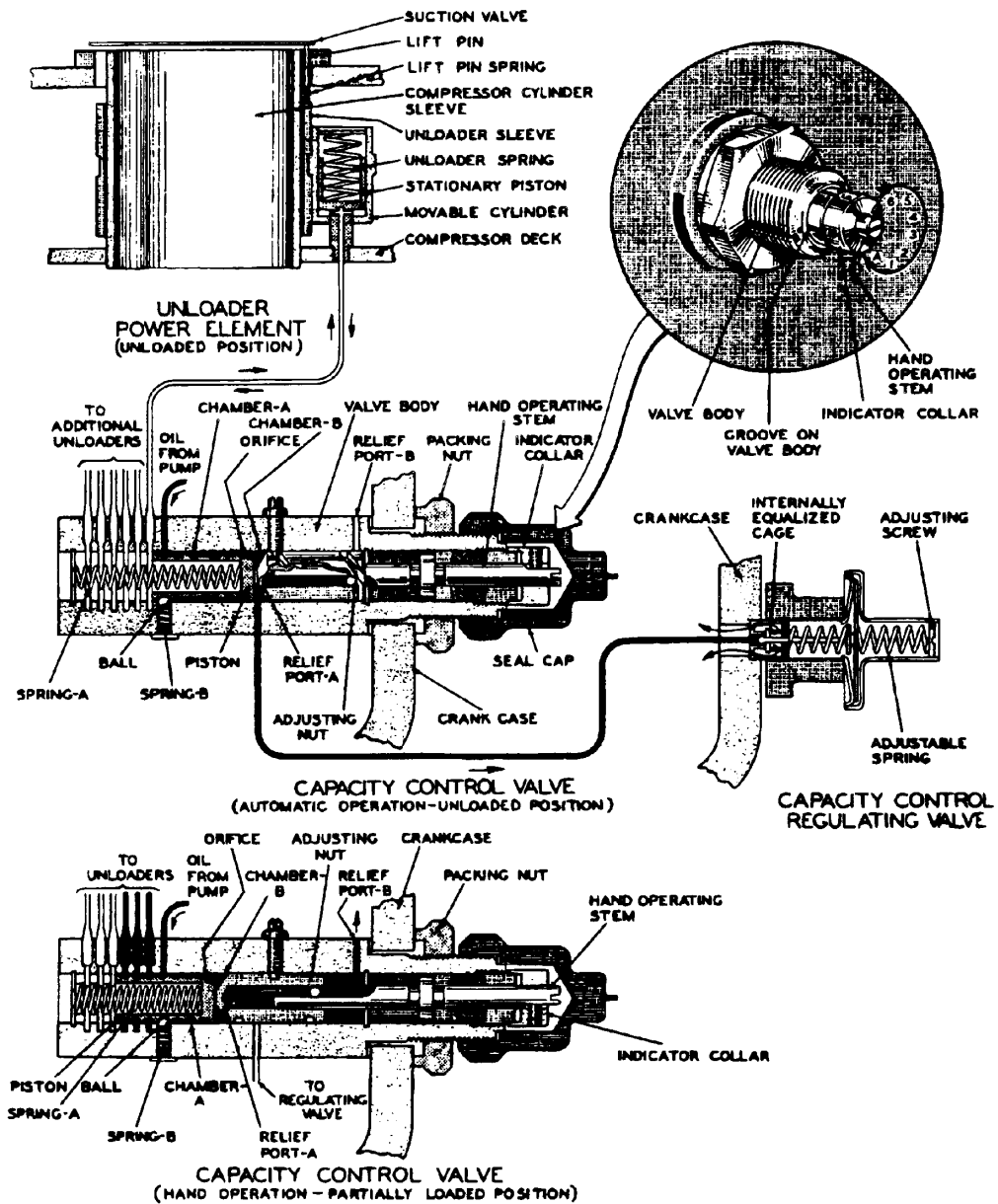


Figure 516-3-36. Capacity Control Operation with Moveable Cylinder - York

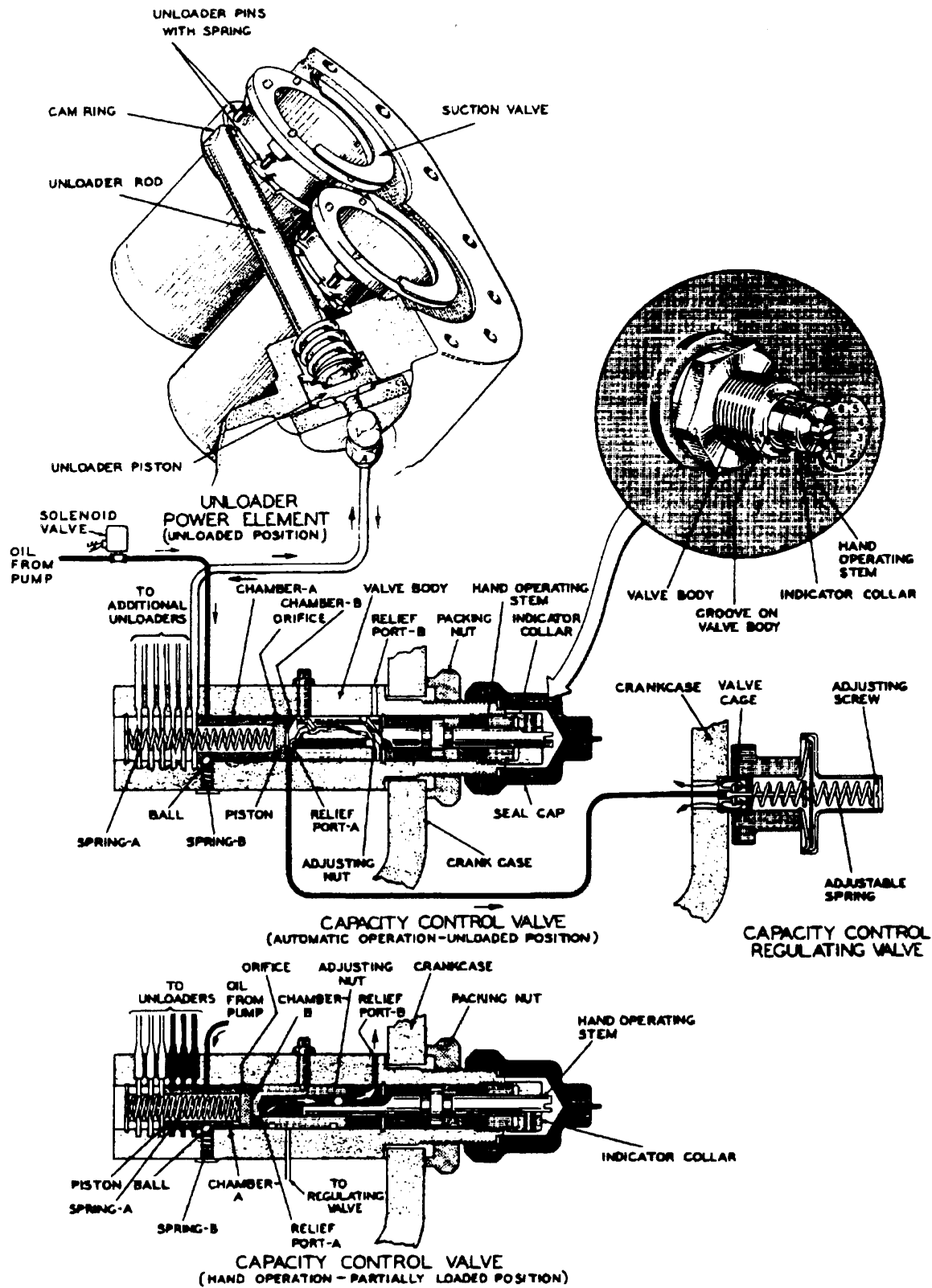


Figure 516-3-37. Capacity Control Operation with Cam Ring - York

516-3.2.19.3.3 The unloader rod rotates the cam ring to raise the lift pins. If the suction pressure continues to fall, the regulator will relieve more oil pressure from chamber B to the crankcase. The piston in the capacity control valve will continue to move, one step at a time, toward chamber B until all cylinders equipped with power elements are unloaded. If the cooling load increases and suction pressure rises, the regulating valve will close, permitting oil pressure to build up in chamber B, reloading cylinders, one at a time, in accordance with load requirements. [Figure 516-3-34](#) and [Figure 516-3-35](#) show the sequence of cylinder loading and unloading.

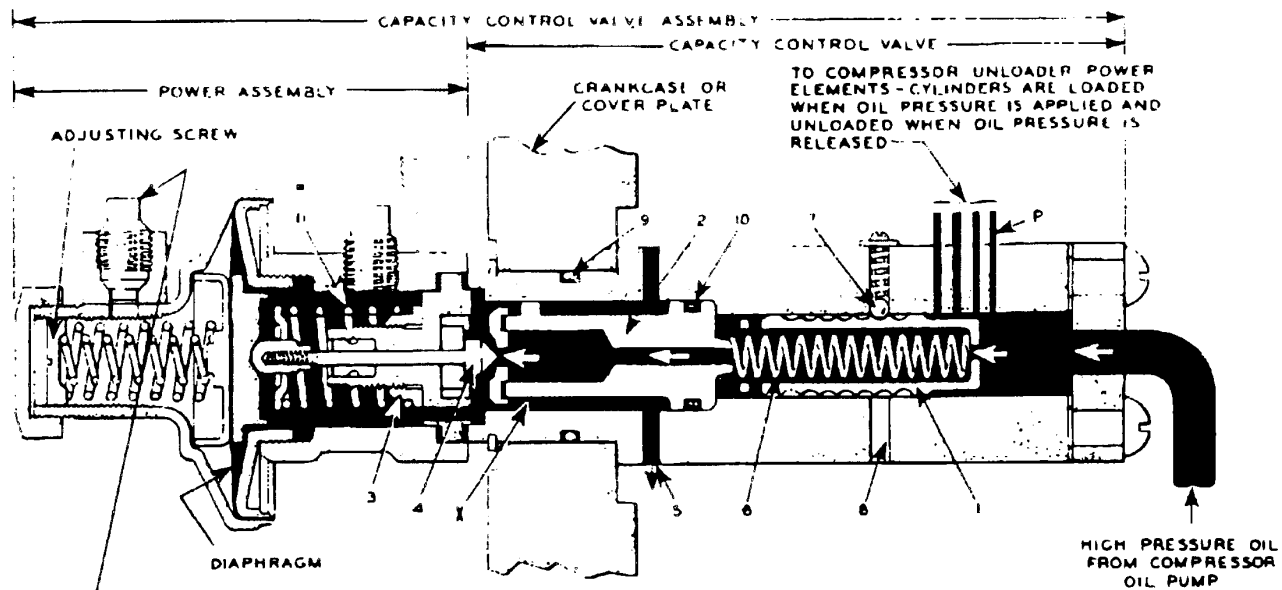
516-3.2.19.4 Manual Operation. For hand control, the capacity control valve piston can be positively located at any desired position by turning the hand-operating stem, which repositions the threaded adjusting nut within the capacity control valve (insets - [Figure 516-3-36](#) and [Figure 516-3-37](#)). The position of the capacity control valve piston is indicated by lining up the numbered marks on the indicator collar with the groove on the valve body. When the A is lined up with the groove, the stem is turned counterclockwise as far as it will go. Turning the stem clockwise to position one moves the piston so that chamber A communicates with and loads the power elements in sequence, until the hand operating stem is turned clockwise, approximately one complete turn to load all cylinders equipped with power elements. When the hand-operating stem is turned to any one of the numbered positions, the regulating valve is inoperative (inset - [Figure 516-3-36](#)). When the stem is turned clockwise, the threaded adjusting nut moves to compress spring A. This uncovers relief port B in the top side of the capacity control valve and permits oil from chamber B, which would flow to the regulating valve during automatic operation, to flow directly to the crankcase through relief ports A and B.

NOTE

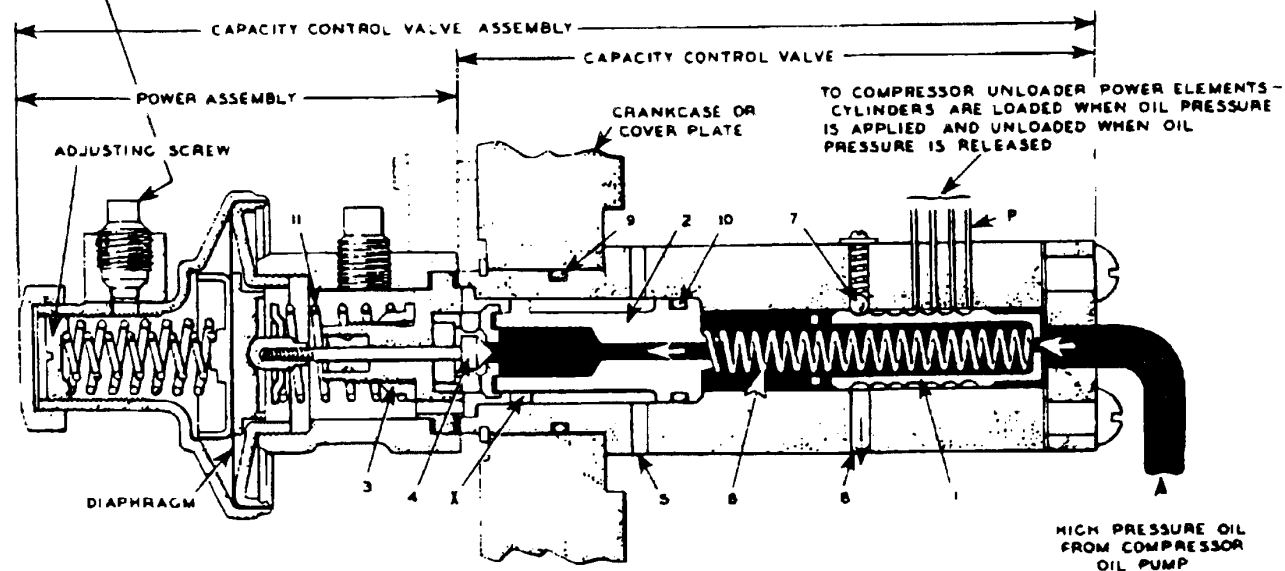
The seal cap of the capacity control valve is equipped with a screwdriver fitting for turning the slotted hand-operating stem.

516-3.2.19.5 Adjustment of Capacity Control. Refer to paragraph [516-3.2.18.5](#).

516-3.2.19.6 Automatic Operation - Combined Control and Regulator Valve. The compressor capacity control system is actuated by means of high-pressure oil from the compressor oil pump as shown in [Figure 516-3-38](#). Oil pressure to the power element loads associated cylinders and release of this pressure unloads them. All piping between the capacity control valve and individual power elements is loaded inside the crankcase.



Detail A - Control Valve - Loaded Position



Detail B - Control Valve - Unloaded Position

LEGEND

1. Plunger	6. Spring
2. Bushing	7. Spring Loaded Ball(s)
3. Power Assembly Cage	8. Oil Relief Port
4. Power Assembly Cage Valve	9. O-Ring
5. Crankcase equalizing and oil return port	10. O-Ring
	11. Power Assembly Cage Spring

Figure 516-3-38. Capacity Control Valve Operation - York

516-3.2.19.7 Capacity Control Operation. Refer to [Figure 516-3-38](#). High-pressure oil from the compressor oil pump enters the capacity control valve and exerts pressure on the bottom of the plunger (1). At the same time a portion of this oil passes through the hole in the plunger bottom, filling the plunger travel space and the hole in the bushing (2). The end of this bushing is gasketed to the bottom of the power assembly cage (3), in which is located a valve (4). This valve is direct-acting. The valve (4), when open, permits oil to return to the crankcase through the opening X in the flange of the bushing (2), the concentric space surrounding this bushing, and the drain hole (5) (detail A - [Figure 516-3-38](#)). The movement of the plunger (1) against the tension of the spring (6) is affected and controlled by two factors as follows:

- a. The amount of oil being bypassed to the crankcase through the power assembly cage valve (4). This establishes a varying differential pressure on the bottom of the plunger. When the valve (4) moves in an opening direction, the pressure on the spring side of the plunger is reduced to the point where the plunger is moved against spring tension toward the outside of the crankcase (detail A - [Figure 516-3-38](#)). This uncovers one or more of the control valve oil ports (P), permitting high-pressure oil to flow to one or more cylinder unloaded power elements. Oil pressure to these elements causes the associated cylinder or cylinders to LOAD. When the valve (4) moves in a closing direction, the pressure differential on the plunger decreases. With this valve fully closed, the pressure on both sides of the plunger becomes equalized and the plunger is moved toward the inside of the crankcase by the spring (6) (detail B - [Figure 516-3-38](#)). This causes oil pressure to unloader power elements to be relieved and the associated cylinder or cylinders to be UNLOADED.
- b. The positioning effect of the two spring loaded balls (7) on the plunger (only one of these balls is shown in the illustrations). These balls engage the grooves on the outer surface of the plunger, causing it to move with a stepped motion and to move only when a definite change in oil pressure differential has been established. They also position the plunger in relation to unloader oil ports (P), permitting high-pressure oil to enter, or reduced pressure oil to leave these ports one at a time. The capacity control valve may assume any of four loading or unloading positions, depending on suction (crankcase) pressure.

516-3.2.19.8 Loading And Unloading. The function of loading and unloading is as follows:

- a. When the plunger is moved against the compression of the spring (6) toward the outside of the crankcase (detail A - [Figure 516-3-38](#)), unloader oil ports (P) are progressively uncovered, one at a time, permitting the passage of high-pressure oil from the compressor oil pump through individual feed lines to cylinder unloader power elements. This causes the controlled cylinder or cylinders to LOAD, or to operate at full pumping capacity.
- b. When the plunger is moved by the spring (6) toward the inside of the crankcase (detail B - [Figure 516-3-38](#)), unloader oil ports (P) are uncovered, one at a time, in reverse order to the space formed by the plunger bore and grooves on the plunger. High-pressure oil from the compressor unloader power element or elements relieves into this space and is returned to the crankcase through the oil relief port (8), causing the associated cylinder or cylinders to UNLOAD.
- c. Since plunger movement depends on compressor oil pressure, the compressor will always start unloaded and cannot be loaded until oil pressure has built up.

516-3.2.19.9 Power Assemblies - Suction Pressure Controlled Power Assembly (Details A and B - [Figure 516-3-38](#)). This unit is operated by the combined action of suction (crankcase) pressure against the inner side of the diaphragm and atmospheric pressure plus the pressure of the adjusting spring on the outside of the diaphragm. The power assembly cage (3) is the internally equalized type, and is provided with the type of valve (4) that moves in an OPENING direction to LOAD cylinders when the diaphragm moves outwardly with an INCREASE in suction (crankcase) pressure, and in a CLOSING direction to UNLOAD cylinders when the diaphragm moves

inwardly with a **DECREASE IN THIS PRESSURE**. Adjustment requires turning the adjusting screw to decrease the tension of the spring on the outer side of the diaphragm, causing the compressor to begin to unload/load at a lower suction pressure (Figure 516-3-38). By means of the power assembly, the number of compressor cylinders pumping at full capacity is proportioned to and regulated by the amount of work to be done by the compressor. At lower suction pressure, the compressor capacity is reduced (compressor is unloaded). As the suction pressure increases, the compressor pumping capacity or loading is increased.

516-3.2.19.10 Repairing Capacity Control Valves - York. In repairing or replacing these valves, proceed as follows:

- a. Capacity Control Valve. If the capacity control valve fails to function, the complete assembly will be furnished as a replacement part. The valve may be replaced (Figure 516-3-37 and Figure 516-3-39), as follows:

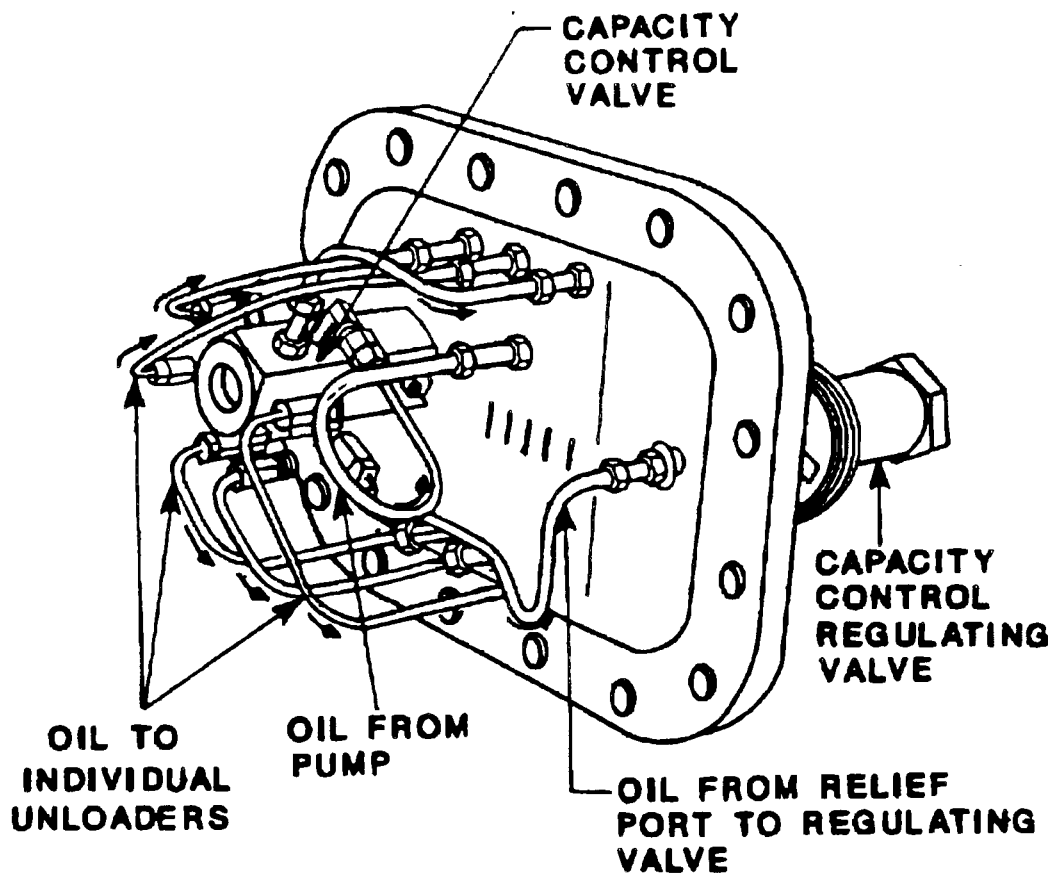


Figure 516-3-39. Inside View - York Cover Plate

- 1 Pump down the compressor and drain the oil from the crankcase.
- 2 Disconnect external oil lines from the cover plate where the capacity control valve is installed.
- 3 Remove the cover plate complete with control valve, regulating valve, and internal oil piping.
- 4 Disconnect the internal oil piping from the capacity control valve.
- 5 Remove the seal cap and the locknut that secures the valve body in the coverplate.
- 6 Pull the valve out of the cover plate.

- 7 Clean the replacement valve assembly with an approved cleaning solvent and install the valve following the preceding steps in reverse.

NOTE

Check the technical manual for the correct capacity control valve to order, as two sizes are used depending on the number of compressor cylinders. When installing a new valve, plug unloader connections that are not used.

- b. Regulating Valve. If the capacity control regulating valve fails, the valve cage may be replaced. To replace the cage proceed as follows:
 - 1 Pump down the compressor and drain the oil below the valve level.
 - 2 Remove screws that secure the valve body to the cover plate and lift the valve out of the cover.
 - 3 Install new cage and assemble the valve, with gasket, into the cover plate.
- c. Combination Control and Regulating Valve. The capacity control assembly for 3-3/4 by 3 and 2-5/8 by 2-1/4 compressors is not interchangeable due to differences in internal parts. If replacement parts other than the power assembly are necessary, replace the entire control valve. The power assembly is replaceable separately. To remove the combination control valve proceed as follows:
 - 1 To remove the regulating valve, see paragraph [516-3.2.19.10.b](#).
 - 2 To remove the capacity control valve, drain the oil from the compressor crankcase.
 - 3 Remove the hand-access hole cover that is on the lower, opposite side of the compressor and directly in line with the hole cover that has the pressure-regulating valve mounted on the outside.
 - 4 Reach inside the crankcase and disconnect the piping from the capacity control valve.
 - 5 Using spring-washer pliers, remove the retaining ring that secures the capacity control valve to the hole cover. Reach inside the crankcase and withdraw the capacity control valve with its O-ring, into and out of the crankcase.

516-3.2.19.11 Reinstallation Capacity Control Valve - York. To install the capacity control valve, proceed as follows:

1. Thoroughly clean the replacement assembly to remove any protective coating and coat with a light film of clean compressor oil.
2. Install a new O-ring in its groove on the outside of the capacity control valve. Using care so as not to damage the O-ring, install the capacity control valve from inside the crankcase. See that it is squarely and firmly seated in the cover plate.
3. Using spring-washer pliers, install the retaining ring. Make sure that the ring is properly seated.
4. From inside the crankcase, connect the piping.
5. Using a new gasket, install the hand-access hole cover.
6. Fill the compressor crankcase with clean oil.
7. Evacuate the compressor.

516-3.2.19.12 Checking and Adjusting Compressor Capacity Control Valve. Following system installation or corrective maintenance, check, and adjust, if necessary, the setting of the compressor capacity control valve. This should be accomplished after the temperature pulldown period. During the pulldown, back out the adjusting

screw the whole way to allow full compressor capacity during pulldown. The checking procedure is necessary to ensure that the system will produce rated capacity before compressor unloading begins, and that the compressor will operate under stable system loads at each step of the unloading before it is stopped by the low-pressure refrigerant control switch. Determine the control point required for the capacity control valve. The control point is defined as the compressor suction pressure at which the first step of compressor unloading occurs and is proportional to, but not equal to, the minimum evaporator suction pressure required for the application. It should be selected so that the last step of unloading occurs when the minimum suction pressure is reached in the evaporator. A decrease in compressor suction pressure of 3 to 4 psi is required to cycle the capacity control valve from the first to the last step of unloading. A suction pressure drop of at least 1 psi should be allowed between the evaporator and compressor. Hence, the control point should be no more than 2 to 3 psi above the minimum evaporator suction pressure. Adjust the capacity control valve to the control point with the compressor running under load as follows:

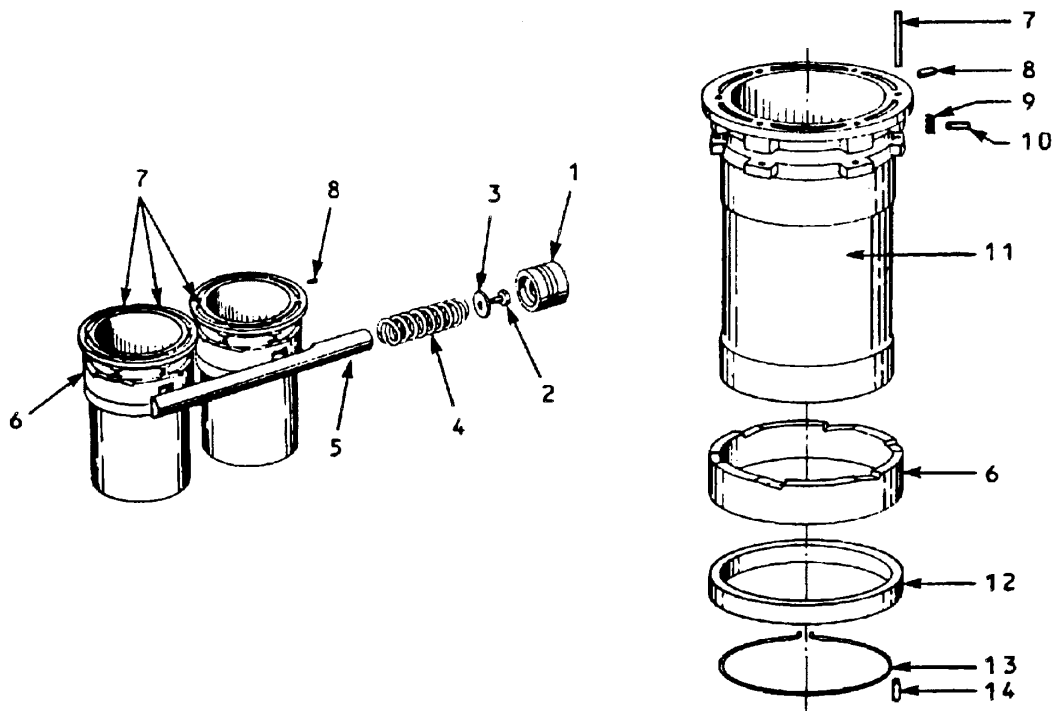
1. Verify that the compressor suction valve is opened.
2. Expose the adjusting screw on the capacity control valve (see [Figure 516-3-38](#) and turn it fully counterclockwise (relieving spring tension) to obtain a suction pressure at least 4 psi higher than the control point.
3. Reduce the compressor suction pressure to the control point by slowly closing the compressor suction shutoff valve.
4. Turn the capacity control valve adjusting screw clockwise while maintaining the suction pressure at the control point until the first cylinder unloads. Unloading can be detected by a slight but definite change in audible compressor noise followed by a slight and often temporary increase in suction pressure.
5. Check the adjustment by slowly reopening and slowly reclosing the compressor suction shutoff valve while simultaneously observing the suction pressure and listening for unloading occurring at the control point.
6. Repeat steps 3 through 5 above until it is certain that the first cylinder unloads at the control point.
7. The capacity control valve is now set for optimum performance. Slowly reopen the compressor suction shutoff valve for normal system operation.

516-3.2.19.13 Unloader Power Element - York. The unloader power element found in these two series of compressors may be of two types as follows:

- a. [Figure 516-3-36](#) shows one of the unloader power elements. Unloader power elements are screwed into the compressor deck between the suction gas chamber and the crankcase. This element consists of a stationary piston and a movable cylinder. The movable cylinder engages the unloader sleeve, which is free to move up or down on the cylinder sleeve. When oil pressure is admitted to the power element, the movable cylinder pushes the unloader sleeve down and permits the suction valve to operate normally. When oil pressure to the power element is relieved through the capacity control valve, the spring-loaded cylinder moves the unloader sleeve up, raising the suction valve off its seat by means of lift pins. In this position the cylinder is completely unloaded.
- b. [Figure 516-3-37](#) shows the other arrangement of the unloader power element. The unloader mechanisms (power elements) are located in the end of the compressor, one at each bank of unloaded cylinders. Each element consists of a rotating cam ring and unloader rod actuated by means of an oil-pressure-operated unloader piston and a spring. The rotating cam ring operates unloader pins that lift the suction valves off their seats to unload a bank of two cylinders. When oil pressure is admitted to the unloader piston, the unloader rod moves the cam rings to lower the suction valves and load the cylinders. When oil pressure is removed from the unloader piston, the spring returns the rod and moves the cam ring to lift the suction valves off their seats and unload one bank of cylinders. A normally closed solenoid valve is installed in the oil supply line from the

compressor oil pump to the capacity control valve (Figure 516-3-36). This valve is wired into the compressor control circuit through a time relay to ensure that all cylinders equipped with unloaders remain unloaded for approximately 3 minutes after the compressor is started.

516-3.2.19.14 Repair or Inspection of the Unloader Power Assembly. To remove the unloader power element (Figure 516-3-36), remove the discharge valve assembly, cylinder sleeve, and unloader sleeve. (See paragraph 516-3.2.23.4.) Figure 516-3-40 details the other unloader power assembly. The cylinder sleeve (11) in this arrangement is fitted with a loose fit so that it may be removed in the field. Each unloader cylinder sleeve is locked to the housing with a pin (8) to keep it from rotating out of position. To remove these sleeves, first unbolt the unloader piston plate and remove carefully, so that the unloader piston, under tension from the spring, does not fly out. Ease out the sleeve, taking careful notice of the position of the slot in the cam ring in relation to the retaining pin (8) that locks the sleeve to the housing. If this slot is out of position when the unloader is reassembled, the lug on the unloader rod will not coincide with the slot in the cam ring. Mark this position as each sleeve is removed to ensure proper reassembly. Before replacing the unloader piston cover, push on the unloader piston with the hand and observe both cylinders to see that the loader mechanism is working properly. Unloaders are designated as either right- or left-hand (RH or LH stamped on cam ring). All parts of the unloader device are interchangeable except for the cam rings, which have cams sloped in opposite directions. The designation is determined by the position of the unloader rod in respect to cylinders, when looking from the end of the compressor facing the unloader piston. When unloaders are to the left of the cylinder, they are designated as left hand. Those with unloaders to the right are designated as right hand. The only difference between the left- and right-hand (LH and RH) sleeve assemblies is the cam ring (6). It is important, however, when converting a LH to a RH or a RH to a LH, that lift pins be rotated 180 degrees so that beveled ends will make full contact with the cam ring. Only make this conversion in an emergency, if the proper sleeves are not immediately available.



Ref.	Item	York Part No.	Navy Stock No.
1	Unloader Piston	64-357 PK	H66YOR20619
2	Hex Head Cap Screw	21-1468P	H43S4161-80
3	Push Rod Washer	64-356PK	H43W7576-2220
4	Unloader Device Spring	29-3933PK	H66YOR20618
5	Push Rod Assembly	64-353SL	H66YOR20624
6	Cam Ring (Left Hand)	64-346PL	H66YOR20584
6	Cam Ring (Right Hand)	640346PL	H66YOR20628
7	Lift Pin	64-350PK	H66YOR20587
8	Locating Pin	229-3991P	H66YOR20666
9	Lift Pin Spring	29-4021PK	H66YOR20667
10	Roll Pin	29-4551P	
11	Cylinder Sleeve, Bare	29-4184PM	H66YOR20668
12	Cam Ring Support Ring	64-348PL	H66YOR20589
13	Retaining Ring	64-349PK	H66YOR20588
14	Locking Pin	29-3990P	
6-14	Cylinder Sleeve, RH complete	64-345SL	H66YOR20622

Figure 516-3-40. Unloader Power Assembly

516-3.2.20 COMPRESSOR SERVICE, MAINTENANCE, AND REPAIR. The following sections will be dedicated to repair, replacement, maintenance, and inspection procedures for other various compressor plants.

516-3.2.21 PRESSURE RELIEF VALVE. Compressors, both Carrier and York, have safety relief valves to protect them from excessive pressure. Pressure relief valves relieve refrigerant pressure from high to low side in the event that the compressor discharge shutoff valve is inadvertently closed. The setting and number of these relief valves vary in accordance with manufacturers' standard commercial practice. Relief valves may be set as high as 350" 35 psig since compressors are used for both R-12 and R-22. Check relief valves for evidence of leaking whenever the compressor is disassembled. Change the relief valve if defective or if the valve has ever opened due to excessive pressure. The location of relief valves in different compressors varies. Some valves are screwed into the crankcase and project through the valve plate. Other valves are located on the suction and discharge manifold cover, while other compressors are equipped with external relief valves mounted on a bypass line between the suction shutoff valve and discharge manifold. Refer to the technical manual for a particular compressor and the relief valve setting supplied by the manufacturer.

516-3.2.22 CARRIER COMPRESSOR SERVICE. Disassemble the compressor to service or check compressor parts such as crankshaft, bearings, connecting rod, and piston. [Figure 516-3-41](#) shows a 5H compressor disassembled and typical internal parts. Before a compressor is opened, remove the refrigerant from the compressor by the pump-down method. To open, proceed as follows:

1. Start the compressor, close the suction service valve, and reduce the crankcase pressure to 2 psig (bypass the low-pressure switch if necessary).
2. Stop the compressor and isolate from the system by closing the discharge service valve.
3. Recover any residual refrigerant. Drain oil if necessary.
4. After disassembly, clean all parts with an approved solvent.
5. Before assembly, coat all parts with clean compressor oil, and clean and inspect all gasket surfaces. Replace all gaskets with new factory-made gaskets. Coat gasket surfaces with oil. See [Table 516-3-3](#) for torque values for various bolts and capscrews.

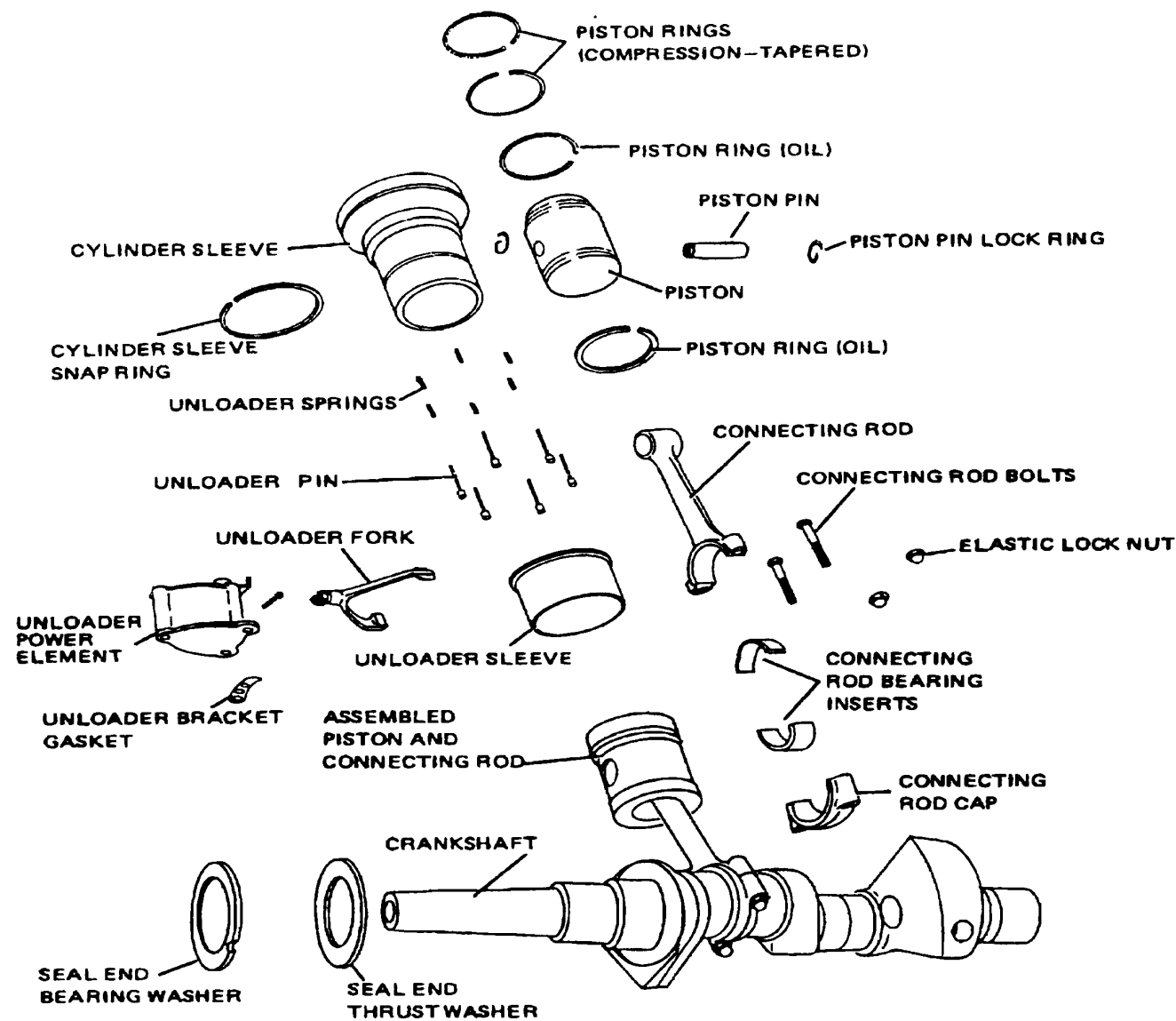


Figure 516-3-41. Internal 5H Compressor Components (Typical) - Carrier

Table 516-3-3. TORQUE VALUES - CARRIER COMPRESSORS

SF Units			
Size Dia. (inch)	Threads Per Inch	Torque Range (lb-ft)	Usage
1/4	Pipe	20-25	Pipe Plug - Pump End Bearing Head
		20-25	Pipe Plug - Crankshaft
		20-5	Pipe Plug - Suction and Discharge Manifold Cover

Table 516-3-3. TORQUE VALUES - CARRIER COMPRESSORS -

Continued

SF Units			
Size Dia. (inch)	Threads Per Inch	Torque Range (lb-ft)	Usage
1/4	28 NF	10-15	Unloader Power Element Assembly - Crankcase
		10-15	Unloader Cylinder Cover Plate - Unloader Cylinder Bracket
		12-15	Discharge Valve Capscrew - Inner Seat
		12-15	Discharge Valve Guide Assembly - Valve Plate
		12-15	Oil Pump Cover - Pump End Bearing Head
		10-12	Auxiliary Control Valve Cover - Valve Body
5/16	24 NF	22-25	Connecting Rod Bolt - Locknut
		15-20	Capacity Control Valve - Hand Hole Cover
3/8	Pipe	30-35	Pipe Plug - Pump End Bearing Head
3/8	16 NC	25-29	Cylinder Head - Crankcase
		25-29	Shaft Seal Cover Plate - Crankcase
		25-29	Bottom Plate - Crankcase
		25-29	Suction and Discharge Manifold Cover - Crankcase
		25-29	Pump End Bearing Head Assembly - Crankcase
		25-29	Hand Hole Cover - Crankcase
3/8	24 NF	30-35	Suction Manifold - Crankcase
		30-35	Flywheel Screw - Crankshaft
7/16	20 NF	25-30	Oil Return Check Valve Assembly - Crankcase
1/2	13 NC	80-85	Suction Service Valve - Crankcase
		80-85	Discharge Service Valve - Crankcase
5/8	11 NC	120-130	Suction Service Valve - Suction Manifold
5/8	18 NC	60-75	Magnetic Plug - Crankcase
		60-75	Magnetic Plug - Pump End Bearing Head
		60-75	Oil Bypass Plug - Pump End Bearing Head
		60-75	Modulating Valve Adapter - Pump End Bearing Head
		60-75	Lockscrew - Pump End Bearing Head
		45-55	Oil Relief Valve Assembly - Crankcase
3/4	10 NC	60-75	Cap-Oil Relief Valve Assembly
		45-50	Flywheel Locknut - Crankshaft
1-1/2	18 NEF	34-45	Sight Glass Clamping Gland - Hand Hole Cover
No. 6	32	8-10	Auxiliary Control Valve Cover - Valve Body
5H Units			
1/16	Pipe	10-15	Pipe Plug - Auxiliary Control Valve Body
1/8	Pipe	15-20	Pipe Plug - Pump End Bearing Head
1/4	Pipe	20-25	Pipe Plug - Crankcase
		20-25	Pipe Plug - Pump End Cover
		20-25	Pipe Plug - Crankshaft
1/4	28 NF	12-16	Oil Pump Cover - Pump End Bearing Head
		8-12	Auxiliary Control Valve Cover - Valve Body
		8-12	Special Capscrew - Auxiliary Control Valve Body

Table 516-3-3. TORQUE VALUES - CARRIER COMPRESSORS -

Continued

SF Units			
Size Dia. (inch)	Threads Per Inch	Torque Range (lb-ft)	Usage
5/16	24 NF	18-22	Unloader Power Element - Crankcase
		18-22	Capacity Control Valve - Pump End Cover
		18-22	Discharge Valve Guide Assembly - Valve Plate
		18-22	Discharge Valve Guide - Inner Seat
		18-22	Cylinder Bracket
3/8	Pipe	30-35	Pipe Plug - Pump End Bearing Head
		30-35	Pipe Plug - Crankshaft
3/8	16 NC	25-29	Capillary Tube Assembly - Pump End Bearing Head
		28	Connecting Rod Bolt (Alum. Rod)
7/16	14 NC	35-60	Suction and Discharge Manifold Cover - Crankcase
		55-60	Discharge Manifold - Cylinder Heads
		55-60	Valve Plate - Crankcase
		55-60	Cylinder Head - Crankcase
		53-60	Hand Hole Cover - Crankcase
		55-60	Pump End Cover and Pump End Bearing Head - Crankcase
7/16	20 NF	40-45	Connecting Rod Bolt - Locknut*
1/2	Pipe	35-40	Pipe Plug - Crankcase
		35-40	Pipe Plug - Pump End Bearing Head
		30-35	Pressure Relief Valve - Suction and Discharge Manifold Cover
		30-35	Pressure Relief Valve - Crankcase
1/2	13NC	80-90	Suction and Discharge Manifold - Crankcase
		80-90	Suction Manifold Cover - Crankcase
5/8	11 NC	140-150	Suction Manifold Cover and Suction Manifold - Crankcase
5/8	18 NF	60-75	Magnetic Plug - Pump End Bearing Head
		60-75	Modulating Valve Adapter - Crankcase
		60-75	Oil Bypass Plug - Crankcase
		60-75	Oil Bypass Plug - Pump End Bearing Head
		60-75	Oil Bypass Plug - Pump End Cover
		80-90	Hollow Lockscrew - Pump End Cover and Center Main Bearing Housing
		45-55	
		80-90	Oil Pressure Relief Valve - Crankcase
7/8	14 NF	60-75	Cap-Oil Pressure Relief Valve Assembly
		55-65	Seal Plug - Pump End Bearing Head
3/4	Pipe	45-50	Oil Pressure Relief Valve - Crankcase
		45-50	Pipe Plug - Crankcase
1	Pipe	50-55	Pipe Plug - Crankcase
1-1/2	18 NEF	35-45	Sight Glass Clamping Gland - Hand Hold Cover
No. 6	32	8-10	Auxiliary Control Valve Cover - Valve Body
NC - National Coarse NEF - National Extra Fine NF - National Fine * Steel Rod.			

6. After reassembly, evacuate the compressor and open suction and discharge valves. Add oil if necessary, restart compressor, and adjust refrigerant charge.

516-3.2.22.1 Cylinder Head Inspection. Remove cylinder heads. Check heads for warping, cracks, and damage to gasket surfaces.

516-3.2.22.2 Compressor Valve Inspection. Suction and discharge valve assemblies are shown in [Figure 516-3-42](#).

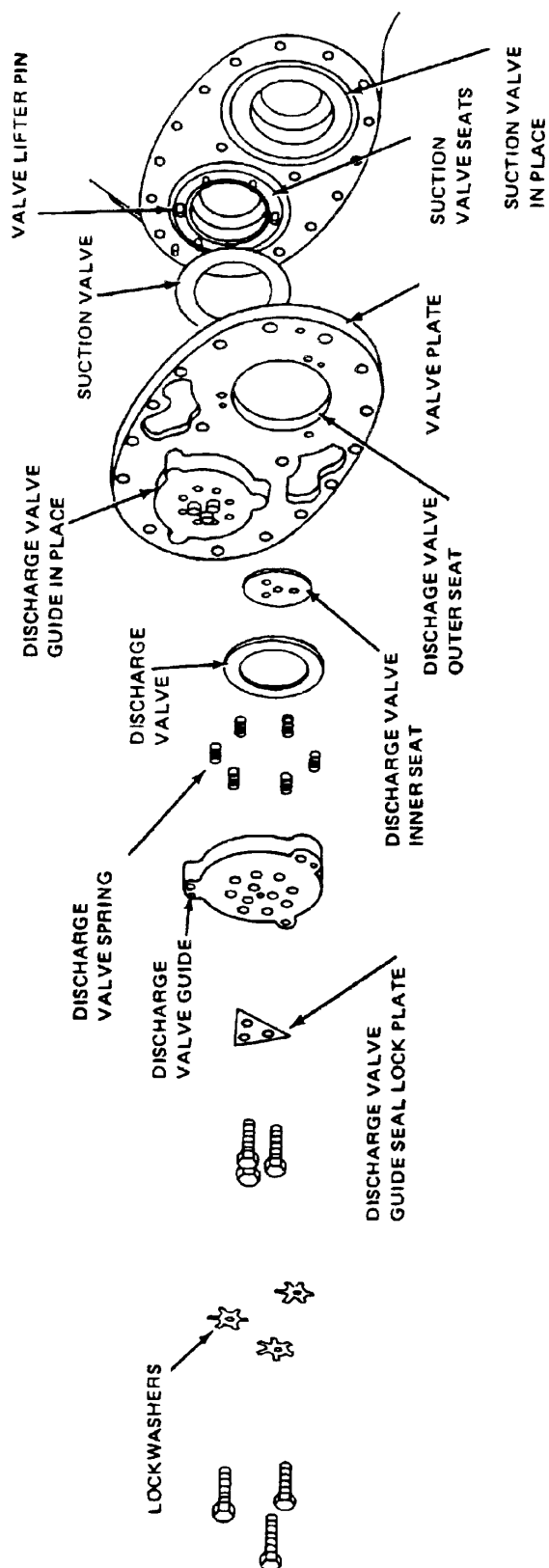


Figure 516-3-42. Suction and Discharge Valve Assembly

516-3.2.22.3 Disassembly, Inspection, and Reassembly of Compressor Valves.

CAUTION

Installation of a short stroke valve plate into a long stroke compressor will cause internal damage.

NOTE

Installation of a long stroke valve plate into a short stroke compressor will cause no damage, but will result in a minor loss of capacity.

516-3.2.22.3.1 Procedures are as follows:

a. To disassemble:

- 1 Remove cylinder head
- 2 Loosen capscrews holding the discharge valve seat to the discharge valve guide and capscrews holding the valve guide to the valve plate
- 3 Remove the valve plate from the cylinder block, and the discharge valve guide from the valve plate.

b. Inspect suction and discharge valve discs and valve seats for cracks or excessive wear (refer to [Table 516-3-1](#)). Check cylinder deck valve stops for uneven wear. Replace valves if cracked or worn. If valve seats are worn, replace the complete valve plate assembly. Inspect valve springs for signs of failure. Replace any broken or distorted springs. To reassemble, pistons shall be below tops of cylinder sleeves. Turn the crankshaft or force pistons down.**NOTE**

Long-stroke compressors have a different valve plate thickness than short-stroke compressors. Long-stroke compressors have valve plate part number 5H46-120A, with a thickness of 0.591 inch. In addition, the long stroke valve plate is stamped LS. Short stroke compressors have valve plate part number 5H40-120A, with a thickness of 0.563 inch. Ensure that the correct one is installed.

c. To reassemble:

- 1 Place suction valve springs in valve plate recesses. The large spring coil shall be in full contact with bottom of recess.
- 2 Place the suction valve disc on valve springs. Press the disc into the valve plate recess. Slide valve retainer clips into place ([Figure 516-3-43](#)). Locate clips so they do not cover valve lifter springs or pins. Valve retainer clips 5F20-2061 (5F compressors) or 5H40-2061 (5H compressors) are field-supplied.
- 3 Bolt the valve plate to the cylinder block. Remove valve retainer clips. Keep for future use.
- 4 Place discharge valve springs in discharge valve guide spring recesses.
- 5 Place the discharge valve disc over springs and fit the inner seat in place over the valve disc. Hand-tighten bolts holding the inner seat to the valve guide (valve guide assembly).
- 6 Place the valve guide assembly on the valve plate. Tighten all bolts and bend tabs on lockwasher and lock plates. Replace the cylinder head.

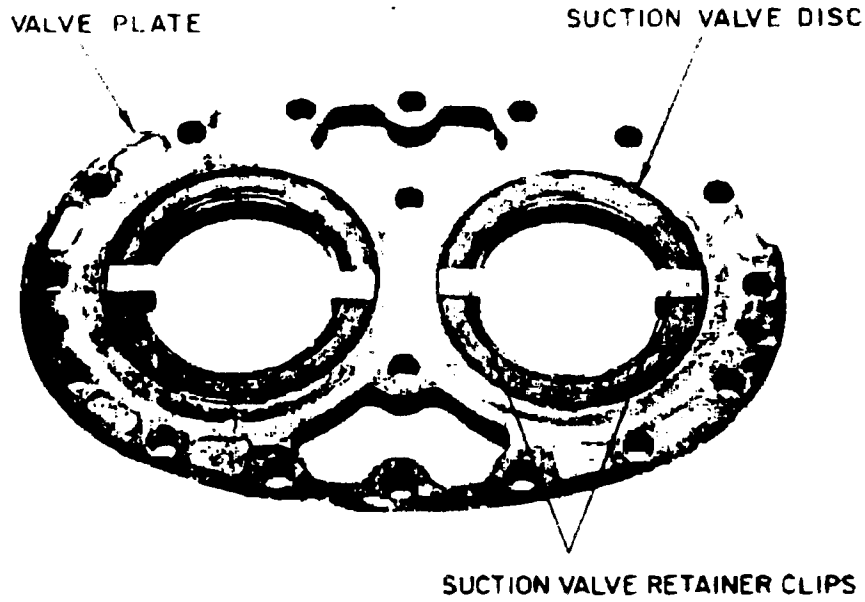


Figure 516-3-43. Valve Clips in Place

516-3.2.22.4 Cylinder And Unloader Sleeves Disassembly - Carrier. To disassemble cylinder and unloader sleeves, remove the cylinder head, suction and discharge valve assembly, and pump end bearing head. Whenever the cylinder sleeve or valve plate is replaced, use a new suction valve disc. To inspect proceed as follows:

1. Turn the crankshaft until the piston is in midposition.
2. Insert a sleeve puller ([Figure 516-3-44](#)) into the cylinder and push it down on to the top of the piston.
3. Tighten the nut on the tip of the sleeve puller to expand the puller in the sleeve.
4. Turn the crankshaft, forcing the sleeve upward until it can be removed.
5. Remove unloader snap rings (5H compressors only). Disassemble unloader sleeve, pins, and springs.
6. Examine sleeve bore for wear. Use micrometer calipers if necessary. Check suction valve seats for scratches, wear, and freedom of movement. When new rings are being installed in a used cylinder sleeve, break the hard, glazed surface of the cylinder sleeve to reduce wearing-in period of new rings. Use no. 80 emery cloth or rehone lightly. Clean sleeves thoroughly after breaking glaze.

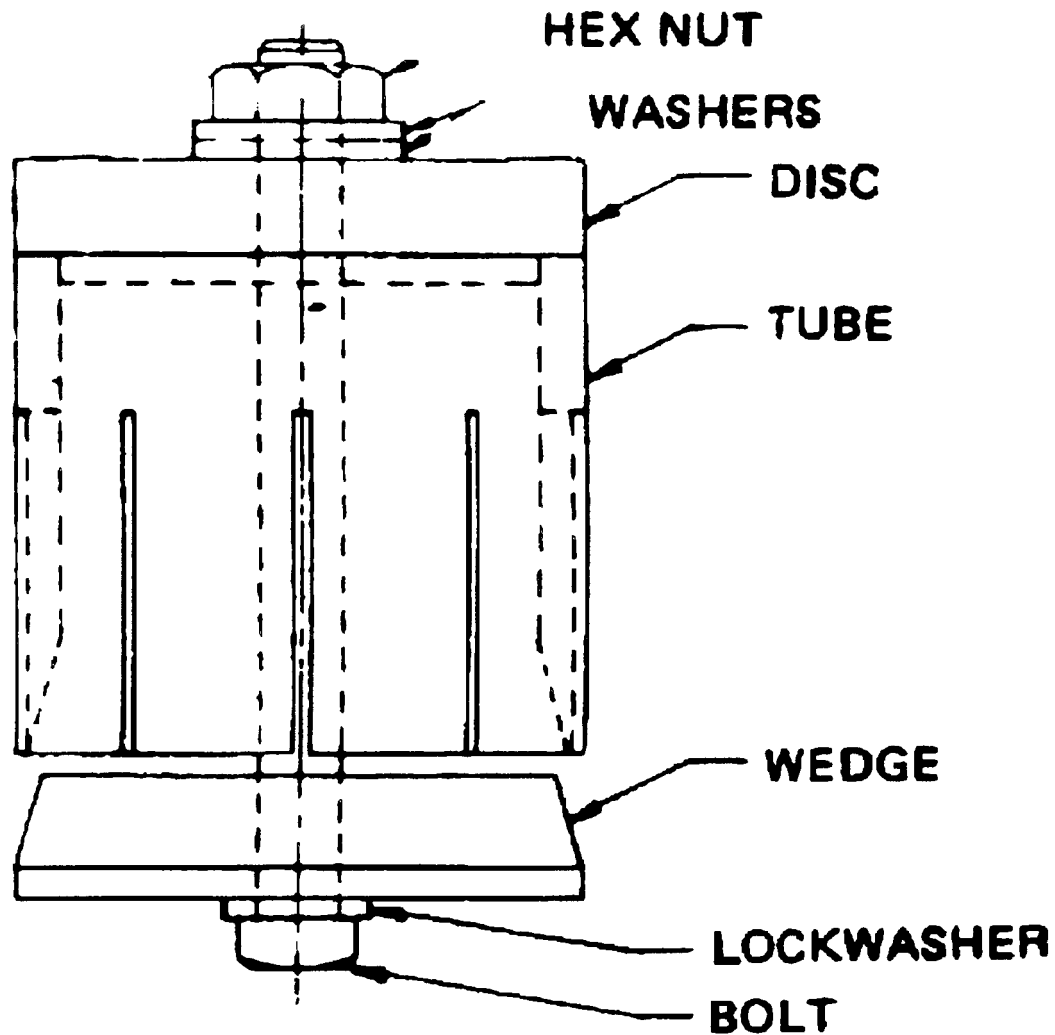


Figure 516-3-44. Sleeve Puller

516-3.2.22.5 Cylinder and Unloader Sleeve Reassembly - Carrier. To reassemble:

1. Rotate the crankshaft so the piston is at top center.
2. Lubricate piston rings and the beveled lower edge of the cylinder sleeve.
3. Stagger ring gaps around the piston.
4. With turning motion, work the sleeve over the piston and rings. Compress and align each ring with the beveled edge of sleeve.
5. Seat the sleeve in the suction manifold partition and cylinder deck recess.
6. Rotate the sleeve so any two valve lifter pin holes lie equal distances from longitudinal axis of compressors (Figure 516-3-45). In this position lifter pins line up with suction valve springs.

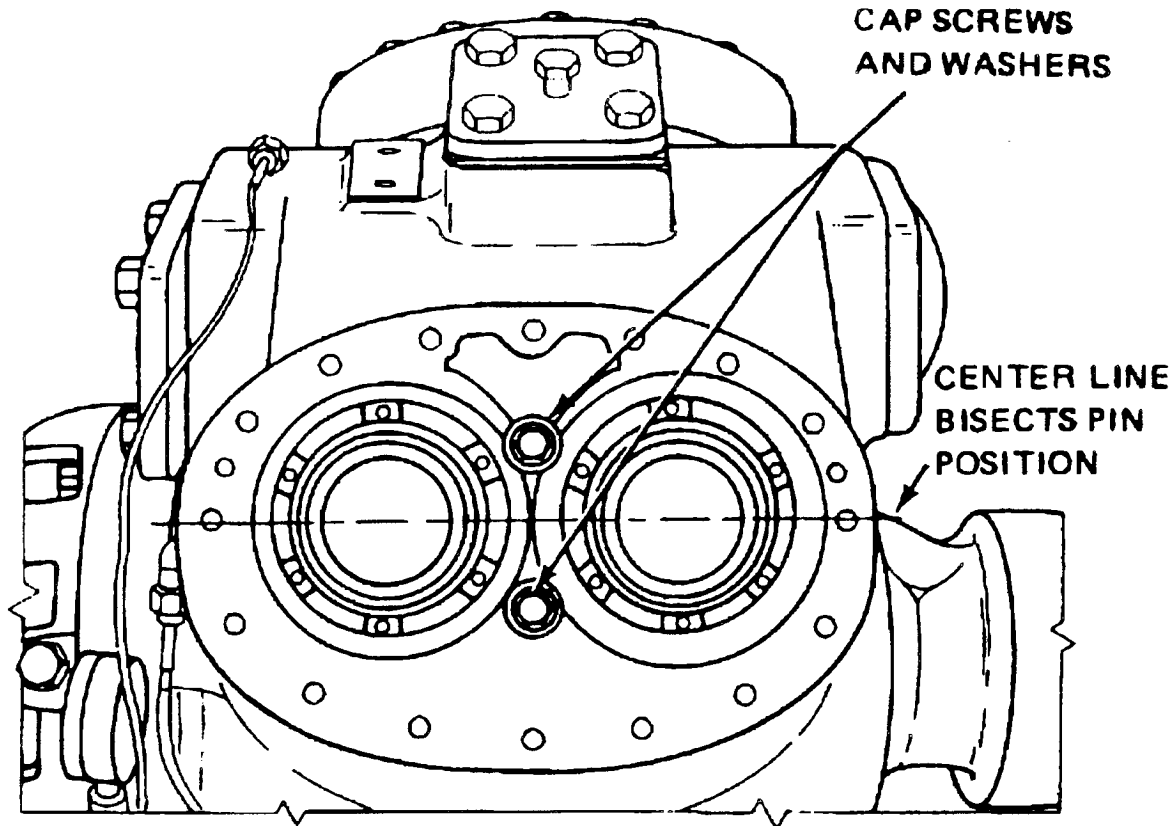


Figure 516-3-45. Position of Cylinder Sleeves

CAUTION

Never operate the compressor with heads or valve plate removed.

516-3.2.22.6 Connecting Rods and Pistons - Carrier. Carrier compressors may have either steel or aluminum connecting rods. 5F and 5H short-stroke compressors have steel connecting rods and iron pistons with bearing inserts. All 5H long-stroke compressors have or had aluminum connecting rods and pistons. Some of the newer and rebuilt 5H long stroke compressors have steel connecting rods with bearing inserts. In 5H long stroke compressors, the aluminum connecting rod serves as a bearing against the crankshaft journal. Any wear on the crankshaft journal necessitates a new crankshaft; whereas, for compressors with steel connecting rods, Carrier has available bearing inserts of 0.010 and 0.020 inch undersized to take care of crankshafts where journals have been reground undersized for wear. To inspect connecting rods and pistons, proceed as follows:

1. Gain access to rods and pistons by removing the cylinder head, valve plate, and hand hole cover or bottom plate.
2. Refer to [Figure 516-3-41](#). Remove connecting rod caps. Label caps and rods so they may be reinstalled in the same places on the crankshaft.
3. Remove the cylinder sleeve, connecting rod, and piston assembly together by pushing the assembly up through the cylinder deck. Take care that the piston does not come through the top of the sleeve. The connecting rod will not pass through the sleeve, and it is difficult to get rings back into the cylinder without breaking them or damaging suction valve seats.

4. Remove piston assembly from the bottom of the cylinder sleeve.
5. Disassemble connecting rods from pistons by removing retaining rings and piston pins.
6. Remove two compression rings (plain) and two oil rings, one vented and one plain ([Figure 516-3-46](#) - steel piston). Aluminum pistons have two compression rings and one oil ring (vented) ([Figure 516-3-47](#)).
7. Keep each connecting rod and piston assembly together for proper reassembly. Check all parts and crankpin journals for wear ([Table 516-3-1](#)). Replace as necessary.

NOTE

All current and future 5H compressors will have steel connecting rods with bearing inserts.

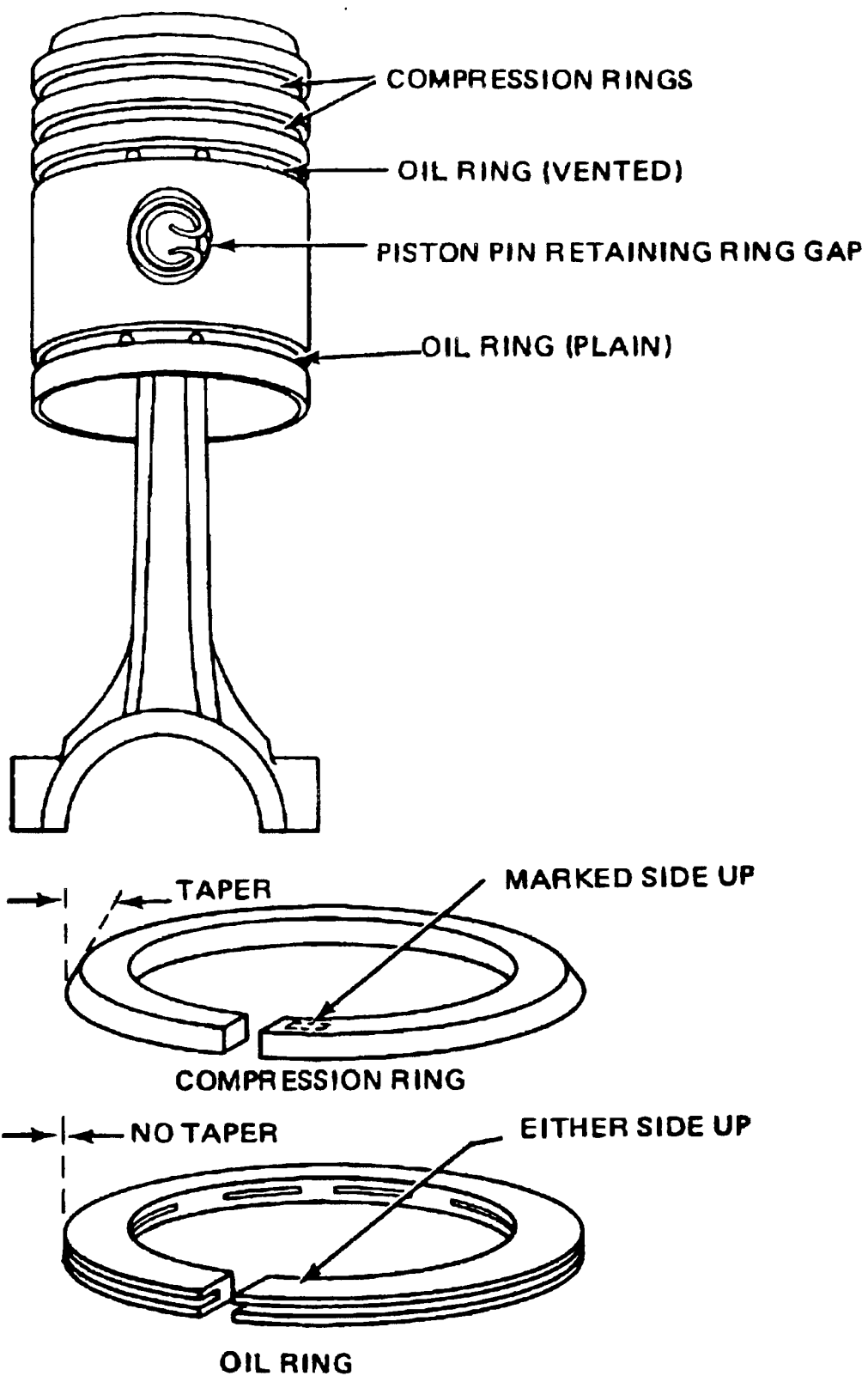


Figure 516-3-46. Position of Piston Rings and Piston Pin Retaining Rings

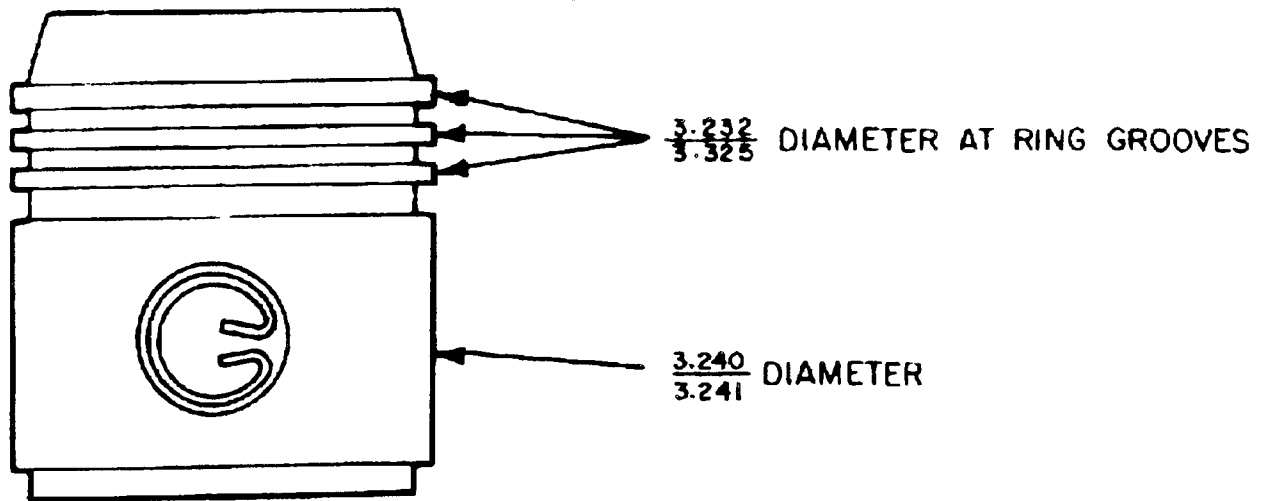


Figure 516-3-47. Aluminum, Long-Stroke Piston Diameter

516-3.2.22.7 Connecting Rods and Pistons Reinstallation - Carrier. To reinstall:

1. Attach connecting rods to pistons with piston pins and lock in place with retaining rings. Piston pins are selectively fitted for a push fit; reassemble in the pistons from which they were removed.
2. Place piston pin retaining rings, with gap on side, on the piston (Figure 516-3-46). They shall be tight enough so they cannot be rotated by finger pressure.
3. Reinstall rings as follows:
 - a Check the ring gap by inserting each ring separately in the cylinder approximately 3/8 inch from the top. The ring gap shall be between 0.007 and 0.017 inch.
 - b Install compression rings on the piston with side marked "top" toward the piston head. Install oil rings with either side up.
 - c Stagger ring gaps around piston.
 - d Measure side clearance between the ring and piston (approximately 0.001 inch). Check rings for free action.
4. Lubricate piston rings and the beveled lower edge of the cylinder sleeve. Insert the piston assembly into the bottom of the cylinder sleeve.
5. Reinstall rod bearings as follows (Figure 516-3-41):
 - a If bearing inserts are damaged and the crankshaft is not worn, it is only necessary to replace inserts (steel rods). For aluminum rods the rod shall be replaced. Do not file bearing caps. Place inserts in connecting rod and connecting rod caps so knobs on inserts fit into notches on the rod and cap. Freely lubricate the insert bearing and crankpin before installing caps.
 - b Install the cylinder sleeve, connecting rod, and piston assembly at the same time. Turn the connecting rod and install the cap so chamfered sides are against the radius of the crankpin (small knobs and rod and caps shall be on same side of journal).

516-3.2.22.8 Crankshaft and Bearings - Carrier. The following details servicing of the crankshaft, crankshaft journals, and bearings associated with the shaft.

a. Disassembly:

- 1 Remove cylinder heads, valve plates, connecting rod and piston assemblies, and the pump end main bearing head.
- 2 On 5H80, 5H86, 5H120 and 5H126 compressors, remove the hollow center main bearing lockscrew located beneath the plug (Figure 516-3-48) and loosen the hollow-cup setscrew (Figure 516-3-49) until the center main bearing can be slid from its support. On 5H86, 5H120, and 5H126 compressors, disconnect the oil line to the center main bearing.



Figure 516-3-48. 5H80, 5H86, 5H120, and 5H126 Center Main Bearing Housing Setscrew Location

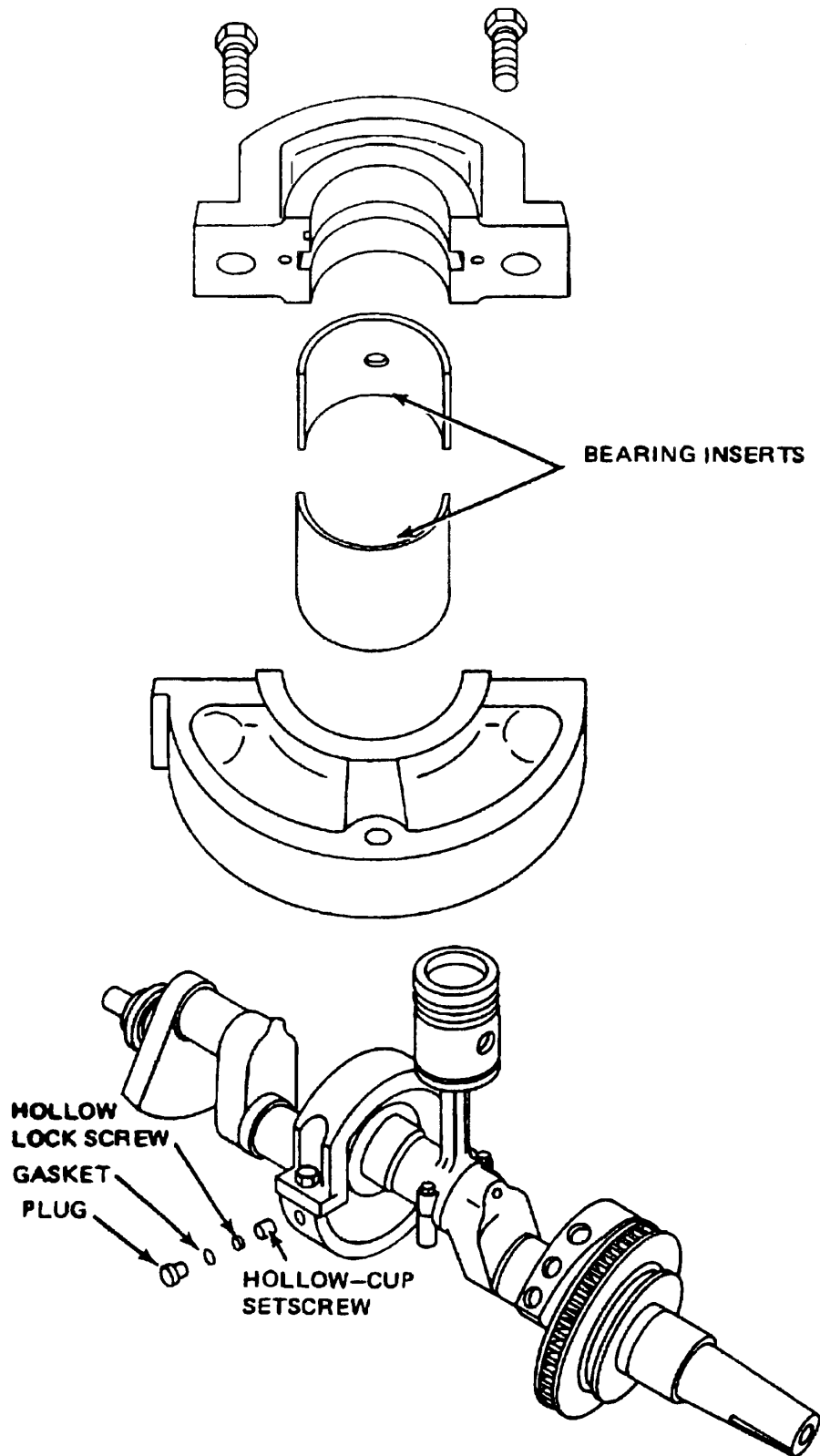


Figure 516-3-49. Center Main Bearing 5H120 and 5H126

- 3 Pull the crankshaft out through the pump end opening.
- 4 To remove the 5H120 or 5H126 oil separator (Figure 516-3-50) from the crankshaft, heat to 180°F or more by immersion in hot water or oil. If water is used, be sure that all traces have been removed before reassembly. Do not heat the impeller with a torch.

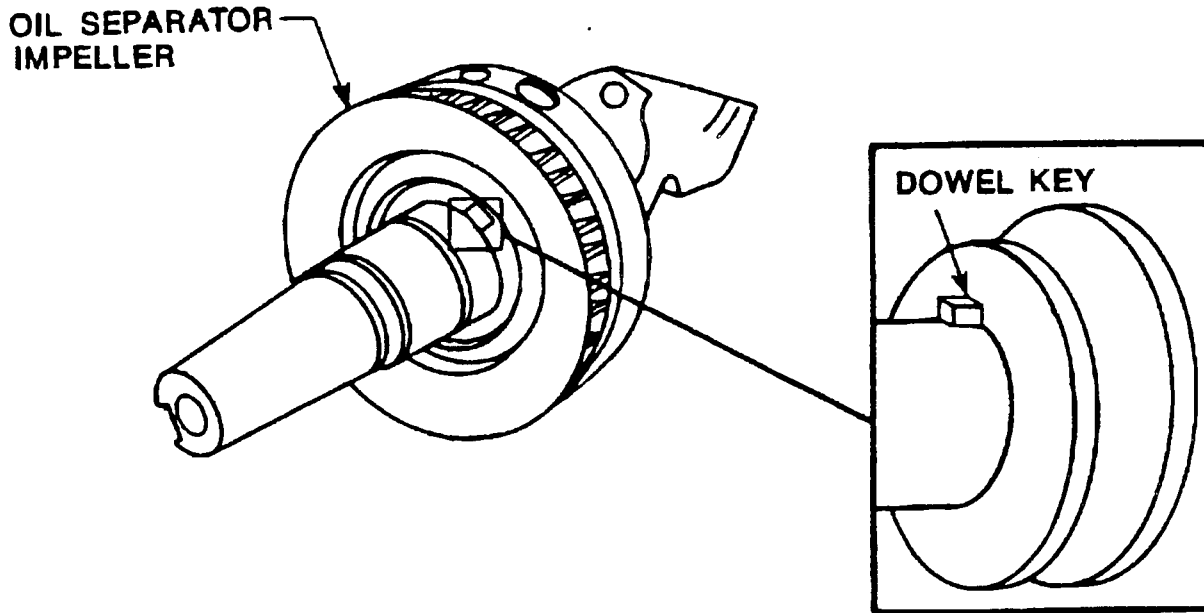


Figure 516-3-50. Centrifugal Oil Separator

b. Inspection:

- 1 Check crankshaft journals for wear and tolerances shown in Table 516-3-1. Remove crankshaft plugs, check oil passages, and clean if clogged.
- 2 Connecting rod bearing inserts and main bearings are available for crankshafts reground 0.010- to 0.020-inch undersized. A worn crankshaft suitable for regrounding to above tolerances may be exchanged for a factory-reground crankshaft and bearings. Factory-reground crankshafts are stamped on both ends with an A (0.010-inch undersized), or B (0.020-inch undersized) for use with compressors with steel connecting rods only. Crankshaft journals for aluminum connecting rods cannot be turned down. If scored, replace the shaft.

CAUTION

Check with Carrier Transicold Div. to determine the correct refinishing procedures for specific compressor crankshafts. When a crankshaft is reground, all journals (main and connecting rod) shall be undersized the same amount.

- 3 On crankshafts reground locally, hold throw to 1.001 inches for 5F compressors and 1.376 inches for 5H compressors. Stamp A or B on the crankshaft and pump end bearing head next to oil pressure gauge connection.

NOTE

Shaft journals may be built up if desired with use of chrome plate 0.005 or 0.010 inch on the diameters. Chrome plate only is acceptable. Metallizing or other methods are not acceptable and have not worked.

- 4 Determine maximum and minimum journal diameters for undersized shafts by subtracting the amount (inch) that the shaft will be ground undersize from the factory. Maximum and minimum tolerances are shown in [Table 516-3-1](#). For example, the factory tolerance for a 5H40 seal end journal is 2.6225 to 2.6235 inches. A crankshaft reground to 0.010-inch undersize is then held between 2.6125 and 2.6135 inches.
- 5 When the crankshaft is reground, remove crankshaft plugs and clean oil passages. Replace and tighten plugs before installing the crankshaft.
- 6 To reinstall the 5H120 and 5H126 oil separator impeller, install the dowel key ([Figure 516-3-50](#)) with axis parallel to axis of the crankshaft. Position the key so chamfered edge is toward radius of the crankshaft journal.
- 7 Heat the oil separator impeller to 180°F or more by immersion in oil or hot water and install on the crankshaft. If water is used, remove all traces before reassembly. Be sure that the dowel key lines up with the impeller keyway and that the impeller fits the key snugly.
- 8 Be sure that the seal end thrust washer is in place on the dowel key in the crankcase.
- 9 Insert the crankshaft and replace the pump end bearing head, connecting rod and piston assemblies, valve plate, and cylinder head. On 5H80, 5H86, 5H120 and 5H126 compressors, replace the center main bearing setscrew and lockscrew as described in paragraph [516-3.2.22.9.2](#). On 5H120 and 5H126 compressors, reconnect the oil line to the center main bearing.

516-3.2.22.9 Main Bearings - Carrier. 5H80 through 5H126 compressors have three main bearings; pump end, center, and seal end. All other compressors have two, pump end and seal end. Pullers are available or can be easily made up for replacing main bearings. The outside diameter of the puller shoulder fits through the seal end bearing housing. Use of the puller on seal end bearings is shown in [Figure 516-3-51](#) and [Figure 516-3-52](#). The puller cannot be used to pull pump end bearings, but the puller shoulder can be used to press a new pump end bearing into place.

NOTE

Main bearings are precision made and should not be reamed, bored, or shimmed.

516-3.2.22.9.1 Pump End Main Bearing. The pump end main bearing may be serviced as follows:

a. Disassembly:

- 1 Remove the pump end bearing head. (Remove the pump end cover first on 5H40, 5H46, 5H60, 5H66, 5H80, and 5H86 compressors).
- 2 Inspect the bearing for tolerance shown in [Table 516-3-1](#). If the pump end main bearing is worn, remove the bronze bearing washer and the bearing. To remove the bearing, use a hacksaw blade and make at least three cuts in the bearing (DO NOT cut all the way through the bearing) about an inch apart; then, use a tube collapsing tool and a hammer to pry up the bearing between the cuts.
- 3 Inspect the bearing housing for wear ([Table 516-3-1](#)) and damage.
- 4 Remove any burrs.
- 5 Wipe away filings and clean surfaces.

b. Reassembly:

- 1 Lubricate outside of new bearing with heavy grease (i.e. wheel bearing grease). DO NOT USE AN EXCESSIVE AMOUNT OF GREASE. Synthetic grease may be used.
- 2 Line up hole in the bearing with oil port in the housing.

- 3 Press the bearing into place using a puller shoulder (Table 516-3-4 and Figure 516-3-51 and Figure 516-3-52) and jackscrew or bearing press.

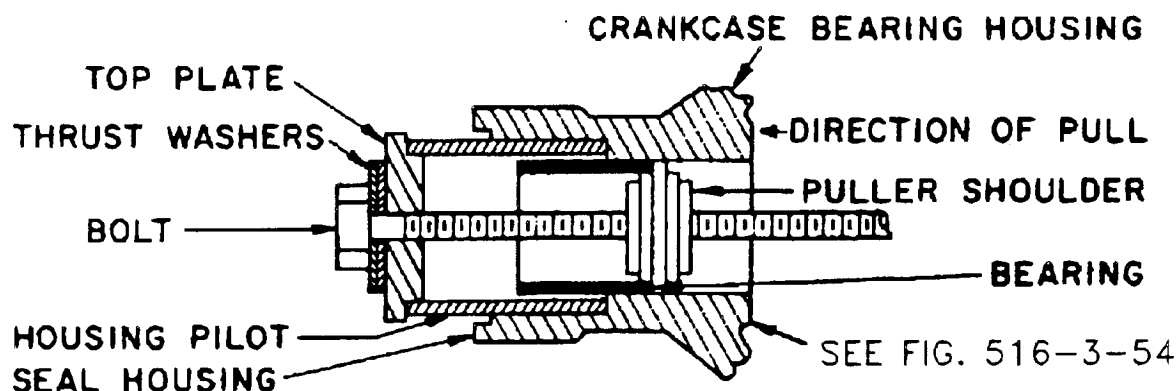


Figure 516-3-51. Removing 5H Seal End Main Bearing

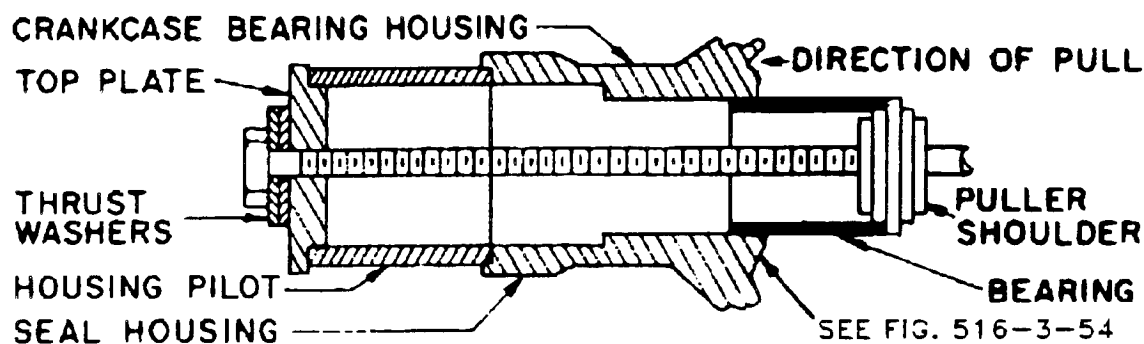


Figure 516-3-52. Installing 5F40 or 5F60 Seal End Main Bearing

Table 516-3-4. MAIN BEARING PULLER SIZES - CARRIER

Compressor	Puller Size
5F20, 5F30	5F20
5F40, 5F60	5F40
5H40, 46, 60, 66 80, 86, 120, 126	5H40
1. All bearing pullers part of 5F20-932 bearing puller assembly. 2. Side of puller marked B is for undersized bearings.	

- 4 Place the bearing washer on the bearing with the notch in the washer properly positioned around the dowel key (Figure 516-3-53).

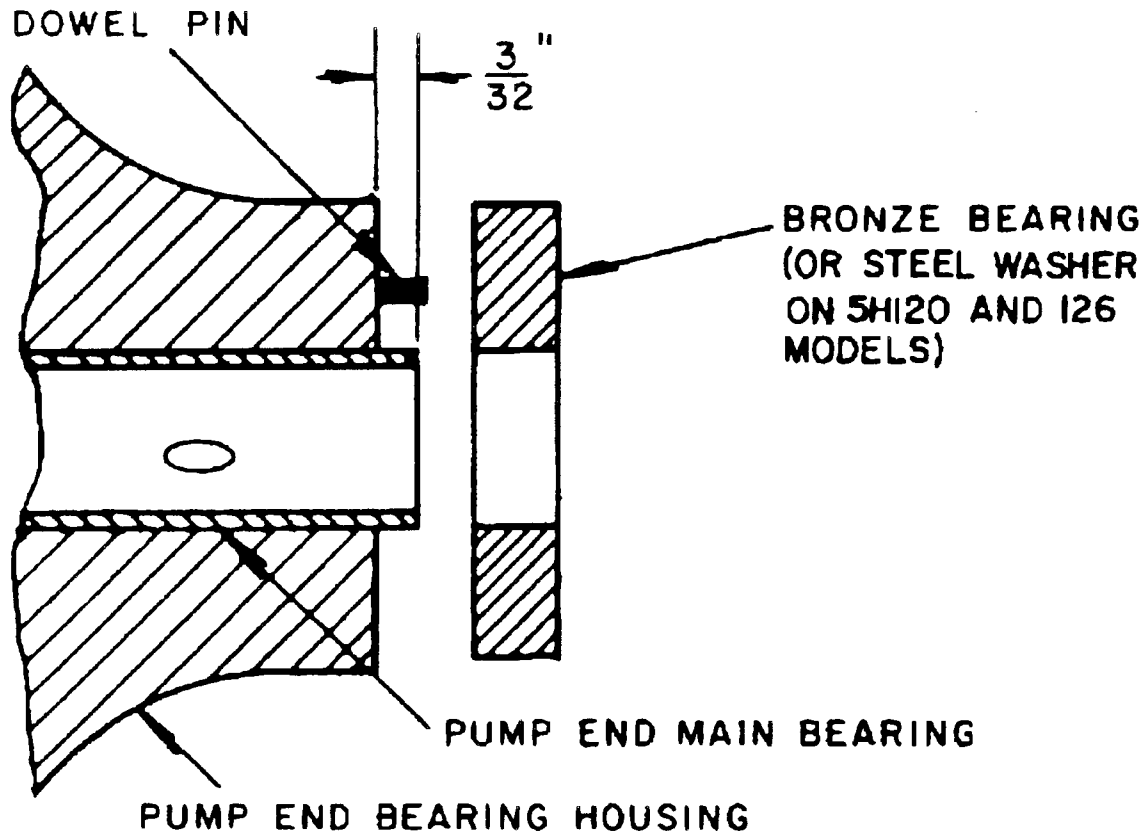


Figure 516-3-53. Pump End Main Bearing Position

516-3.2.22.9.2 Center Main Bearing. The center main bearing and housing for 5H80 through 5H126 compressors may be serviced as follows:

a. Disassembly:

- 1 On 5H86, 5H120, and 5H126 compressors, disconnect the oil line to the center main bearing.
- 2 Remove the plug on the compressor casing (Figure 516-3-48). Then remove the hollow lockscrew beneath the plug (Figure 516-3-49). Next, loosen the hollow-cup setscrew until the center main bearing assembly can be slid from its support. Remove the crankshaft and bearing assembly together. Tap the seal end of the shaft with a wooden or rubber mallet.

- b. Disassemble the bearing (Figure 516-3-49) and inspect for the tolerances given in Table 516-3-1. Mark parts so they can be reassembled in the same relative position. Reassembly: Install the new bearing inserts. Assemble the bearing housing on the crankshaft but do not tighten the hollow-cup setscrews (Figure 516-3-49). Install the crankshaft, center main bearing and housing, and the pump end main bearing assembly. Tighten bolts holding the pump end bearing assembly. Now rotate the crankshaft while tightening the setscrew on the center main bearing housing. The setscrew should tighten fully without any binding of the crankshaft. If binding occurs, shim the opposite side of the bearing housing, using 0.001-inch shim stock.

516-3.2.22.9.3 Seal End Main Bearing. Figure 516-3-51 and Figure 516-3-52 show a puller being used to remove and install a seal end main bearing. The puller shoulder is threaded and acts as a traveling nut. Friction will keep

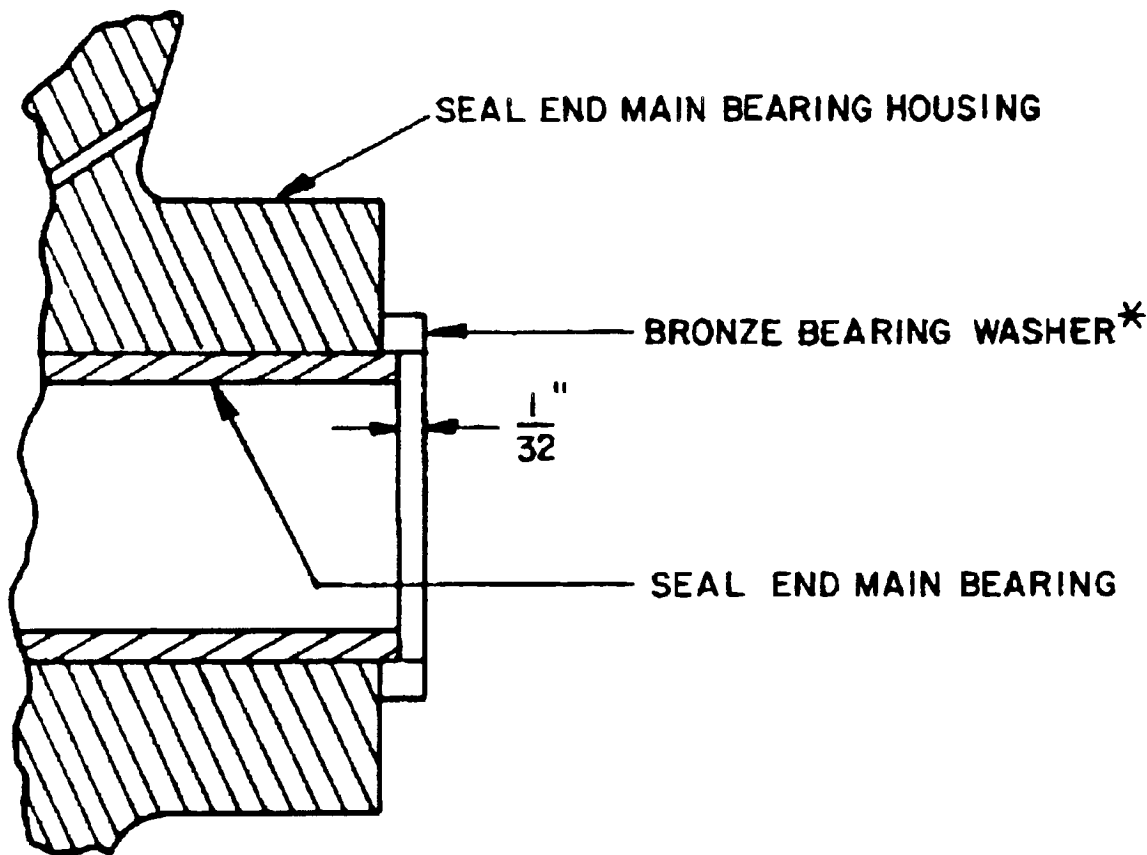
the puller shoulder from turning with the bolt unless threads are damaged. If they are damaged, use a nut between the thrust washer and bolt head. Hold the bolt head stationary and turn the nut. The seal end main bearing may be serviced as follows:

a. Disassembly:

- 1 With the crankshaft removed, use a puller shoulder to remove the seal end main bearings (Figure 516-3-51).
- 2 Inspect the bearing and housing for tolerances shown in Table 516-3-1.

b. Reassembly:

- 1 Remove any burrs and clean the bearing housing before replacing the bearing. Lubricate the outside of bearing with heavy grease.
- 2 Position the bearing so the chamfered edge enters the bearing housing first, oil holes in the bearing and housing are aligned, and the bearing relief groove is at the top.
- 3 Pull the bearing into the housing (Figure 516-3-52). The edge of the bearing should be 1/32 inch below the surface of the bronze bearing washer (Figure 516-3-54).
- 4 Look through the oil pressure regulator opening to see that the oil passage to the bearing is not blocked.
- 5 Blow out the oil groove in the bearing housing and oil lines (if any) to it.



*Steel washer on 5H120 and 5H126 Models.

Figure 516-3-54. Seal End Main Bearing Position

516-3.2.23 YORK COMPRESSOR SERVICE. The compressor shall be disassembled to service and check parts such as crankshafts, bearings, connecting rods, and pistons. Faulty compressor operation very often can be

determined by an operator after becoming accustomed to the sound of a normally operating compressor. As long as the compressor runs normally, and the sound does not change, it can safely be assumed that the compressor is operating properly. Investigate any unusual noise within the compressor. The following are external indications of faulty compressor valve operation:

- a. When operating on suction pressure control, long on-cycles with short off-periods may indicate leaking or broken compressor valves.
- b. A definite rise in temperature of the discharge gas may indicate defective suction or discharge valves, or a leaking relief valve, or both.
- c. Failure to pull down is a possible indication of a broken suction or discharge valve, or both.
- d. The operator periodically should feel the heads to check for hot spots or one particular head that is running hot. Check where the heads bolt to the discharge manifold. If this condition occurs, it is an indication of broken or leaking valves within that bank of cylinders.
- e. If leaking or broken valves are suspected, remove the heads and examine the valves for breakage.

516-3.2.23.1 Service Details. Details of servicing the York compressor R series ([Figure 516-3-55](#)) and the 2-5/8 by 2-1/4 are discussed in paragraphs [516-3.2.23.2](#) through [516-3.2.23.6.6](#). General information as applicable to the other compressors is pointed out. Use the applicable technical manual for guidance.

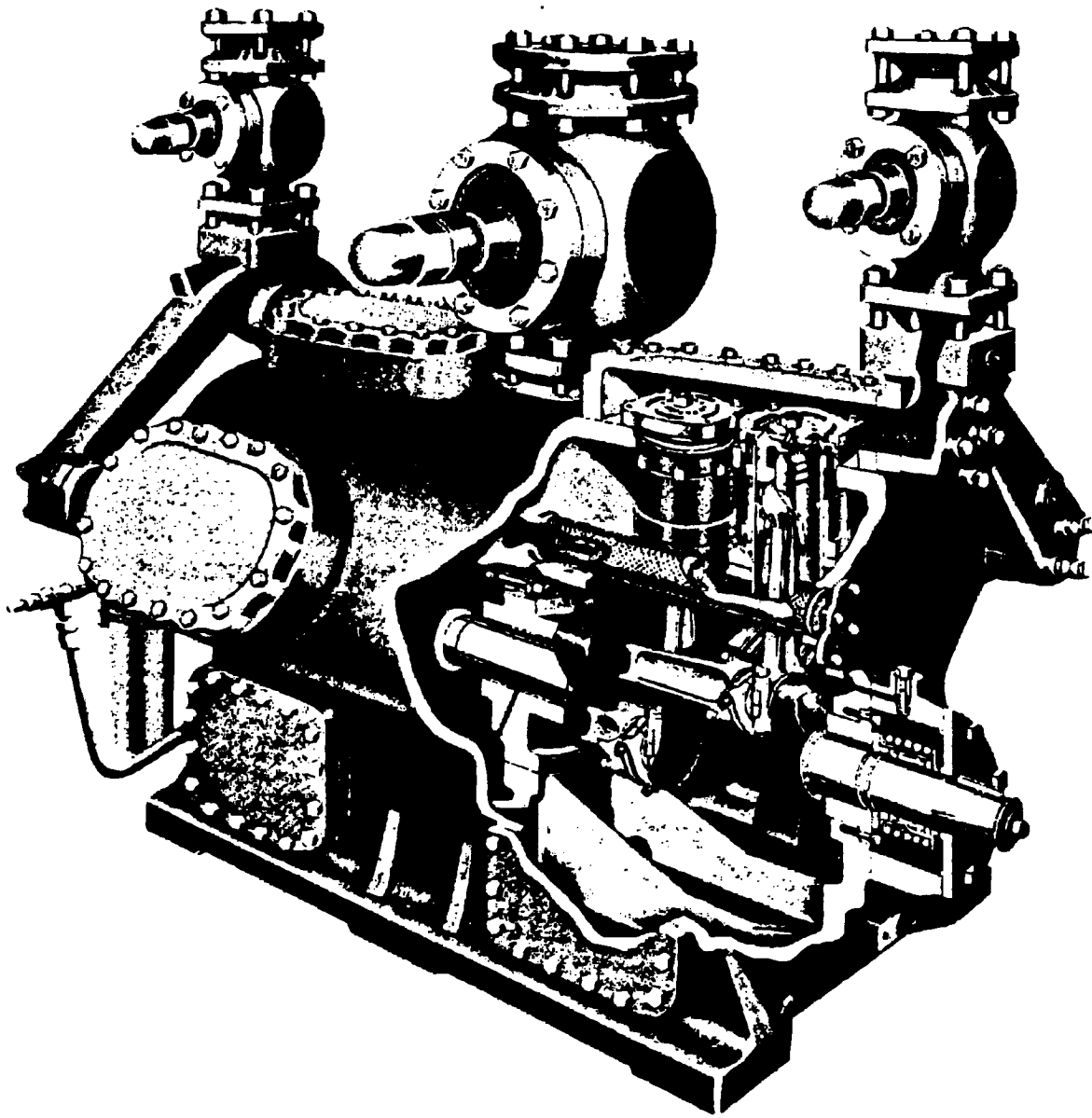


Figure 516-3-55. Cutaway View of R Compressor

516-3.2.23.2 York R Series Compressor Service. To service this compressor proceed as follows:

1. Start the compressor, close the suction service valve, and reduce the crankcase pressure as much as possible (bypass the low-pressure switch if necessary).
2. Stop the compressor and isolate it from the system by closing the discharge service valve.
3. Recover any residual refrigerant. Drain oil if necessary.
4. Before removing the cylinder heads, matchmark each head in relation to its position on the housing. When reinstalling a head, line it up with the discharge manifold and bolt the head to the manifold before bolting the head to the compressor housing.
5. After disassembly, clean all parts with solvent.

6. Before assembly, coat all parts with clean compressor oil and clean and inspect all gasket surfaces. Replace all gaskets with new factory-made gaskets. Coat gasket surfaces with oil. See [Table 516-3-5](#) for torque values for various bolts and capscrews.
7. After reassembly, evacuate the compressor and open suction and discharge valves. Restart the compressor and adjust refrigerant charge.

Table 516-3-5. THREADED FASTENER TORQUES - YORK R COMPRESSOR

Location	Thread	Tightening Torque	
		in-lb	ft-lb
Oil Pump Assembly	8 - 32 UNC	30	--
Solenoid Valve	1/4 - 20 UNC	96	8
Oil Pump Cover	5/16 - 18 UNC	179	15
Main Bearing - Seal End	3/8 - 16 UNC	--	30
Suction Elbow to Housing	3/8 - 16 UNC	--	30
Suction Elbow Cover	3/8 - 16 UNC	--	30
Suction Screen to Strainer Cover	3/8 - 16 UNC	--	30
Suction Strainer Cover	3/8 - 16 UNC	--	30
Cover Head	3/8 - 16 UNC	--	30
Capacity Control Valve	3/8 - 16 UNC	--	30
Seal Cover Plate	3/8 - 16 UNC	--	30
Discharge Valve Assembly ¹	3/8 - 16 UNC	--	Note 2
Power Element Union	3/8 - 24 UNF	--	35
Connecting Rod Bolt ¹	3/8 - 24 UNF	260	21-22
Discharge Valve Screw ¹	3/8 - 24 UNF	--	Note 3
Center Bearing Spacer ¹	1/2 - 13 UNC	240	20
Center Bearing	1/2 - 13 UNC	--	60
Top Head	1/2 - 13 UNC	--	75
Discharge Manifold	1/2 - 13 UNC	--	75
Bearing Head, Pump End	1/2 - 13 UNC	--	75
Handhole Cover	1/2 - 13 UNC	--	75
Seal Cap, Oil Relief Valve	9/16 - 18 UNC	--	50
NOTES:			
1. Critical items - torque only as specified.			
2. 15 for original design, 30 for later models.			
3. For F-series 2-5/8 x 2-1/4 compressors with 5/16 UNF screw, torque to 20-21 ft-lbs; all others 35 ft-lbs.			

516-3.2.23.2.1 Discharge Manifold and Top Heads. To remove the manifold and top heads proceed as follows:

1. Recover the refrigerant from the compressor.
2. Identify the cylinder heads before they are removed from the housing so that they may be replaced on the same cylinder banks from which they were removed.
3. Support the discharge manifold and unbolt it from the cylinder heads. Note the location of the spacer collars.
4. Remove the cylinder heads and lay them aside, being careful not to damage the machined surfaces.
5. When reassembling a top head, be sure to first line up with the discharge manifold and bolt it snugly, before bolting the head to the compressor housing.

516-3.2.23.3 Suction and Discharge Valves. The discharge valve cage and suction valve plate for later compressors have been redesigned. The changes involved and means of identification are as follows:

- a. Discharge valve cage ([Figure 516-3-56](#)). The thickness has been increased 1/8 inch. The valve cage will have four larger core ports rather than eight small ports. The length of the discharge valve cage assembly center bolt has been increased 1/8 inch. The specified torque for the four valve cage holddown bolts has been increased to 30 foot-pounds.
- b. Suction valve plate ([Figure 516-3-57](#) and [Figure 516-3-58](#)). Valve plate thickness has been increased 0.020 inch. The valve plate will have two grooves in the circumference for identification. Gaskets (part no. 064-21704) that fit between the compressor housing and the cylinder sleeve, and between the cylinder sleeve and the suction valve plate have been eliminated. When replacing old suction valve plates ([Figure 516-3-59](#)) with new plates be sure to discard existing gaskets (part no. 064-21704). For 2-5/8 x 2-1/4 compressors, see paragraph [516-3.2.23.6](#).

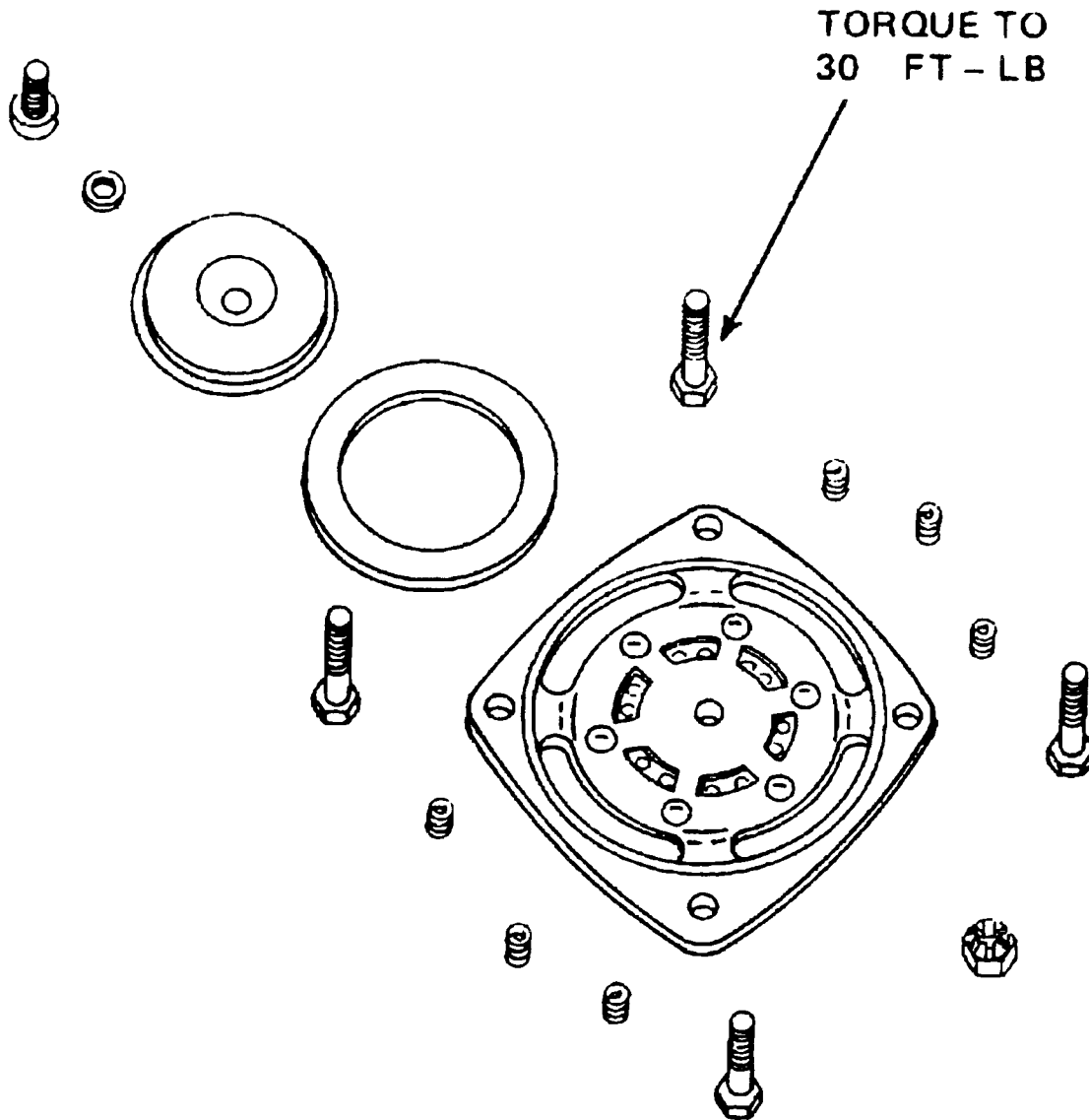


Figure 516-3-56. Discharge Valve Cage

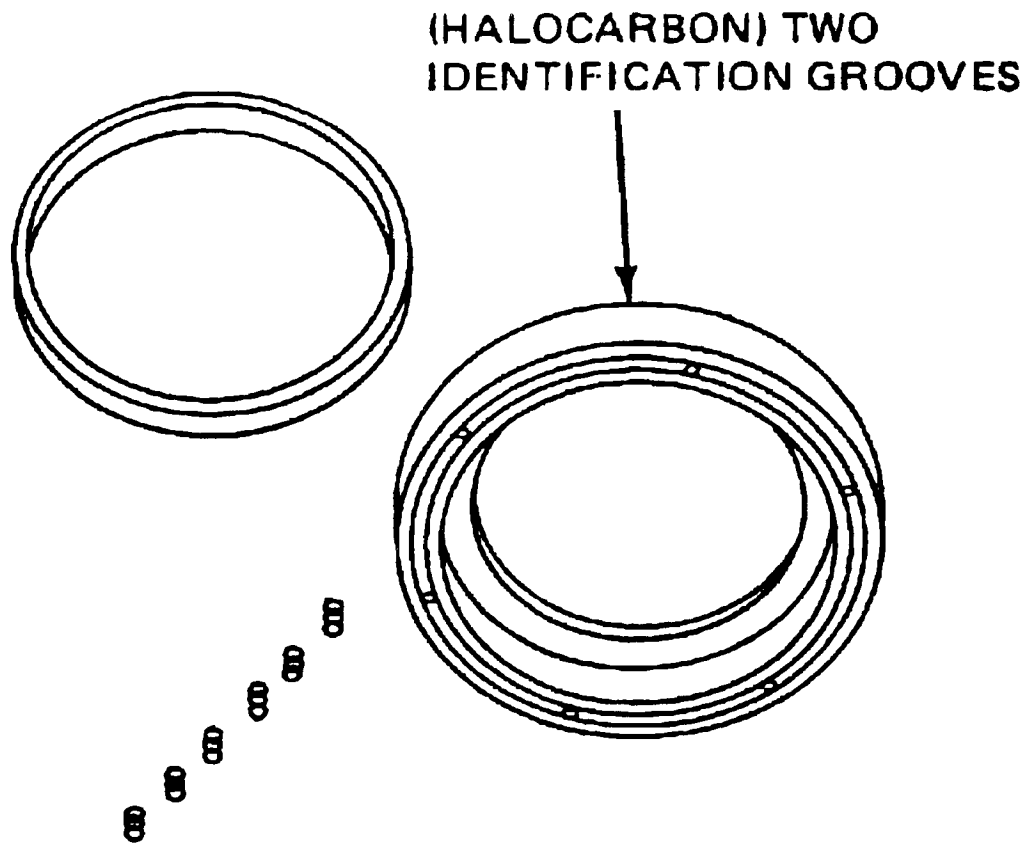


Figure 516-3-57. Suction Valve Plate

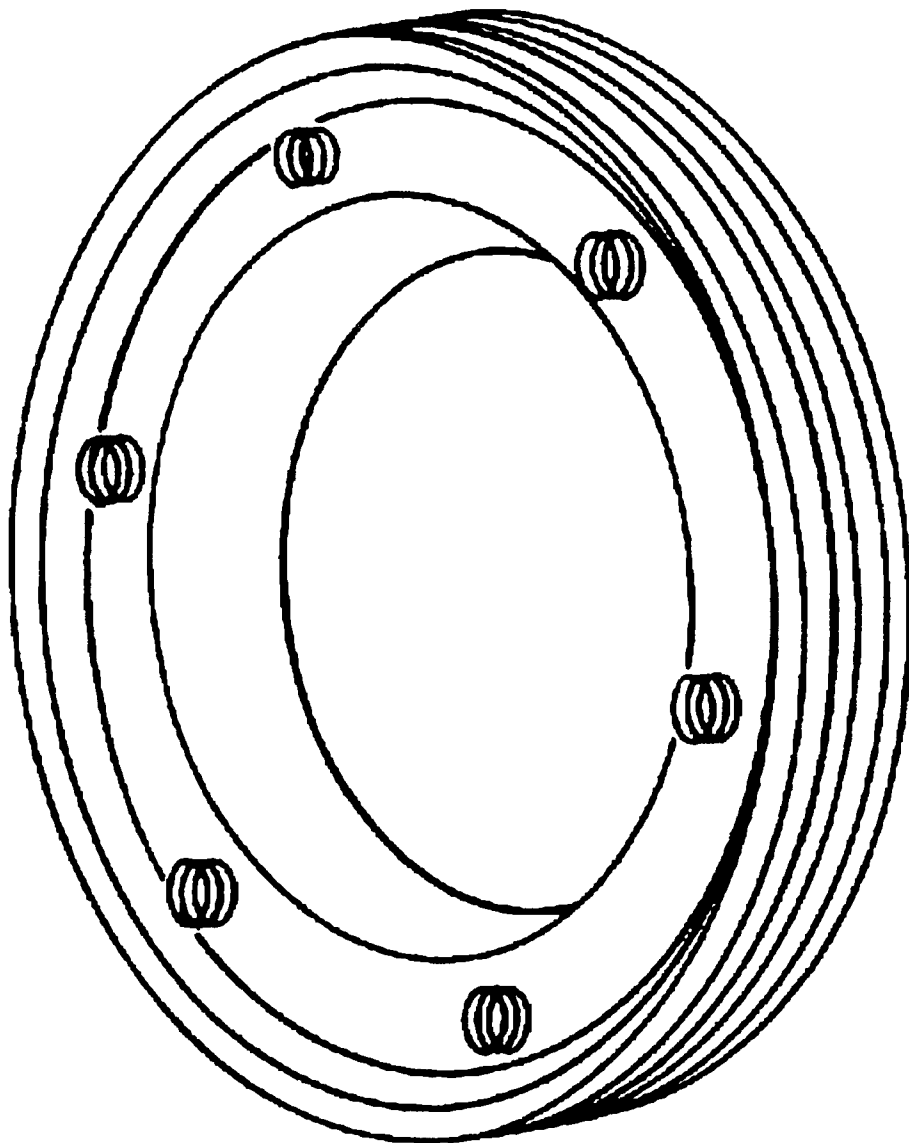


Figure 516-3-58. Suction Valve Assembly (New Design)

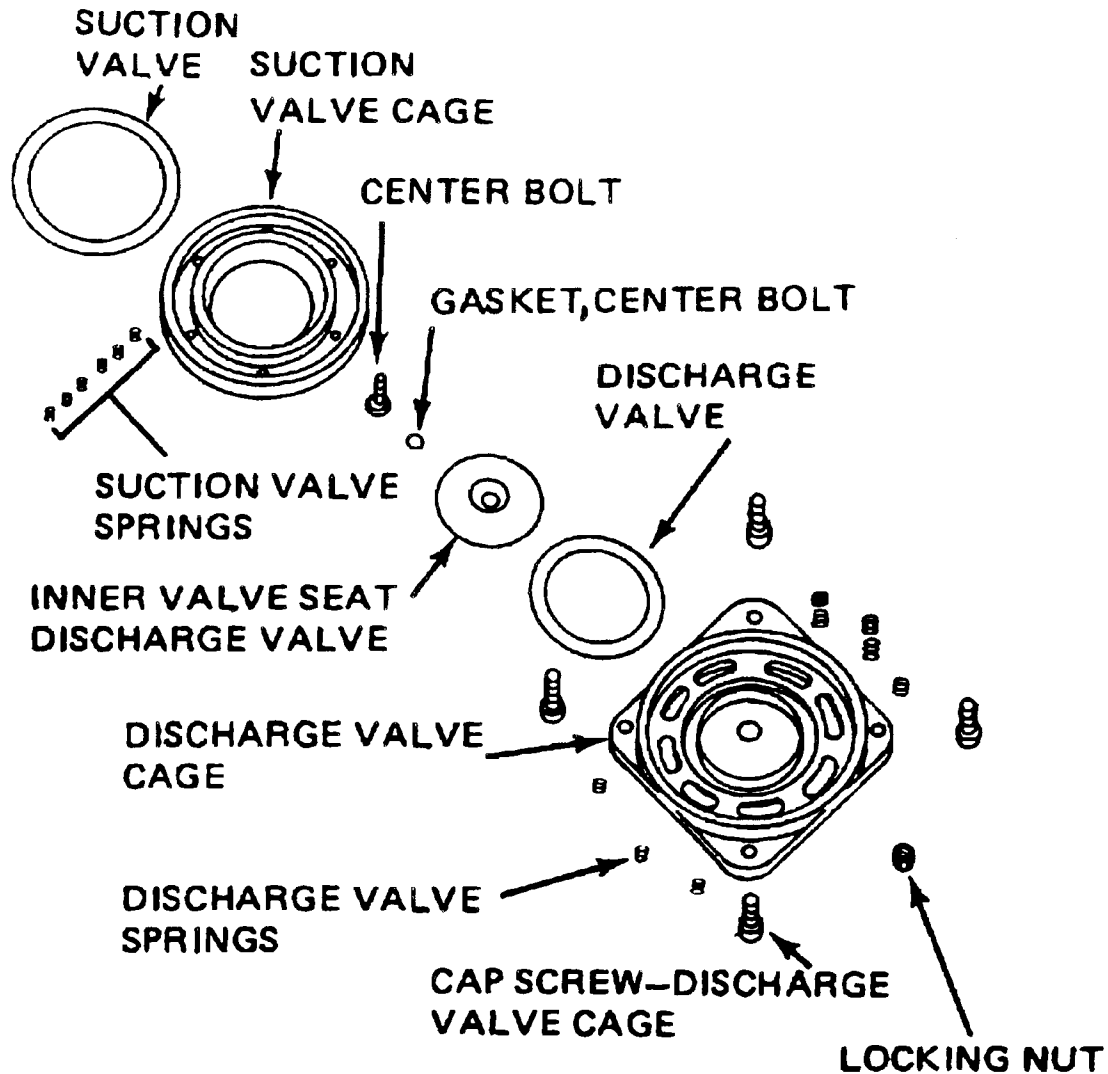


Figure 516-3-59. Suction and Discharge Valves (Original Design)

516-3.2.23.3.1 To remove the suction and discharge valve assemblies proceed as follows:

1. Recover the refrigerant from the compressor.
2. Remove the discharge manifold and top heads.
3. On unloading-type cylinders, remove the oil line that crosses the discharge valve cage.
4. Remove the four screws that hold the discharge valve cage assembly to the compressor housing and remove the discharge valve cage assembly from the compressor. Note that unloader lift pins will raise the suction and discharge valve assemblies as bolts are loosened.
5. Slide fingers inside and under the suction valve and remove the suction valve and cage.

516-3.2.23.3.2 To replace the discharge valve, proceed as follows:

1. Remove the self-locking nut from the center bolt in the discharge valve cage assembly. Note that an Allen wrench will be required to keep the bolt from turning as the nut is removed.
2. Completely disassemble the discharge valve cage and thoroughly examine all parts. Make sure valve seats and ring valve are free of cracks, nicks, or burrs and replace if necessary.
3. Place the discharge valve cage upside down on a clean smooth surface and place the six springs in pockets.
4. Center the discharge valve on springs. Install as originally removed, mating the seats; do not turn over.
5. Insert the center bolt with gasket through the inner valve seat and discharge valve cage. Turn the self-locking nut on the bolt hand-tight.
6. Make sure the valve operates freely, then tighten the self-locking nut to 35 foot-pounds. Check valve operation again after tightening the nut.

516-3.2.23.3.3 To replace the suction valve, proceed as follows:

1. Remove the suction valve from the suction valve cage.
2. If necessary, remove valve springs.
3. Inspect all parts for breakage, cracks, nicks, or burrs and replace if necessary.
4. Place the suction valve cage upside down on a clean smooth and insert the six helical springs, large end first, into pockets.
5. Place the suction valve on the springs. Install as originally removed, mating the seats; do not turn over. Make, or purchase, two clips, as shown in [Figure 516-3-60](#), and slip over the suction valve and cage. Be sure valve operates freely.

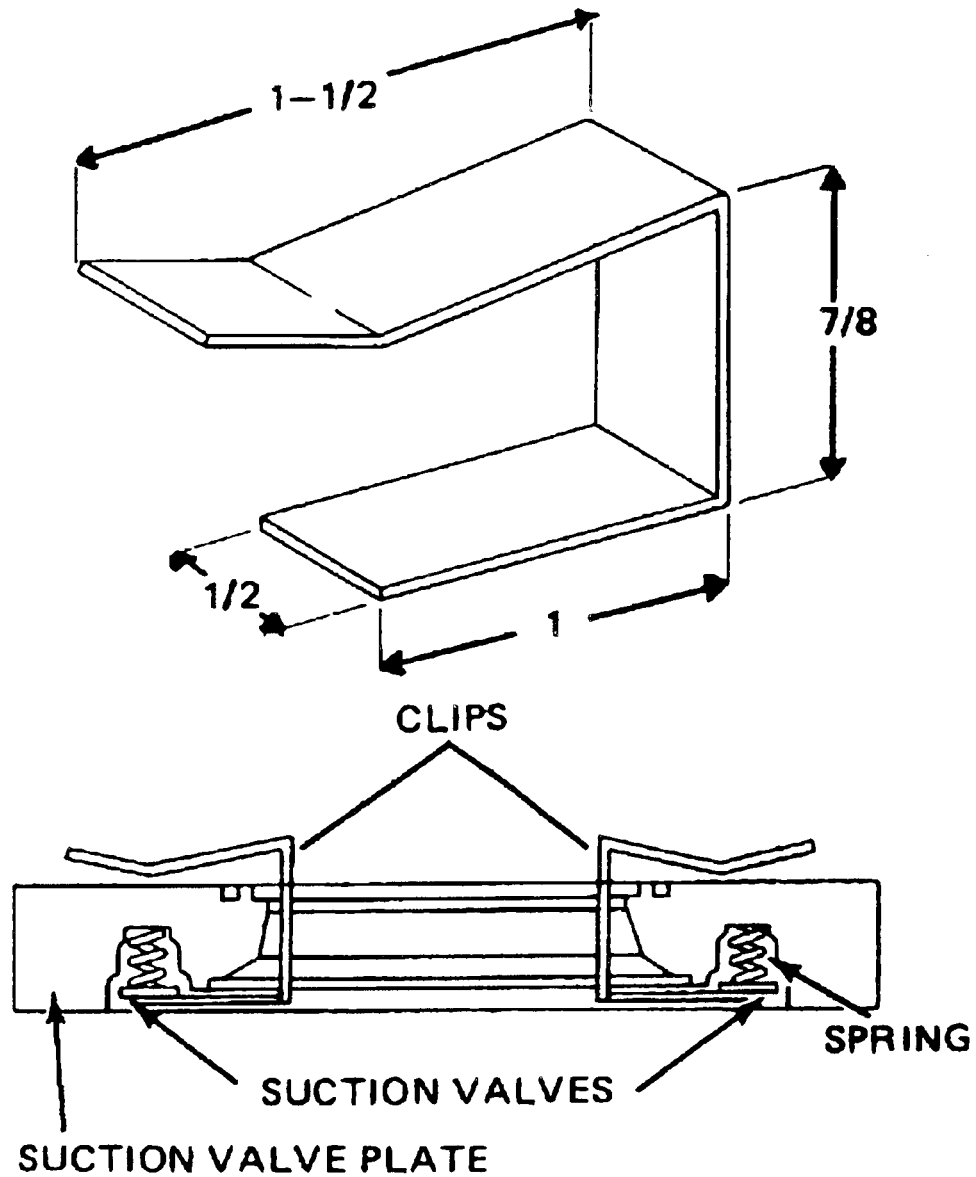


Figure 516-3-60. Suction Valve Retaining Clips

516-3.2.23.3.4 To install suction and discharge valve assemblies ([Figure 516-3-61](#)), proceed as follows:

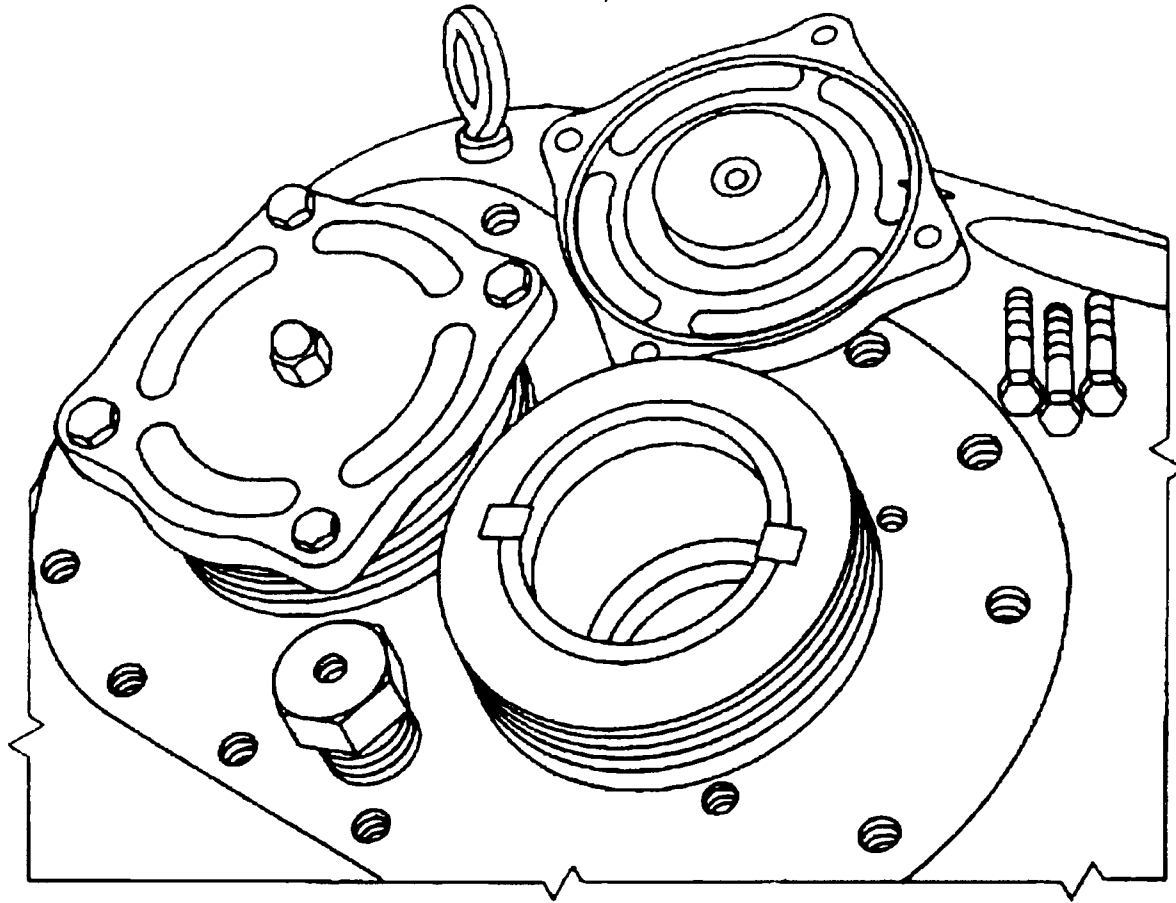


Figure 516-3-61. Suction and Discharge Valve Assembly (New Design)

1. Be sure the gasket is in place on top of the cylinder sleeve and place the suction valve assembly, with clips in place, on top of the gasket.

NOTE

If the compressor is a later design no gasket is used.

2. Firmly press down the suction valve assembly against the spring pressure and remove the two clips. Do not release pressure.
3. While still maintaining pressure with one hand, as described in step 2, slide the discharge valve assembly in place on top of the suction valve assembly.
4. Place two opposite bolts in the discharge valve cage and tighten finger-tight. Insert remaining two bolts and evenly draw down opposite pairs of bolts.

NOTE

If the compressor is an original design, torque the bolts to 15 foot-pounds. If the compressor is a later design, torque the bolts to 30 foot-pounds. DO NOT OVERTIGHTEN.

5. On unloading-type cylinder banks, install the unloader oil line that crosses the discharge valve cage. Note that the longer leg of this oil line is fastened to the unloader power element (between the two cylinders).

6. Replace the compressor top heads, using new gaskets if necessary, on the respective cylinder banks from which they were removed. Insert two bolts loosely to hold the head in place.
7. Bolt the discharge manifold to the top heads and then bolt the top heads to the compressor as described in discharge manifold and top heads (paragraph 516-3.2.23.2.1).

516-3.2.23.4 Servicing Cylinder Sleeves and Unloader Sleeves. To remove the cylinder sleeves and unloader sleeves proceed as follows (Figure 516-3-62):

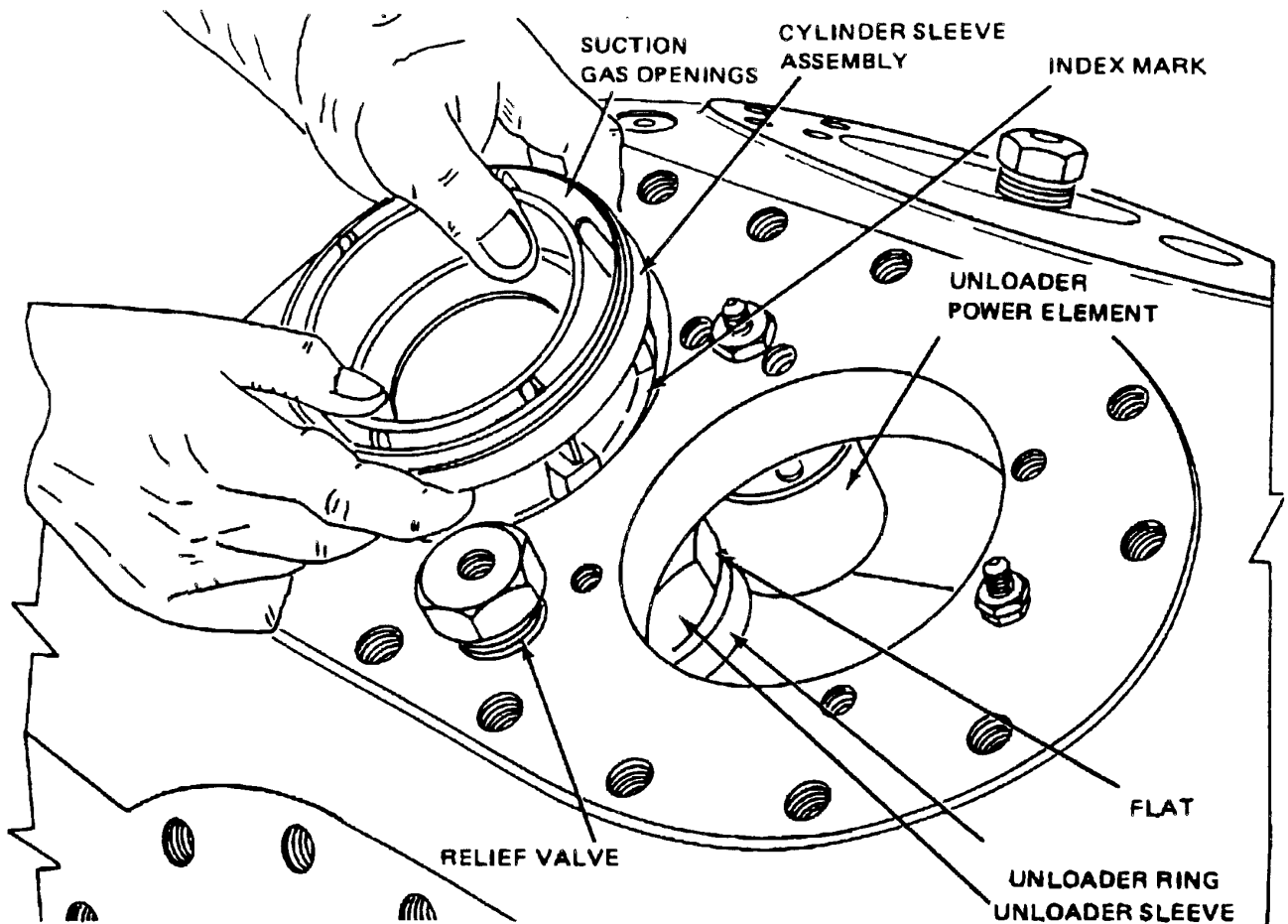


Figure 516-3-62. Removing Cylinder and Unloading Sleeves

1. Recover the refrigerant from the compressor.
2. Remove the discharge manifold, top heads, discharge valve, and suction valve assemblies following respective procedures outlined in preceding sections of this manual.
3. On permanently loaded cylinders, lift the cylinder sleeve from the compressor.
4. On unloading-type cylinders, rotate the cylinder sleeve assembly approximately 180 degrees until the flat surfaces of the unloader sleeve and the unloader ring are aligned with the unloader power element. An index mark

is stamped on the top edge of the unloader sleeve to indicate the position of the flat surface. This index mark can be seen by using a flashlight and looking down into suction gas openings in the cylinder sleeve.

516-3.2.23.4.1 To disassemble the cylinder sleeve ([Figure 516-3-63](#)), proceed as follows:

1. Place the cylinder sleeve assembly upside down on a workbench being careful not to damage machined surfaces on the top of the cylinder sleeve.
2. Compress the unloader ring against the unloader sleeve and install unloader sleeve clips (part no. 064-37002) as shown in [Figure 516-3-63](#). Remove the retaining ring and carefully remove unloader sleeve clips. Be careful that unloader lift pin springs are not lost.
3. Examine all parts for wear and replace as necessary ([Figure 516-3-64](#)).

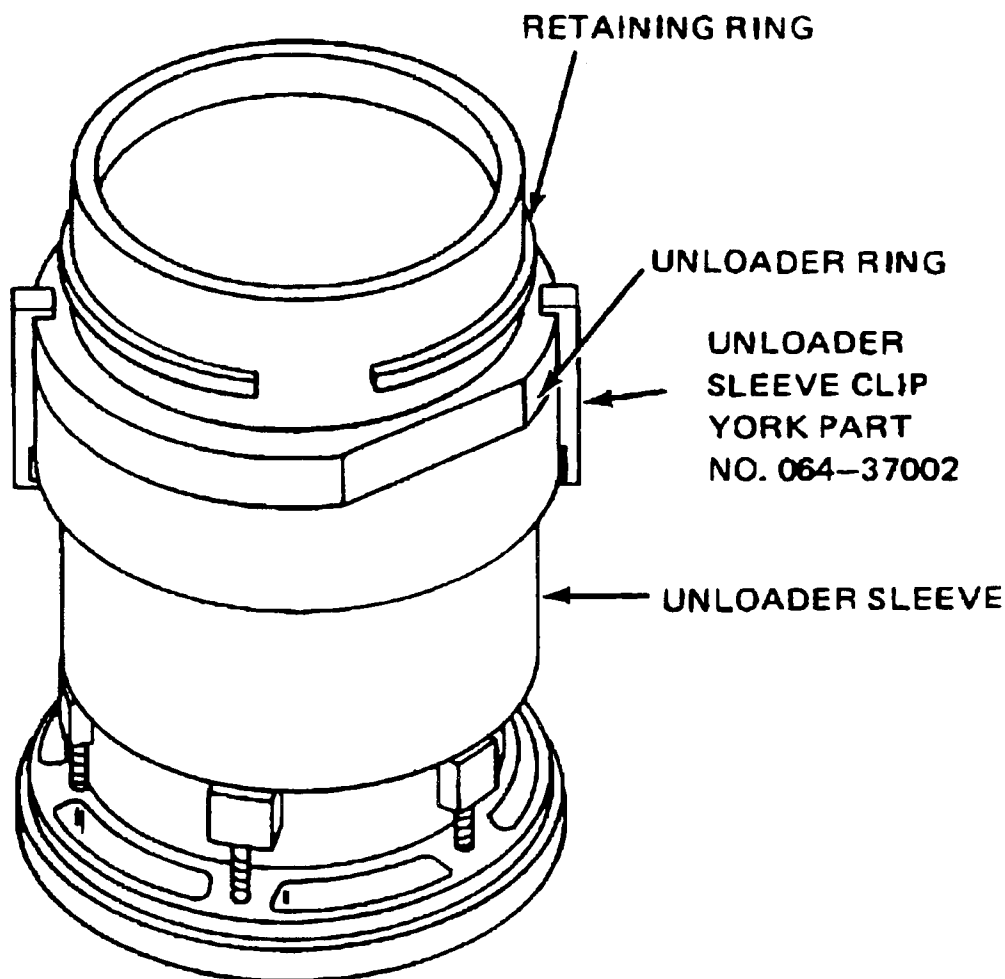


Figure 516-3-63. Unloader Sleeve Clips

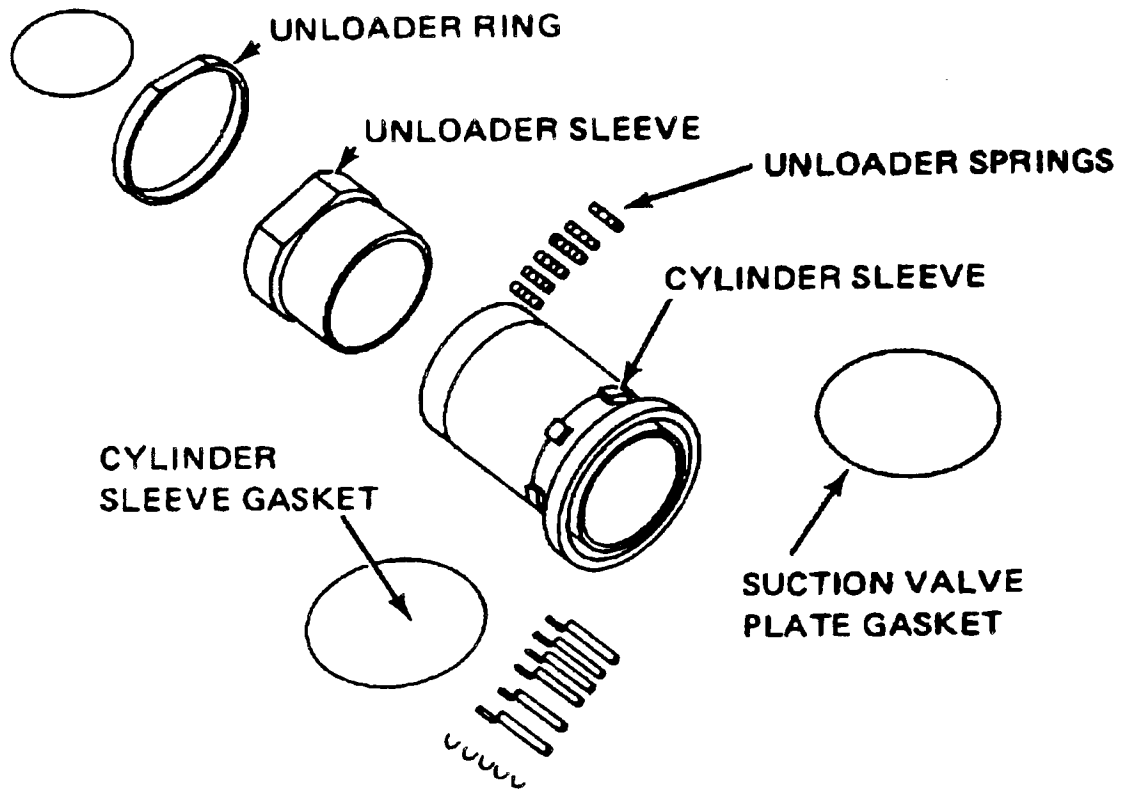


Figure 516-3-64. Unloading Cylinder Sleeve - Exploded View

516-3.2.23.4.2 To assemble the cylinder sleeve, proceed as follows:

1. If removed, insert unloader lift pins, lift pin springs, and retainers. Note that the retainer groove is not in the center of the lift pin. When installing lift pins, the long end of the pin goes up toward the top of the cylinder sleeve. Use a Waldes Truarc Applicator No. CR-018 (0.015 inch) for installing the retainers ([Figure 516-3-65](#)).

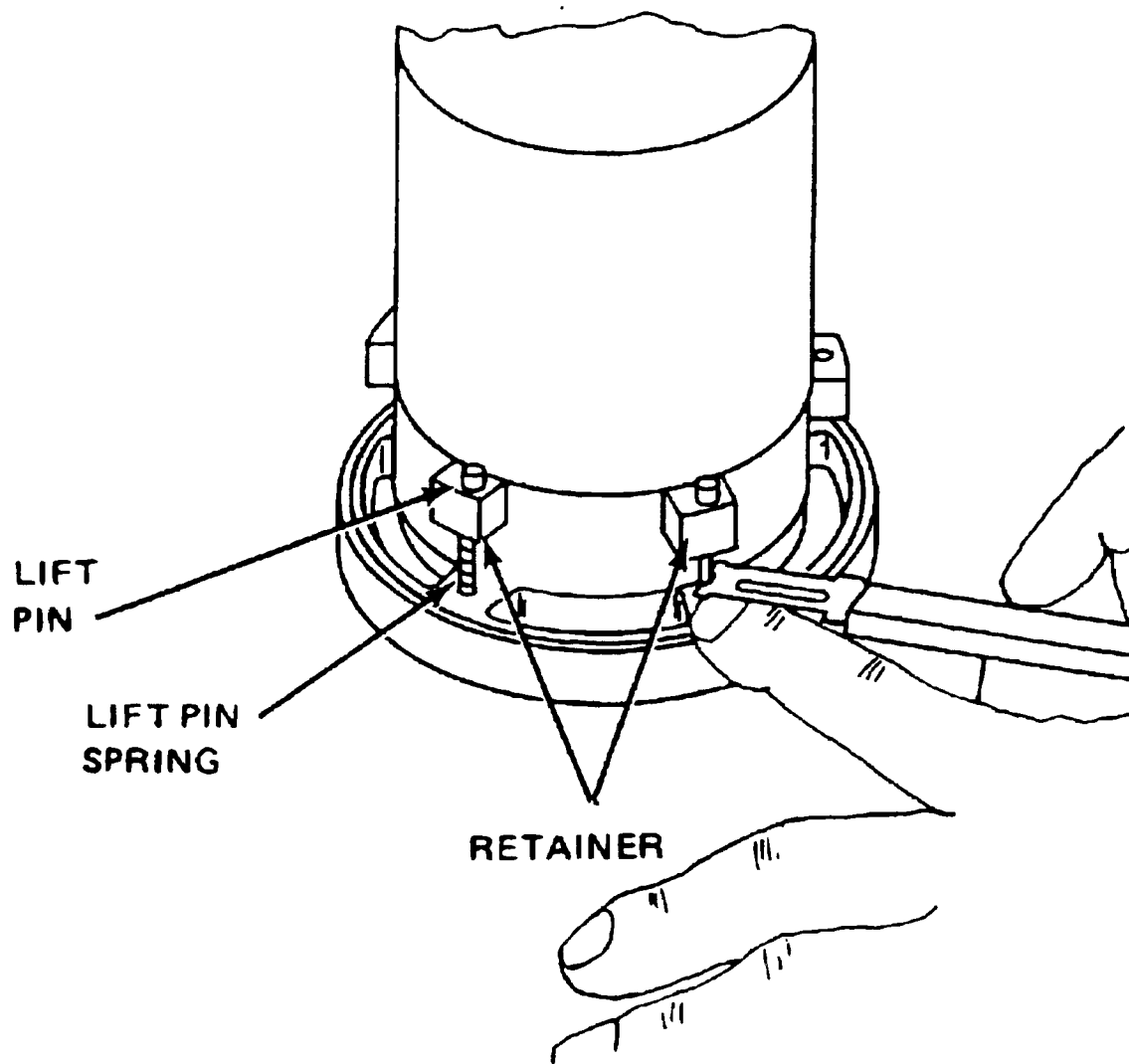


Figure 516-3-65. Installing Lift Pins

2. Place the cylinder sleeve, with lift pins installed, upside down on the table, being careful not to damage machined surfaces on the top of the cylinder sleeve.
3. Apply clean compressor oil to the outside of the cylinder sleeve.
4. Slide the unloader sleeve down over the cylinder sleeve until it rests on lift pins. The raised shoulder on the unloader sleeve should be toward the bottom of the cylinder sleeve.
5. Insert unloader lift pin springs in pockets in the unloader sleeve.
6. Slide the unloader ring over the cylinder sleeve. A roll pin in the unloader sleeve fits into a hole in the unloader ring and flats on the unloader ring and unloader sleeve shall be aligned.
7. Slide the retainer ring over the cylinder sleeve.
8. Place a valve plate on the table with the spring pockets up. Place the partially assembled cylinder sleeve assembly on top of the valve plate so that the lift pins fit into the spring pockets.
9. Place a spare unloader sleeve or unloader ring over the cylinder sleeve assembly and force it down against the

retainer ring until the retainer ring snaps into the groove on the cylinder sleeve. Remove the spare unloader sleeve or unloader ring. Check that the unloader ring snaps back over the retainer ring.

516-3.2.23.4.3 After assembling cylinder sleeves and unloader sleeves as described above, install cylinder sleeves as follows:

1. First install cylinder sleeve assemblies in unloading type cylinders, leaving nonunloading-type cylinders until last.
2. Be sure the gasket that fits between the cylinder sleeve flange and the compressor housing is in place.

NOTE

If the compressor is a later design, no gasket is used.

3. Apply clean compressor oil to the inside of the cylinder sleeve assembly. Slide the cylinder sleeve assembly over the piston and into the compressor housing. Be sure the flat on the unloader sleeve is aligned with the unloader power element. Be sure the cylinder sleeve fits squarely and firmly into the housing.
4. Using two hands as shown in [Figure 516-3-66](#), lift the unloader power element cylinder and rotate the cylinder sleeve assembly so that the unloader power element rests on the raised shoulder of the unloader sleeve as shown in [Figure 516-3-66](#). Rotate the cylinder sleeve assembly so that the flat on the unloader sleeve is 180 degrees away from the power element.
5. Install remaining cylinder sleeve assemblies, one at a time, leaving permanently loaded cylinders until last ([Figure 516-3-67](#)).
6. Reinstall suction and discharge valves, top heads, and discharge manifold(s) as explained in preceding sections.
7. Evacuate the compressor.

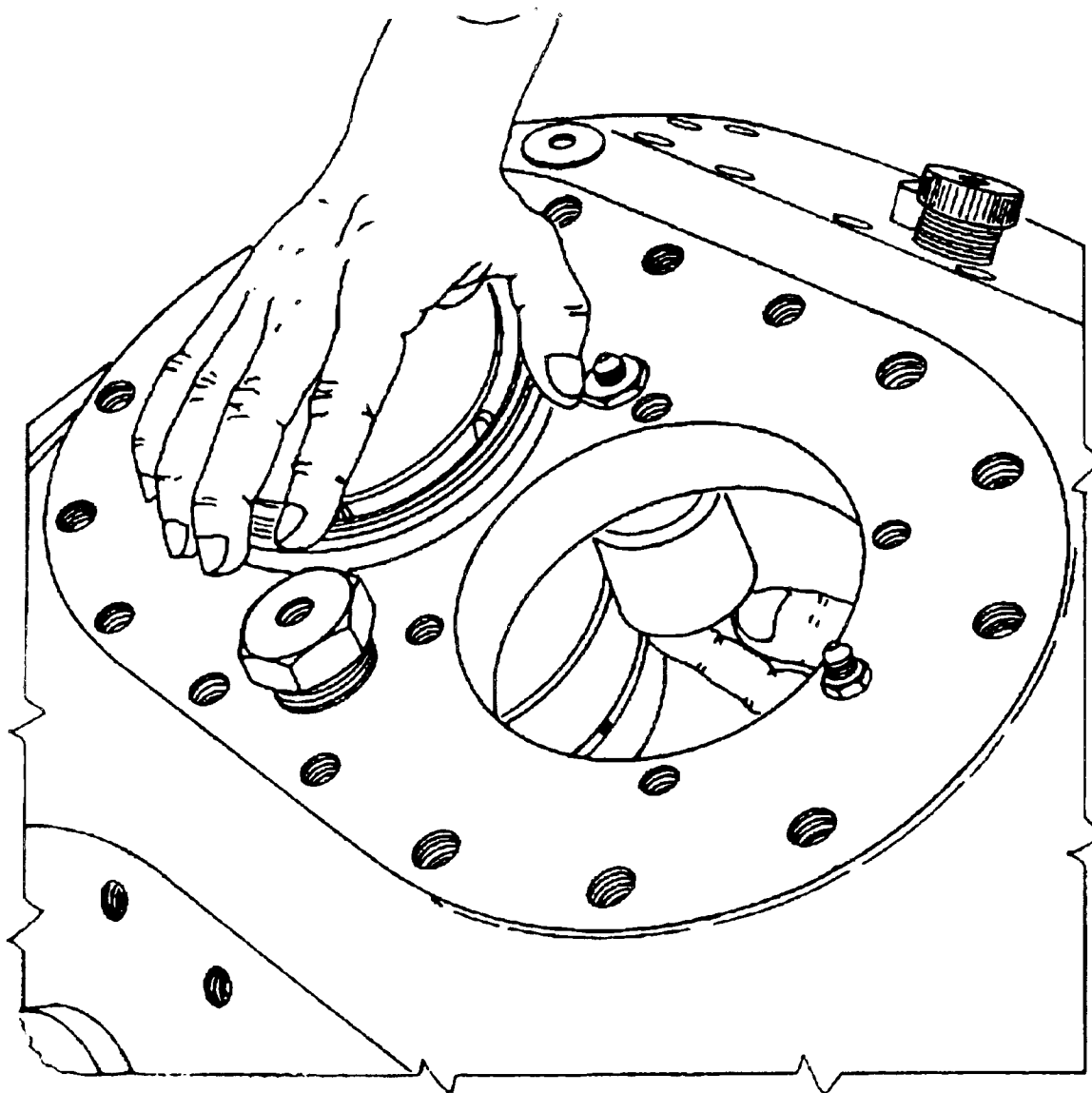


Figure 516-3-66. Installing Cylinder Sleeve and Unloader Sleeve

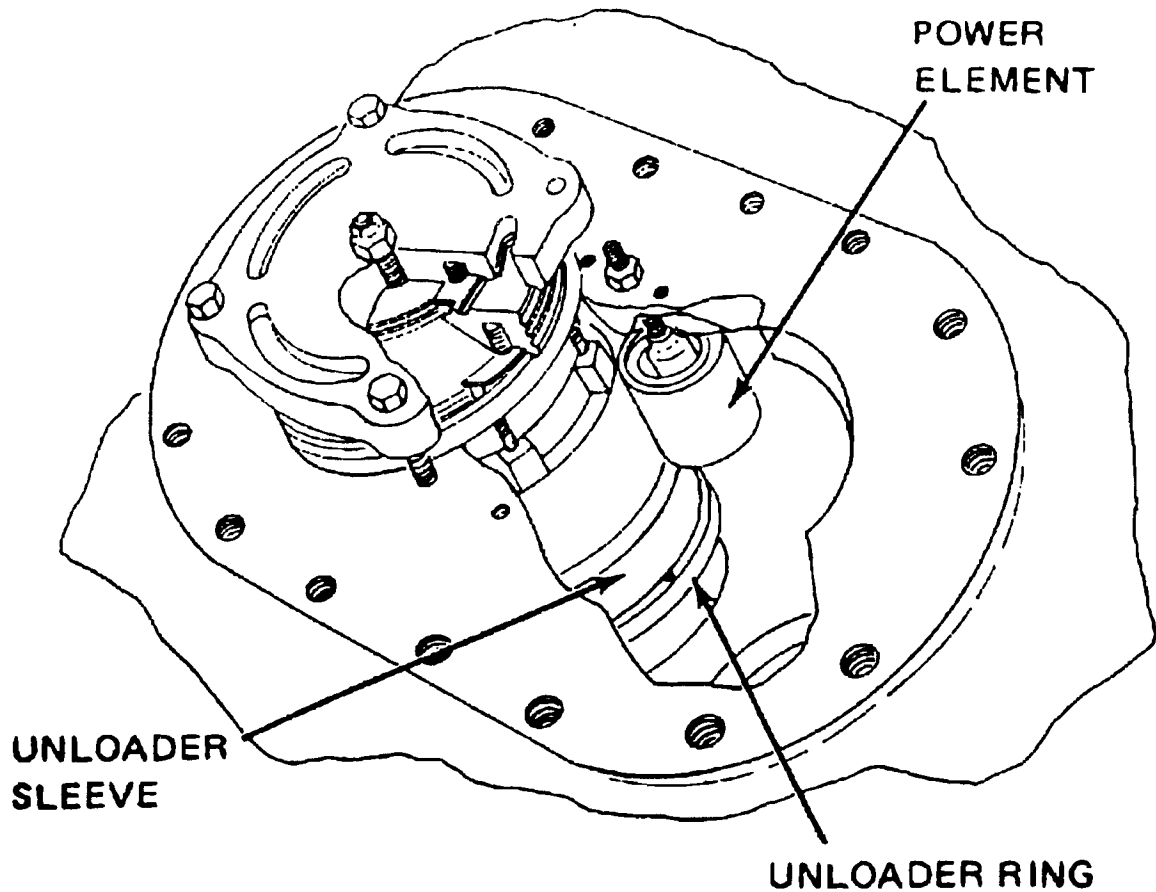


Figure 516-3-67. Unloader Type Cylinder

516-3.2.23.4.4 Unloader Power Elements. Unloader power elements are screwed into the compressor housing between the suction gas chamber and top heads. This element consists of a stationary piston inside of a movable cylinder. If a power element becomes defective, it cannot be repaired; replace it. To replace a defective power element proceed, as follows:

1. Recover the refrigerant from the compressor.
2. Remove the discharge manifold, top heads, discharge valve and suction valve assemblies, and cylinder sleeve following respective procedures outlined in the preceding sections of this manual.
3. Now remove the unloader power element as shown in [Figure 516-3-68](#). A 3/4-inch wrench, cut off as shown, will facilitate removal.
4. Install the new unloader power element using a new gasket. Tighten as specified in [Table 516-3-5](#).
5. Reinstall cylinder sleeve assemblies, suction and discharge valve assemblies, top heads, and discharge manifolds as explained in preceding sections.
6. Evacuate the compressor.

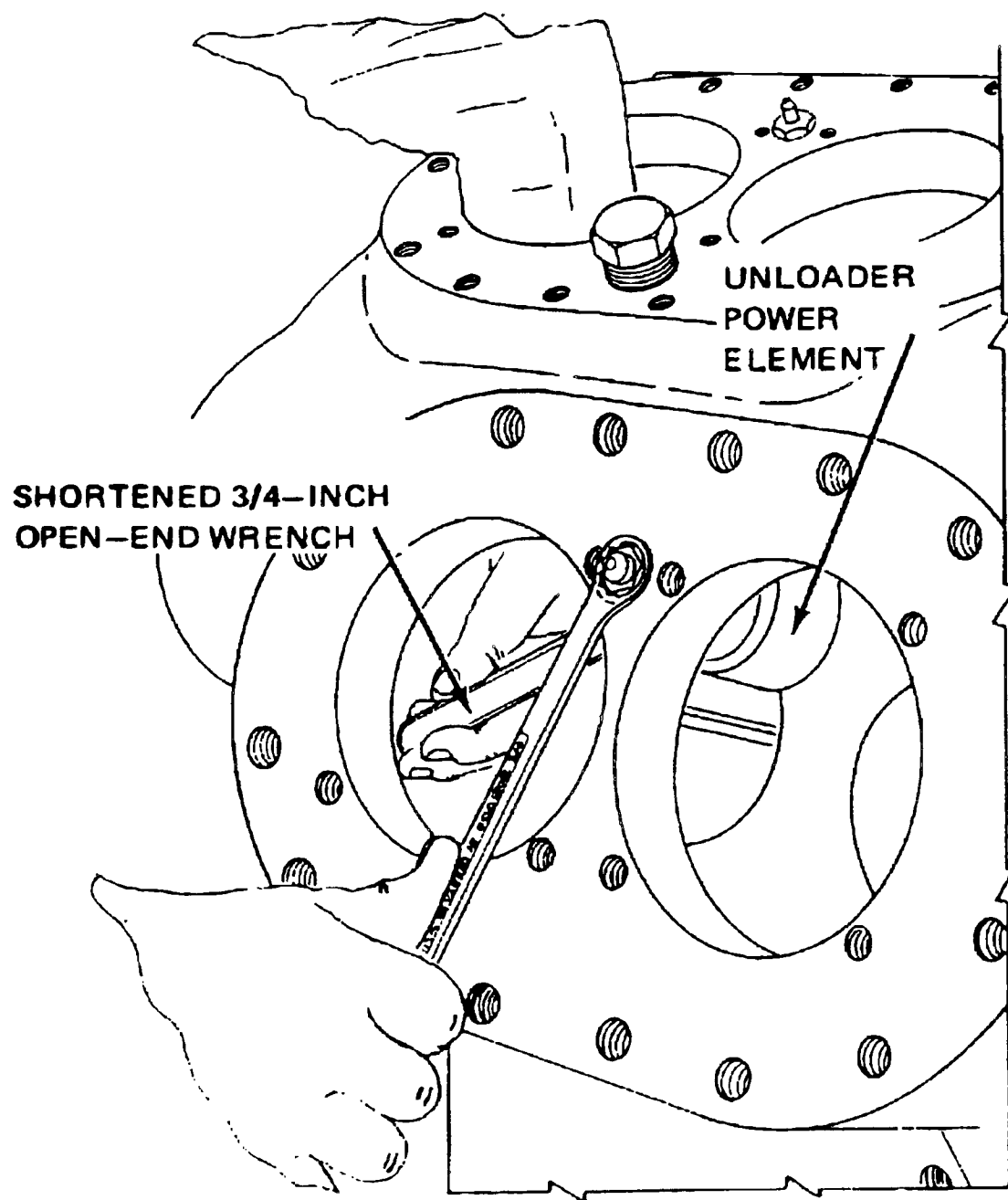


Figure 516-3-68. Installing Unloader Power Element

516-3.2.23.4.5 Servicing Piston and Connecting Rods. To remove pistons and connecting rods, refer to [Figure 516-3-69](#), [Figure 516-3-70](#), and [Figure 516-3-71](#). Proceed as follows:

NOTE

The width of connecting rods at their large end is greater than the inside diameter of the cylinder sleeve. Before a piston and connecting rod assembly can be removed from the compressor housing, remove the cylinder sleeve. Then the piston and connecting rod assembly can be pulled outward from the compressor.

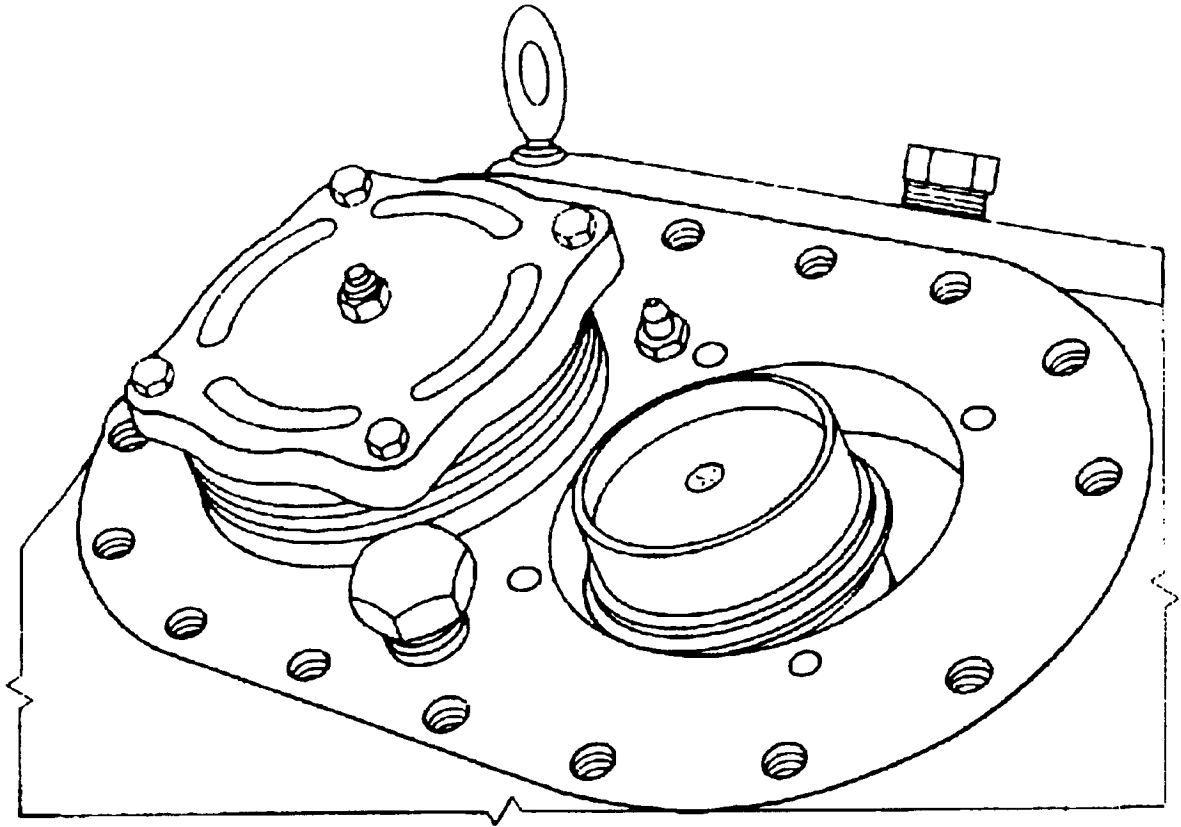


Figure 516-3-69. Removing Piston and Connecting Rods

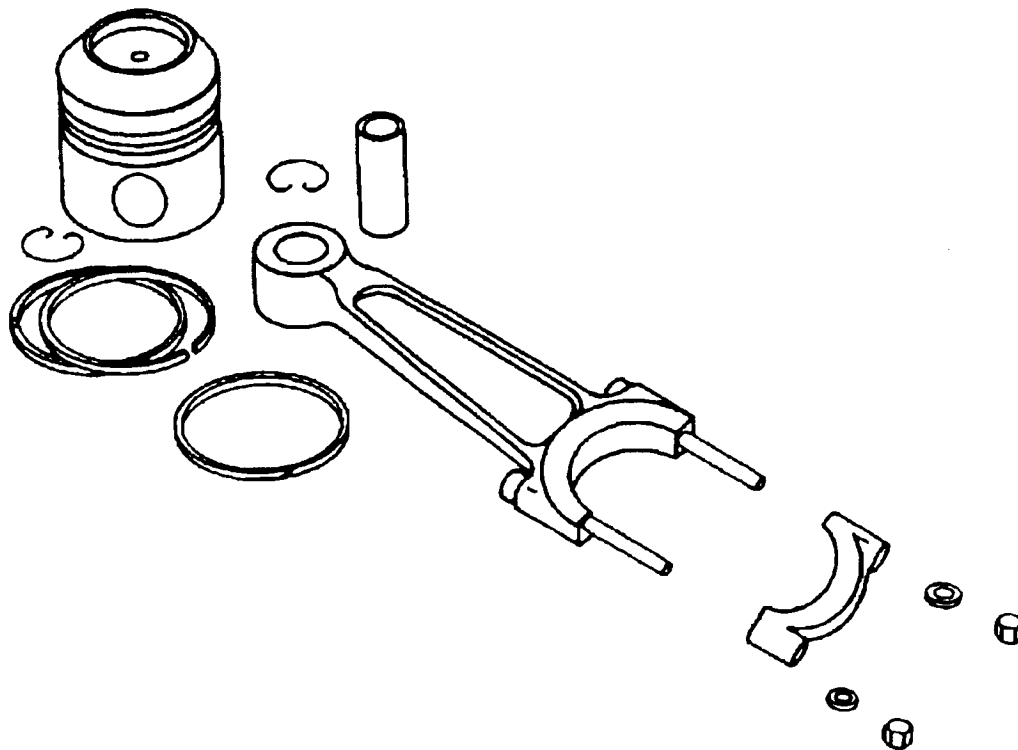


Figure 516-3-70. Piston and Connecting Rod

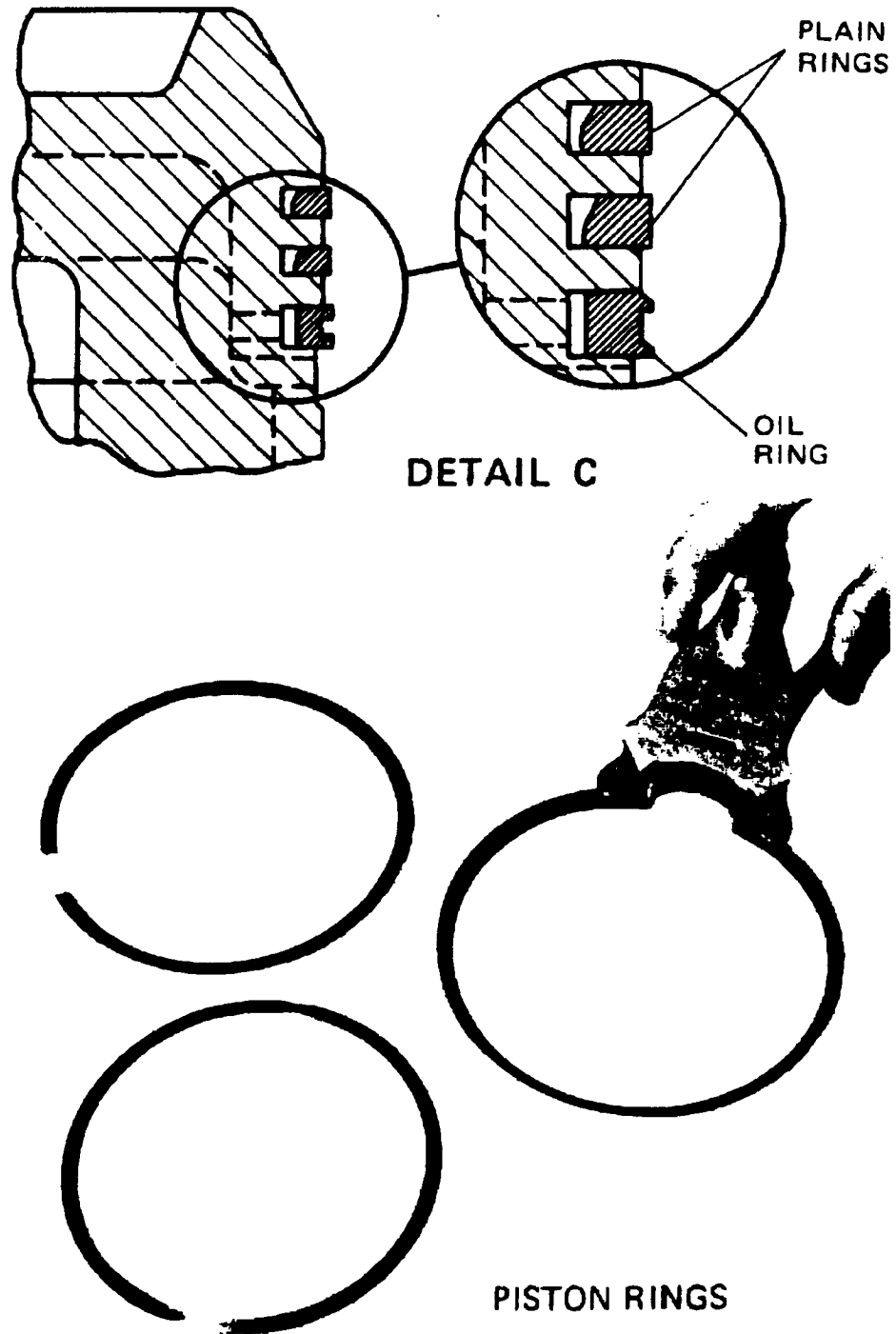


Figure 516-3-71. Installing Piston Rings

1. Recover the refrigerant from the compressor and drain the oil from the crankcase.
2. Remove the suction and discharge valve assemblies. Allow the cylinder sleeve and unloader sleeve to remain in place in the housing.
3. Remove the crankcase hand hold cover plate(s).
4. With cylinder sleeves in place, rotate the crankshaft to a position that will permit ready access to connecting rod bolts to be removed. Loosen nuts and remove the lower half of the connecting rod bearing. Note the identification number stamped on the half-bearing just removed.
5. Ensure that the upper half of the connecting rod bearing remains in place on its crankpin. Rotate the crankshaft to the point where the piston is very near the top of its stroke.
6. Remove the cylinder sleeve and unloader sleeve. Refer to paragraph [516-3.2.23.4](#).
7. Lift out the piston and its connecting rod. Note that the identification number stamped on the upper half of the rod bearing matches the number on the lower half of the rod bearing. These numbers shall ALWAYS match.

CAUTION

Never rotate the crankshaft where one or more piston and connecting rod assemblies are in place unless the related cylinder sleeve or sleeves are in their proper position in the compressor housing. If this caution is not observed, serious damage may occur.

CAUTION

When the bottom half of the rod bearing has been removed and it is necessary to rotate the crankshaft, make certain that the upper half of the rod bearing does not leave its proper place on its crankpin.

8. Remove piston assemblies ONE AT A TIME, repeating steps 4 through 11 for each piston assembly. Proceed to step 13.
9. Remove piston pin retaining rings.
10. Push the piston pin out of the piston.
11. Remove the connecting rod.
12. Remove piston rings.
13. Clean, dry, and oil all parts.

516-3.2.23.4.6 To install the piston and connecting rod assemblies, proceed as follows:

1. The latest compressors use a piston with two plain rings and one oil ring ([Figure 516-3-71](#)). When installing rings, use a ring expander and spread rings only enough to slide them over the piston. Install the oil ring in

the bottom groove first. This is the beveled ring and shall be installed as shown in [Figure 516-3-71](#). Next, install rings in the top grooves. Be sure the dot on rings is toward the top of the piston. Check that all rings compress freely.

2. Set the piston with its top surface down on a bench. Apply clean compressor oil to the piston and connecting rod. Insert the small end of the rod into the piston and slide the piston pin into position. The pin is a sliding fit into the piston and rod. Install retaining rings in each side of the piston.
3. Install cylinder sleeves and piston assemblies, when reused, in their original locations in the compressor housing. Remove the lower half of the connecting rod bearing, allowing connecting rod bolts to remain in position. Check to see that numbers on the two halves of the bearing are matched and that they are on the same side of the connecting rod. Apply a few drops of oil to the crankpin. Insert the piston and connecting rod assembly through the cylinder bore and carefully position the upper half of the connecting rod bearing on its crankpin. Insert the unloader sleeve and cylinder sleeve (paragraph [516-3.2.23.4](#)).
4. Install the lower half of the connecting rod bearing as described in step 3. Using an accurate torque wrench, tighten nuts evenly to a torque of 260 inch-pounds. Hand-turn the crankshaft to ensure there is no binding. Install all piston assemblies, turning the shaft after each rod is installed to be sure no binding exists.
5. Make sure that the compressor crankcase is clean. Install crankcase hand-hold cover plates. Fill the crankcase to the proper level with new oil.
6. Reinstall the suction and discharge valves and the compressor top heads, making sure they are in their original locations, and reconnect the discharge manifold and top heads, using new gaskets as required.
7. Evacuate the compressor.

516-3.2.23.4.7 Main Bearings. Handle main or crankshaft bearings with care to avoid dents and scratches. They are finished to exact tolerances and replacement bearings shall not be scraped or fitted. If one main bearing is replaced, remove the other bearing or bearings for careful examination. If any signs of wear are visible, replace all bearings. It is recommended that the oil be drained from the compressor crankcase and new oil installed when one or more main bearings require replacement. On 4-, 6-, and 8-cylinder compressors, main bearings can be replaced without removing the crankshaft. On 12- and 16-cylinder compressors, it is necessary that connecting rods be removed, and that the crankshaft with the center main bearing be removed from the compressor as a unit.

516-3.2.23.5 Pump End Main Bearings. To replace the compressor pump end main bearing ([Figure 516-3-72](#), [Figure 516-3-73](#) and [Figure 516-3-74](#)), proceed as follows:

1. Recover the refrigerant from the compressor.
2. Drain the oil from the crankcase.
3. Remove the oil pump.
4. Disconnect capacity control oil lines, the oil supply tube, and the oil line feeding the shaft seal.
5. Remove bearing head screws and remove the bearing head from the compressor.
6. Using the bearing removal tool (York part no. 364-37051), remove the bearing from the bearing head.
7. Clean the bearing head thoroughly using an approved safety solvent.
8. Apply clean compressor oil to the outside of the new bearing. Using the bearing removal tool, pull the new bearing into the bearing head, taking care that the bearing squarely enters the bearing head. Continue to pull the bearing into the bearing head until the bearing is 1/16 inch below the surface in the inboard end of the bearing head.

9. Inspect the journal on the end of the crankshaft to see that it is clean and free of nicks or burrs.
10. Oil the journal on the crankshaft and the inside of the bearing.
11. Reassemble the bearing head to the compressor using a new gasket. See [Table 516-3-5](#) for capscrew torques. Rotate the crankshaft to see that no binding exists.

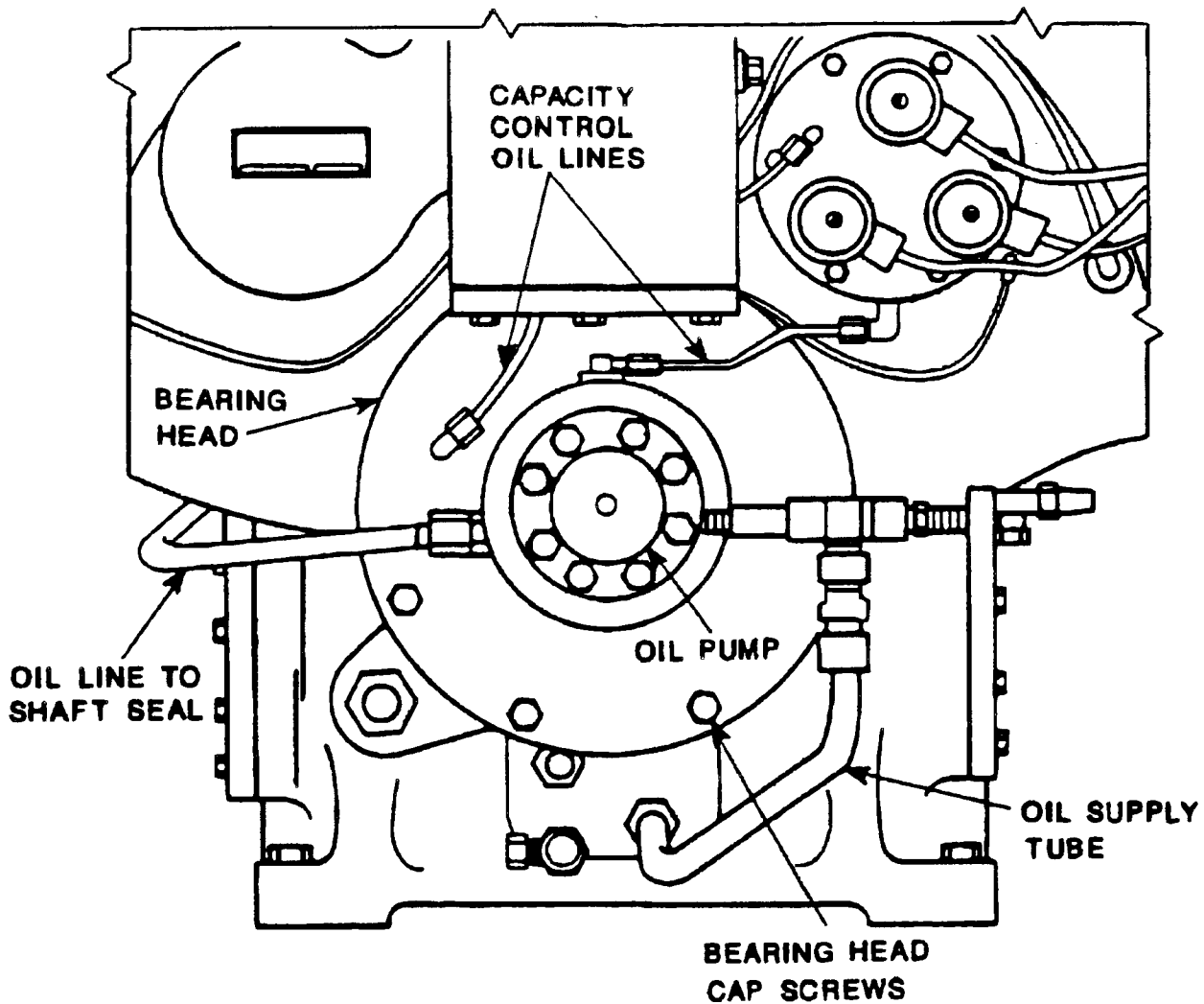


Figure 516-3-72. Oil Pump Bearing Head

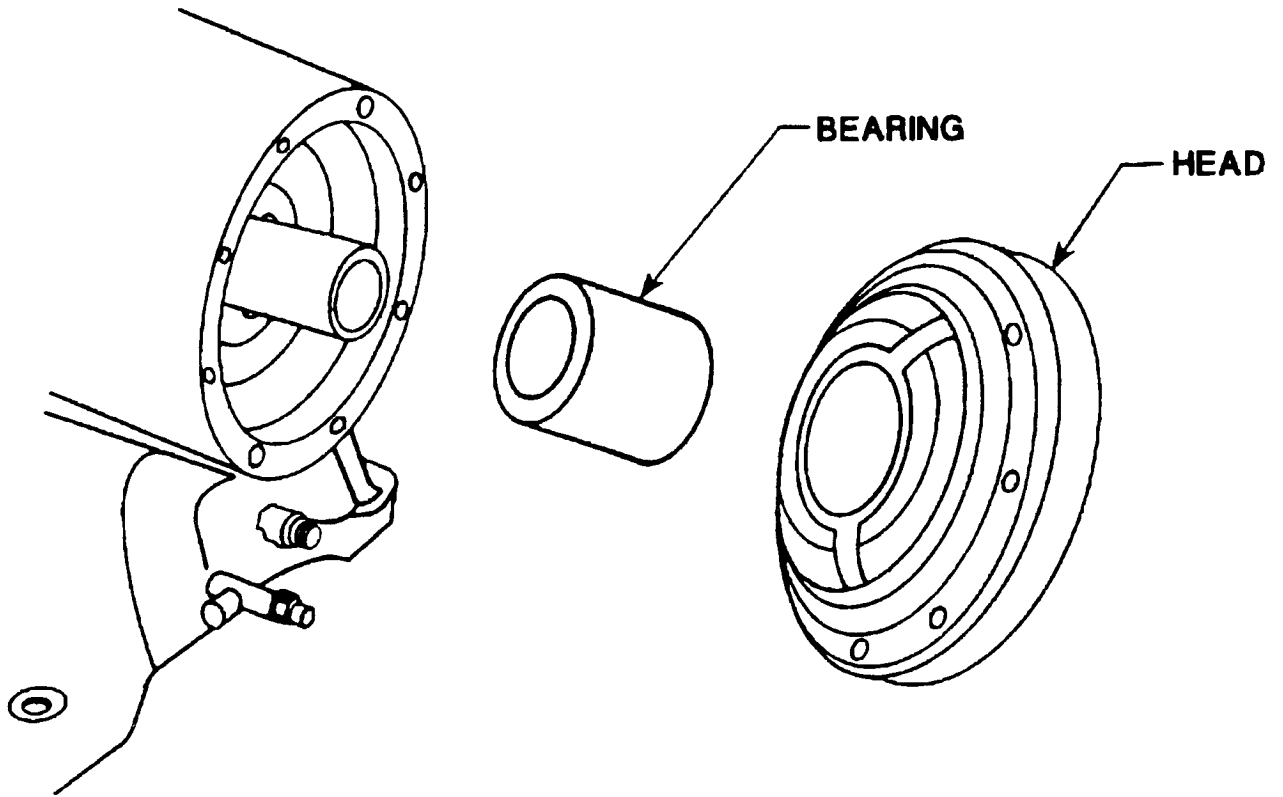


Figure 516-3-73. Pump End Bearing Head and Bearing

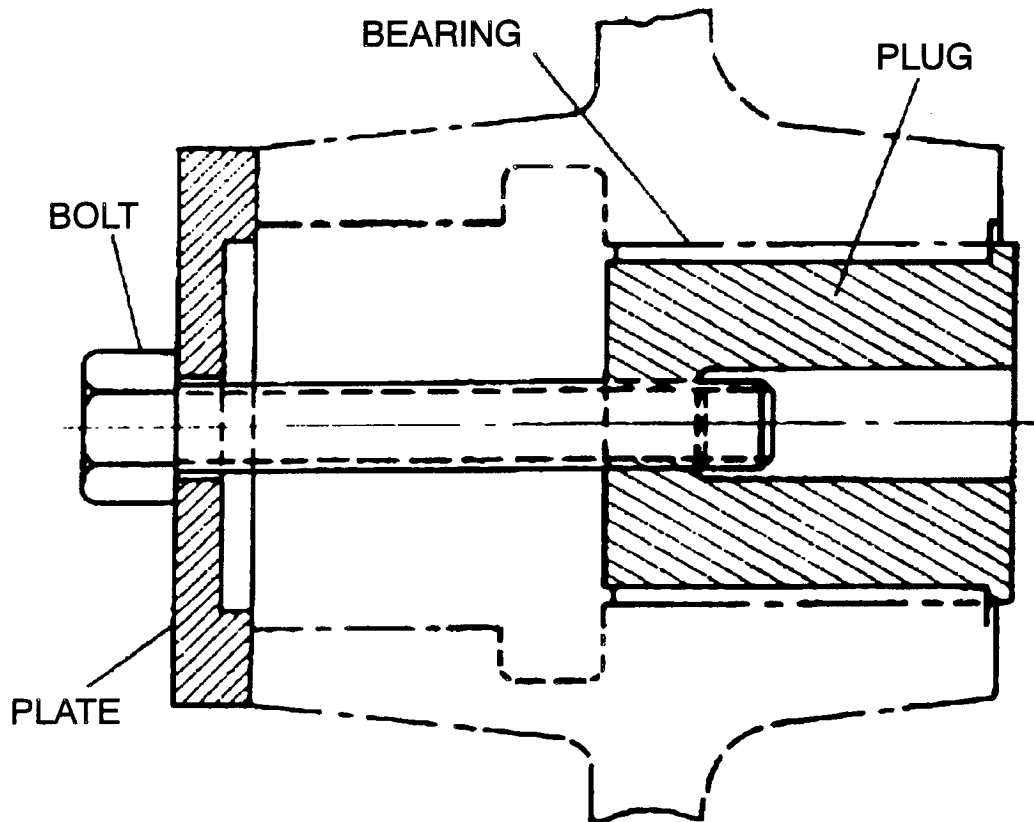


Figure 516-3-74. Bearing Removal Tool

12. Reassemble the oil pump and connect the oil lines and capacity control lines.
13. Fill the compressor with new oil.
14. Evacuate the compressor.

516-3.2.23.5.1 Shaft Seal End Bearings. To replace the compressor shaft seal end bearing, proceed as follows ([Figure 516-3-75](#) and [Figure 516-3-76](#)):

1. Recover the refrigerant from the compressor.
2. Drain the oil from the crankcase.
3. Rotate the crankshaft so the keyway is at the bottom. Remove the flexible coupling or the compressor fly-wheel and the key.
4. Remove the compressor shaft seal. Refer to paragraph [516-3.2.23.6.1](#). Remove the shaft seal spacer; it is positioned on the compressor by two roll pins.
5. Using retaining ring pliers, as shown in [Figure 516-3-75](#), remove the remaining ring, taking care that the compressor crankshaft is not marked or damaged in any way.
6. Remove the shaft seal collar and the locking ball. Use care when removing the ball so that it is not lost.
7. Remove the bearing capscrews.

8. Using two 3/8-inch, 16 capscrews inserted into jacking holes in the bearing flange, carefully remove the bearing from the compressor.

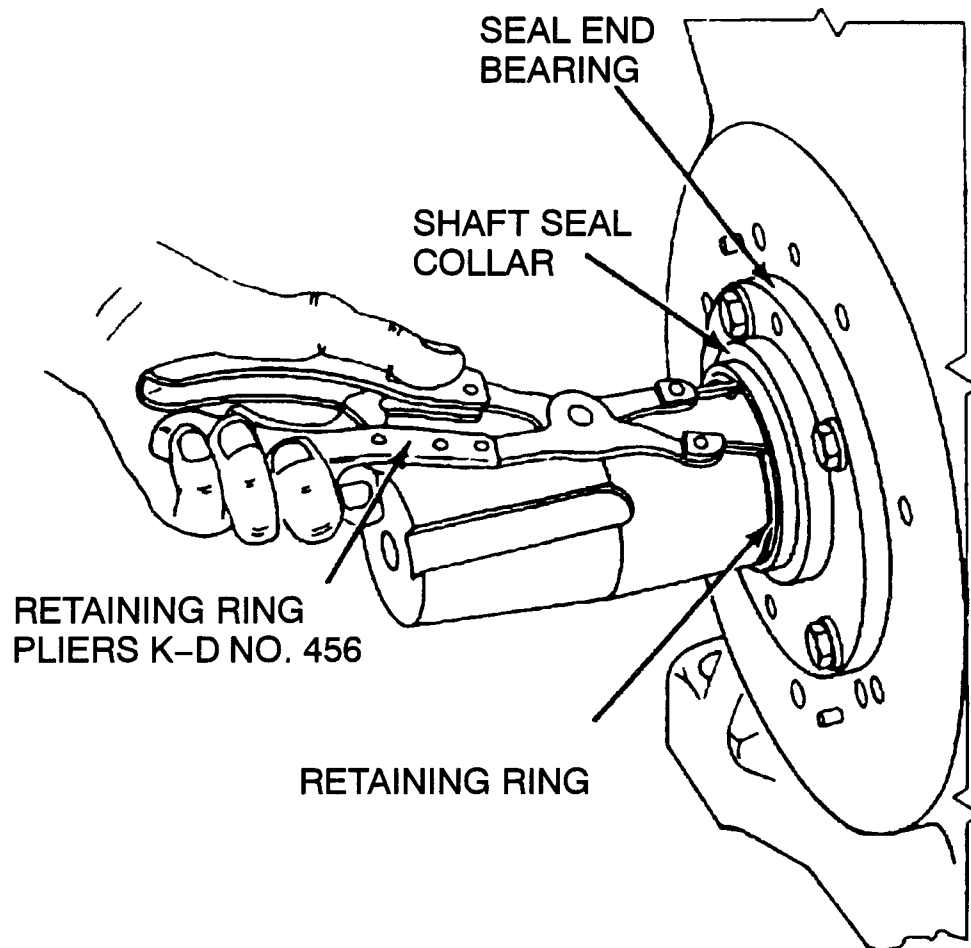


Figure 516-3-75. Removing Crankshaft Retaining Ring

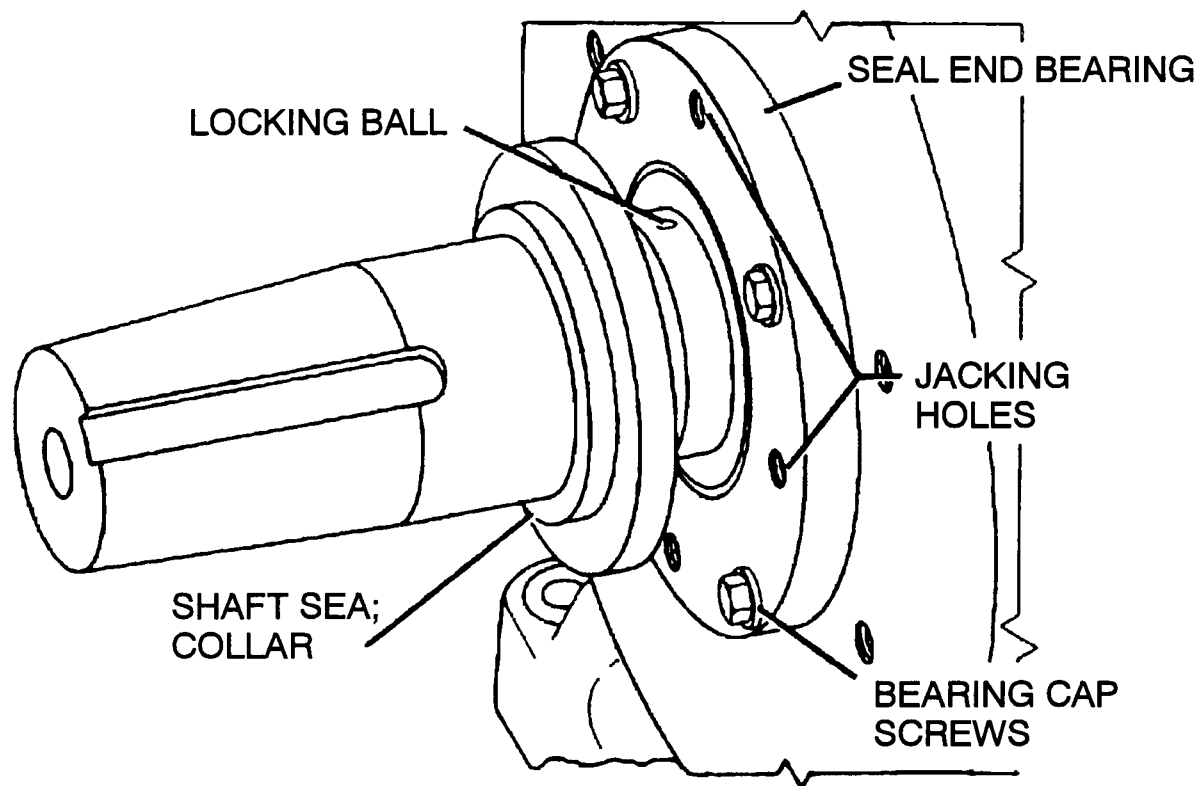


Figure 516-3-76. Seal End Bearing

9. Inspect the journal on the end of the crankshaft to see that it is clean and in good condition.
10. Oil the journal on the crankshaft, and the inside and outside surfaces of the new bearings.
11. Slide the new bearings onto the crankshaft, being careful to avoid damage. As the bearings are being inserted, raise the shaft, as necessary, to take the weight off the bearing. Turn the bearing to the proper position for the four bolt holes in the bearing flange to align with holes in the compressor housing.
12. Insert the four bearing capscrews and flat washers. Tighten capscrews to the proper torque (see [Table 516-3-5](#)).
13. Install the locking ball, shaft seal collar, and retaining ring. Be careful when installing the retaining ring so that the crankshaft is not damaged.
14. Install the shaft seal spacer and shaft seal. Refer to paragraph [516-3.2.26.1](#). Rotate the crankshaft to see that no binding exists.
15. Reconnect the oil supply line.
16. Install the drive components, fill the compressor with new oil, and evacuate the compressor.

516-3.2.23.5.2 Center Main Bearing. For 12- and 16-cylinder models, refer to [Figure 516-3-77](#). The center main bearing on 12- and 16-cylinder models is a two-piece, steel-backed, babbitt type that fits into a spider-type shell, cast in two halves which bolt together on the crankshaft journal. The shell of the upper half is provided with a cast boss that extends to either side of the shell. This boss is split vertically and is provided with a longitudinal hole for the locking bolt and two cone-shaped sleeves that can be forced into the hole when the nut is drawn up

to expand the top half and lock the bearing into position in the housing bore. To replace the center main bearing on the 12- and 16-cylinder compressor, proceed as follows:

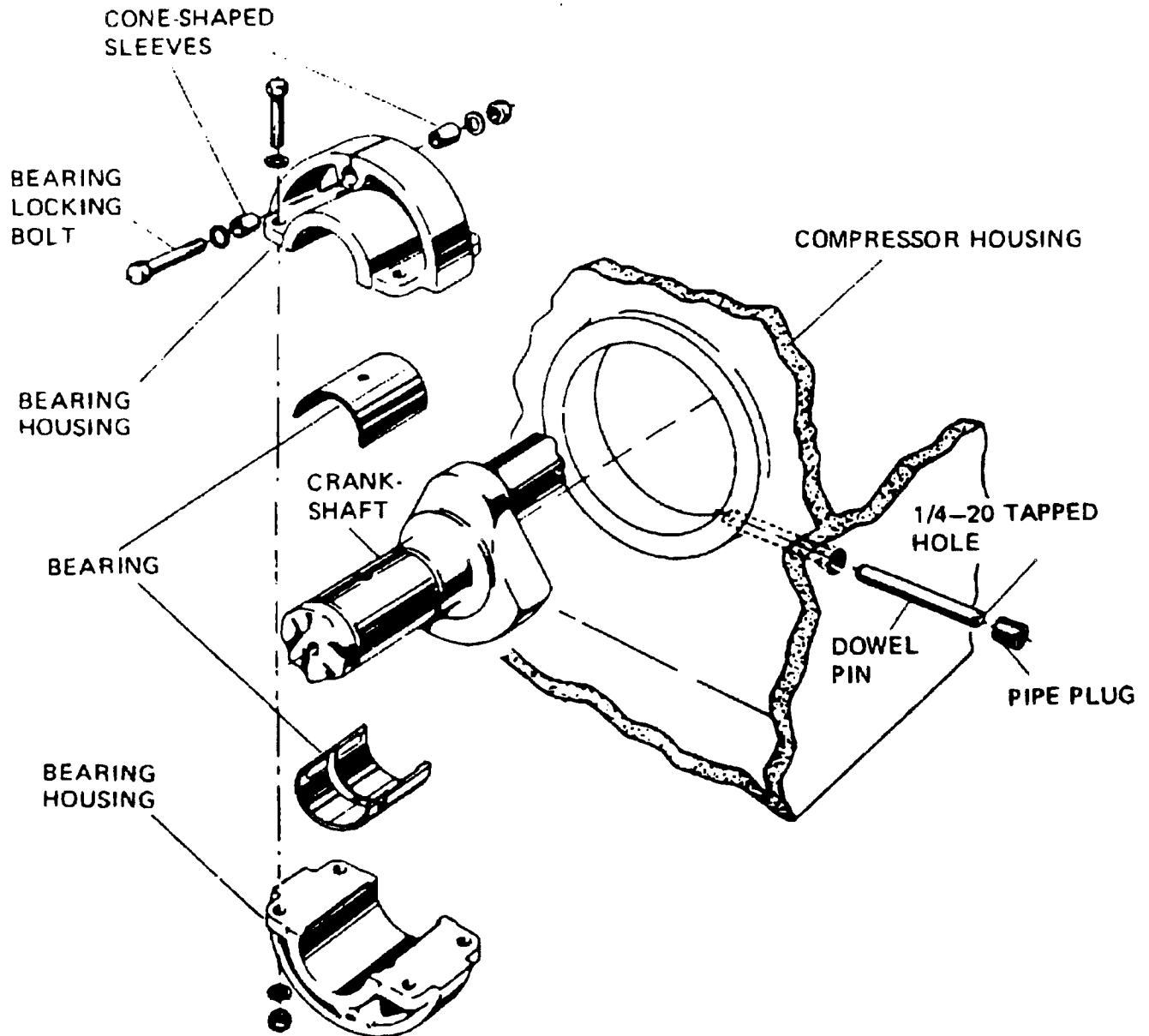


Figure 516-3-77. Center Main Bearing - 12- and 16-Cylinder Compressors

1. Recover the refrigerant from the compressor.
2. Remove the following parts using respective procedures outlined in this manual:
 - a Crankcase cover plates
 - b Shaft seal
 - c Discharge manifolds
 - d Top heads
 - e Suction and discharge valve assemblies
 - f Cylinder sleeve assemblies

g Piston and connecting rods

h Pump end bearing head

3. Remove or loosen the bearing lock bolt and two cone-shaped sleeves in the top half to free the center main bearing assembly from the compressor housing or crankcase bore.
4. Remove the center main bearing dowel pin. This pin is provided with a hole tapped 1/4-20 for inserting a threaded rod about 10 inches long for pulling out the dowel pin. Note that a pipe plug is inserted in the dowel pin hole from the outside of the compressor housing. Remove this plug to gain access to the dowel pin (Figure 516-3-77).
5. With the bearing loosened from its bore in the compressor housing, carefully move the crankshaft, with center main bearing attached, out of the compressor housing through the oil pump end, using a rod slipped into the threaded hole for the flexible coupling capscrew. Avoid any contact of the crankshaft with the compressor housing.
6. Rest the shaft on wood blocks; remove the four bolts, nuts, and lockwashers that hold the two halves of the bearing together; and then remove the complete bearing. Remove the two babbitt bearings from the bearing housing. Examine the crankshaft journal carefully; if signs of wear or roughness are present, replace the crankshaft or hone the journal to satisfactory condition. Check to be sure the oil hole and orifice are open in the bottom half of the bearing housing.
7. Place new babbitt bearings into the two halves of the bearing housing, taking care that the tab on the bearing fits into the notch on the bearing housing. Oil the crankshaft journal and install the new main bearing assembly on the center journal on the crankshaft, making sure that the bottom half is turned, so that the oil drain hole faces the oil pump end when the shaft is installed and that the four nuts and lockwashers are tightened to the proper torque (60 foot-pounds), as shown in Table 516-3-5. Rotate the bearing to be sure no binding exists. Put the bearing locking bolt, two cone-shaped sleeves, and the nut and lockwasher in position loosely in the hole in the top half of the bearing.
8. Place the crankshaft (and center main bearing assembly) into the compressor housing from the oil pump end, carefully lift the shaft into position, and enter the bearing in its bore in the housing. Move the shaft and bearing into position, checking the dowel pin on the threaded rod until it seats in its hole in the shell of the lower bearing half. Tap the dowel pin lightly and remove the threaded rod. Install the pipe plug in the hole in the housing using an approved thread-sealing compound.
9. Install the shaft seal end bearing. Refer to paragraph 516-3.2.23.5.1. Rotate the crankshaft as this bearing is installed to ensure there is no binding. Install the pump end bearing and bearing head. Refer to paragraph 516-3.2.23.5. Turn the crankshaft again to see that no binding exists. Tighten the center main bearing locking bolt to the required torque (20 foot-pounds) (see Table 516-3-5) and lock the bearing securely in position. Turn the crankshaft to be sure no binding exists.
10. Fill the crankshaft with oil to the bottom of the cover plate holes and reassemble the flexible coupling. Evacuate the air from the compressor, admit the refrigerant, and test for leaks. With the hand oil pump (York part no. 470-10654) attached to the compressor oil charging valve, pump in sufficient oil to bring the level to the halfway point on the upper oil sight glass.

516-3.2.23.6 York (2-5/8 by 2-1/4) F Series Compressor Service. Before opening compressor for servicing, review procedure for pumping down (paragraph 516-3.2.23.2). See Table 516-3-6 for torque values.

**Table 516-3-6. THREADED FASTENER TORQUES, FN32A
COMPRESSOR**

Location	Thread	Torque
Sight glass	1/4-20 UNC	40-50 in-lb.
Capacity control valve	1/4-20 UNC	73-83 in-lb.
Discharge cage center	5/16-24 UNF	20-21 ft-lb. *
Oil pump	5/16-18 UNC	19-22 ft-lb.
Capacity control valve	5/16-18 UNC	32-37 ft-lb.
Connecting rod	5/16-24 UNF	20-21 ft-lb. *
Handhole cover	3/8-16 UNC	34-40 ft-lb.
Seal cover plate	3/8-16 UNC	34-40 ft-lb.
Discharge cage corner	3/8-16 UNC	34-40 ft-lb. *
Suction manifold	3/8-16 UNC	34-40 ft-lb.
Discharge manifold	7/16-14 UNC	55-64 ft-lb.
Bearing head	7/16-14 UNC	55-64 ft-lb.
Cylinder head	7/16-14 UNC	55-64 ft-lb.
Cylinder head	7/16-14 UNC	55-64 ft-lb.
Discharge stop valve	7/16-14 UNC	55-64 ft-lb.
Suction stop valve	1/2-13 UNC	84-97 ft-lb.
Crankshaft end	9/16-12 UNC	122-141 ft-lb.
*Critical item: Hand torque to value shown.		

516-3.2.23.6.1 Discharge and Suction Valves, Cylinder Sleeves, and Unloader Power Elements. To remove these parts, refer to [Figure 516-3-78](#), [Figure 516-3-79](#), [Figure 516-3-80](#), and proceed as follows:

1. Disconnect the discharge manifold from the compressor top heads and remove the top heads from the compressor.
2. Remove the four capscrews that secure the discharge valve cage assembly to the housing and lift out the discharge valve cage. The inner discharge plate, suction valve, and suction valve springs will come out with the cage.
3. Remove the discharge valve screw and its beveled gasket. Then lift out the inner plate, discharge valve, and springs ([Figure 516-3-78](#)).

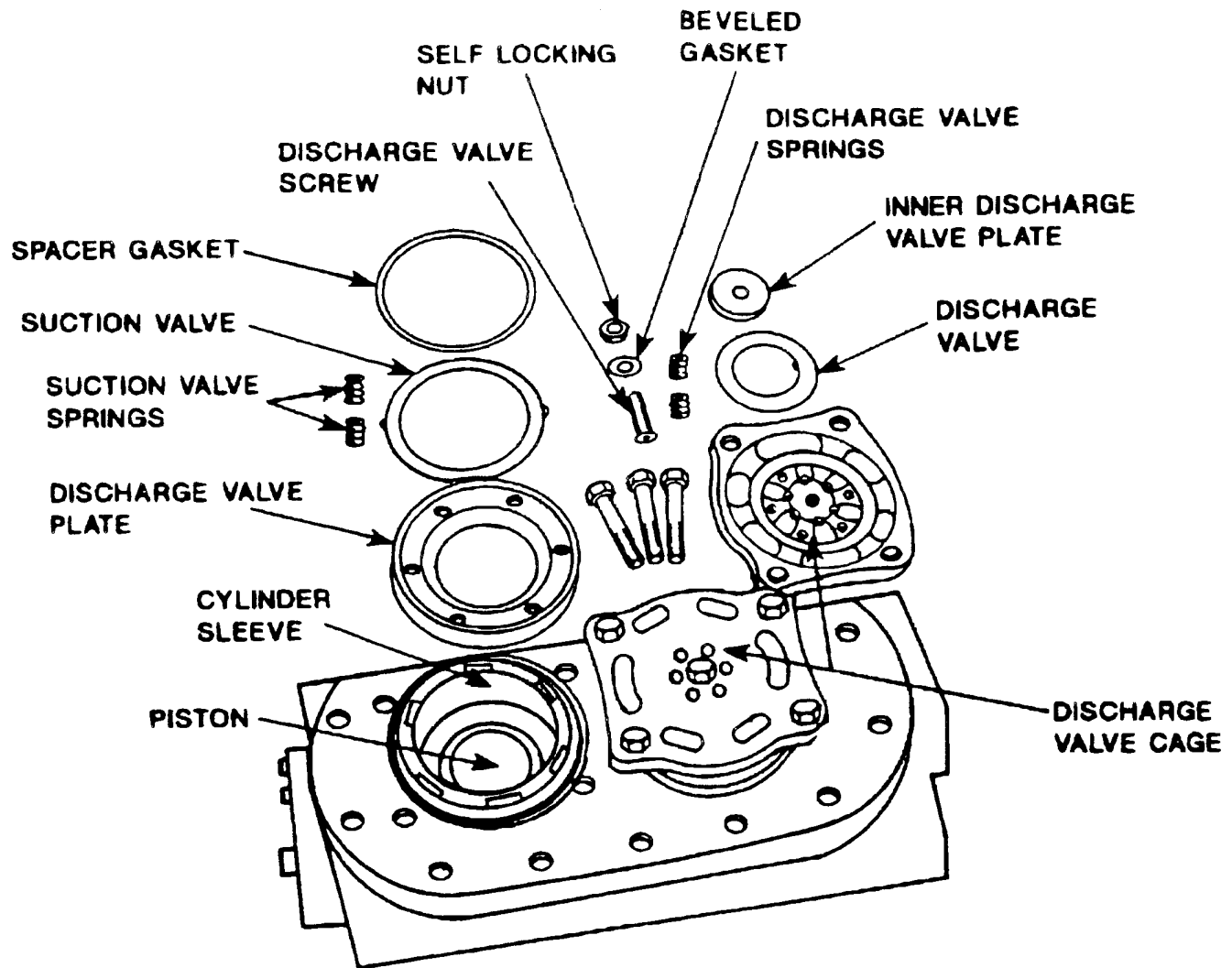


Figure 516-3-78. Removing Discharge Valve Assembly

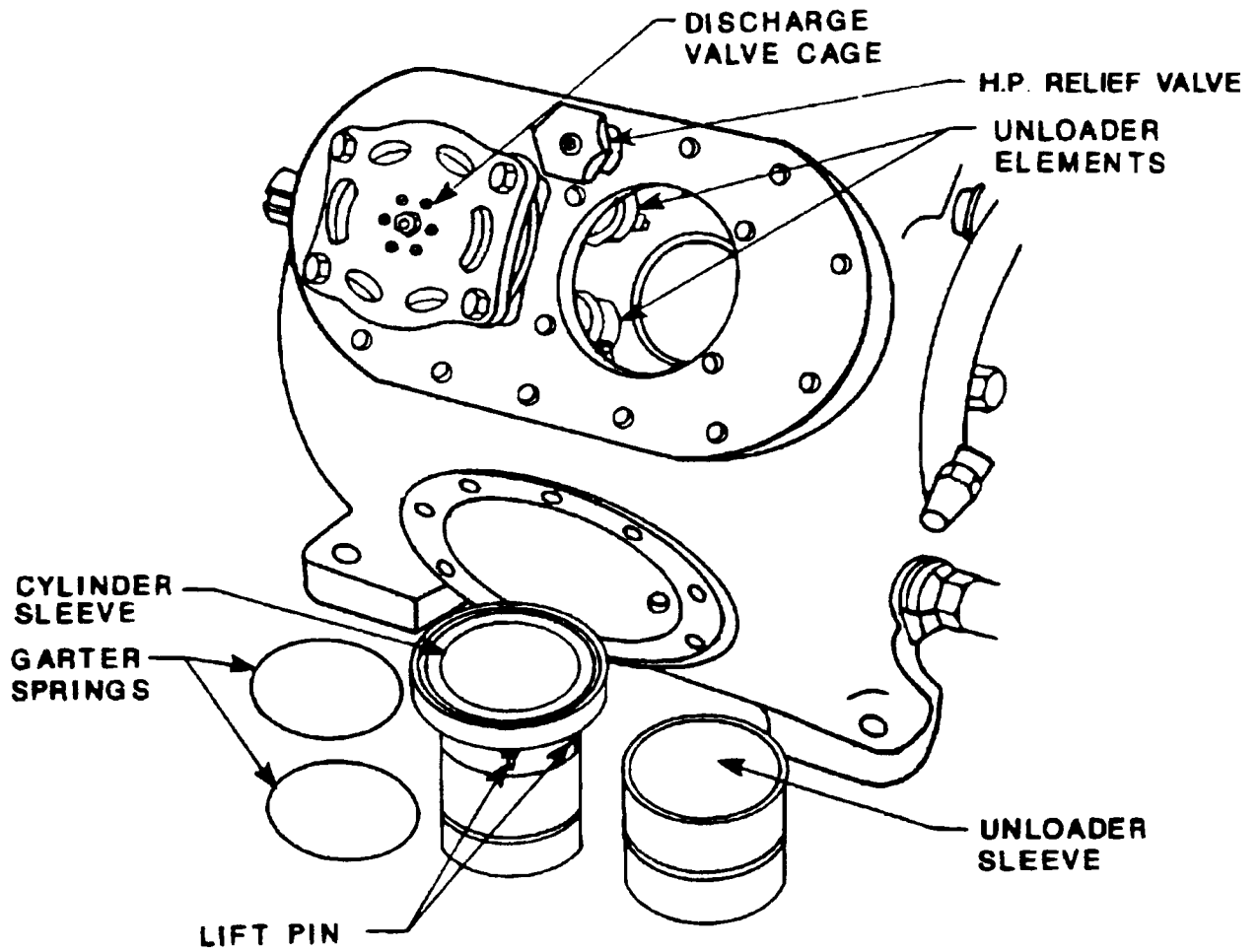


Figure 516-3-79. Removing Cylinder and Unloader Sleeves

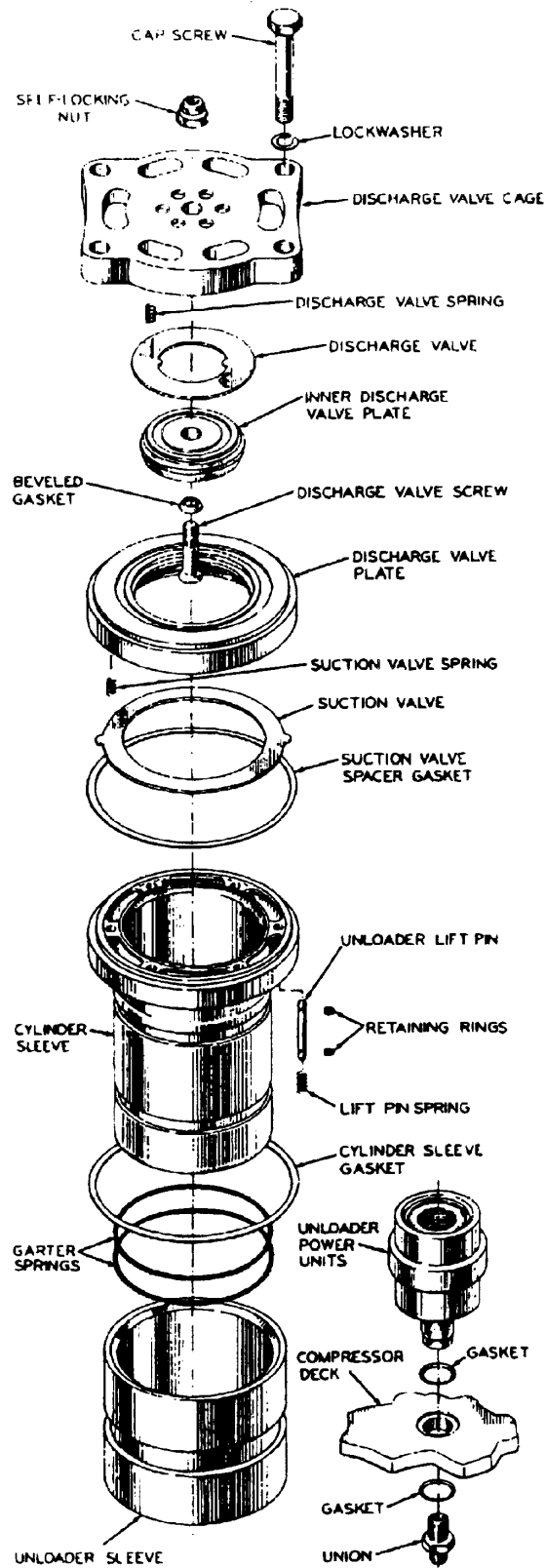


Figure 516-3-80. View of Cylinder Sleeve and Valve Assembly

4. Lift off the discharge valve plate, suction valve springs, suction valve, and spacer gasket.
5. Lift the cylinder sleeve, with unloader lift pins, out of the compressor housing ([Figure 516-3-79](#)). Lift pins are fastened in place by a retaining ring at each end. To remove lift pins, push the pin up against the spring, remove the upper retaining ring, and pull the pin and spring out from the bottom ([Figure 516-3-80](#)).
6. Remove garter springs from their grooves in the outside surface of the cylinder sleeve.
7. Lift the unloader sleeve out of the housing.
8. Unscrew the unloader power element and lift it out of the unit.
9. Clean, dry, and oil all parts. If it was necessary to remove lift pins, renew retaining rings. Inspect valve seats for grooves and renew, if necessary.

516-3.2.23.6.2 Install Unloader Power Elements, Cylinder Sleeves, and Suction/Discharge Valves. If an unloader power element fails to function, a complete element will be furnished for replacement purposes. Read paragraph [516-3.2.23.6.2.1](#) concerning spacer gaskets before reassembling cylinder sleeves and valves. To install a replacement power element, be sure the gasket is in place in its recess in the compressor deck, then screw the element on the union that protrudes up through the compressor deck ([Figure 516-3-80](#)). To install unloader and cylinder sleeves, refer to [Figure 516-3-78](#), [Figure 516-3-79](#), and [Figure 516-3-80](#), and proceed as follows:

1. Rotate the crankshaft until the piston is positioned at its approximate mid-stroke.
2. Set the unloader sleeve in the housing, with its recessed surface engaged with the projection on the outside circumference of the unloader power element and centered in the bored recess in the compressor deck.
3. Be sure lift pins, with spring and retainer rings, are inserted into the cylinder sleeve ([Figure 516-3-79](#) and [Figure 516-3-80](#)).
4. Install the two garter springs in their grooves in the outside of the cylinder sleeve.
5. Slide the lead-coated copper cylinder sleeve gasket in position under the flange of the cylinder sleeve. Carefully lower the cylinder sleeve over the piston and inside of the unloader sleeve. Push the cylinder sleeve down until it rests firmly on the compressor housing. Do not force the cylinder sleeve. The lower end of the sleeve is chamfered to facilitate entering of the piston. Enter the sleeve squarely into the housing and rotate the sleeve as it is being lowered. If the cylinder sleeve has been properly seated against the housing, it should not bind but should spring up about 1/8 inch because of the action of the unloader pins and springs.
6. Install the suction valve spacer gasket on the flange of the cylinder sleeve and set the bare discharge valve plate on the gasket.
7. Using two pieces of angle iron made locally, temporarily bolt the bare discharge valve plate in place to check piston clearance ([Figure 516-3-81](#)).
8. Using a dial indicator, set the piston on its top dead center. Then check the clearance between the top of the piston and the top of the discharge valve plate. The clearance shall be between 0.030 and 0.035 inch. The thickness of the cylinder sleeve gaskets determines the piston clearance. These gaskets are available in thicknesses of 0.005 and 0.010 inch and should be installed between the housing and cylinder sleeve, as necessary, to obtain a piston clearance of 0.030 to 0.035 inch. When the original gaskets are not damaged, reuse them. After the piston clearance in all cylinders has been checked, remove the discharge valve plate and proceed to assemble the valves.

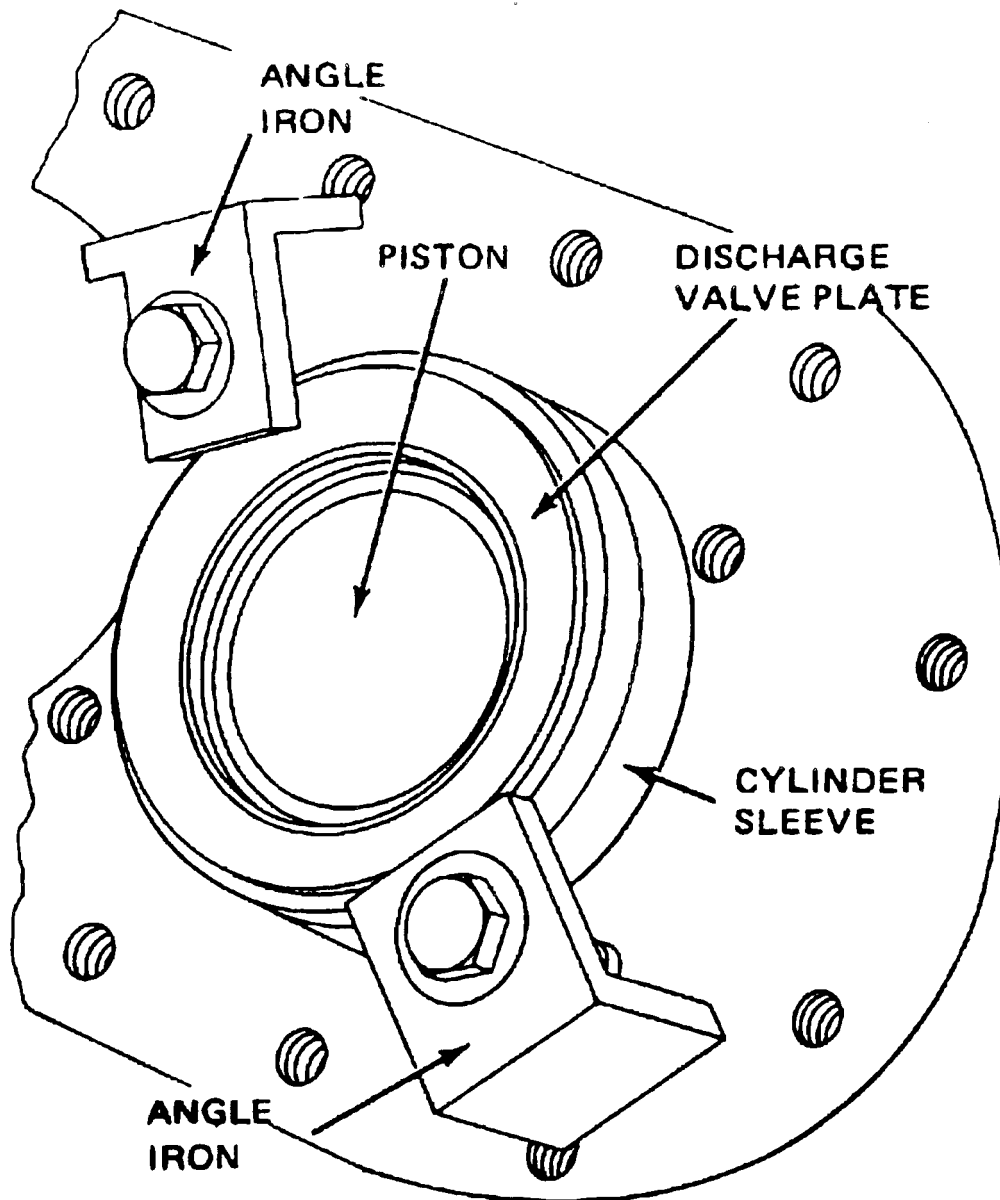


Figure 516-3-81. Clamping Discharge Valve Plates to Check Piston Clearance

516-3.2.23.6.2.1 There are two F series compressor designs in the fleet. The older design of this compressor utilizes spacer gaskets (lead coated copper) between the cylinder sleeves and the compressor deck and between the cylinder sleeves and the discharge valve plate to prevent compressor damage due to insufficient piston clearance ([Figure 516-3-80](#)). These spacer gaskets are not used with the present design cylinder sleeve and discharge valve plate due to the tighter tolerances used in manufacturing the new design parts. During refrigeration operation, with lower suction pressures, a noticeable capacity loss will be experienced if the spacer gaskets are used with the new design parts. The differences involve the discharge valve plate and discharge valve cage assemblies of the compressors. The discharge valve plates on both designs are circular and the discharge valve cages are basically square. However, only the presently designed discharge valve plates have a 3/16 inch V groove on the plate outer circumference and only the presently designed discharge valve cages have beveled turns on each of the four corners. (Where the four cap screws pass through the discharge valve cage, the corners are ground away at an angle on the lower side). If the configuration of the discharge valve plates and cages is the older design, reas-

semble the cylinder and valves assemblies as indicated in paragraph 516-3.2.23.6.2. If the compressor has a mix of old and new discharge valve plates and discharge valve cages, the parts should be changed to be all of the present design. If the discharge valve plate and discharge valve cage are the present design as described above, do not use spacer gaskets when installing the cylinder sleeves and suction/discharge valves.

516-3.2.23.6.3 Suction/Discharge Valve Installation. To install suction and discharge valves, refer to [Figure 516-3-78](#), [Figure 516-3-79](#), and [Figure 516-3-80](#) and proceed as follows:

1. With the spring pocket side of the discharge valve plate up, assemble suction valve springs in their pockets. Set the suction valve in place with valve guides in register with their recesses in the valve plate.
2. To hold the suction valve and springs firmly in place during installation, make up two brass clips over the plate and spring as shown in [Figure 516-3-82](#).

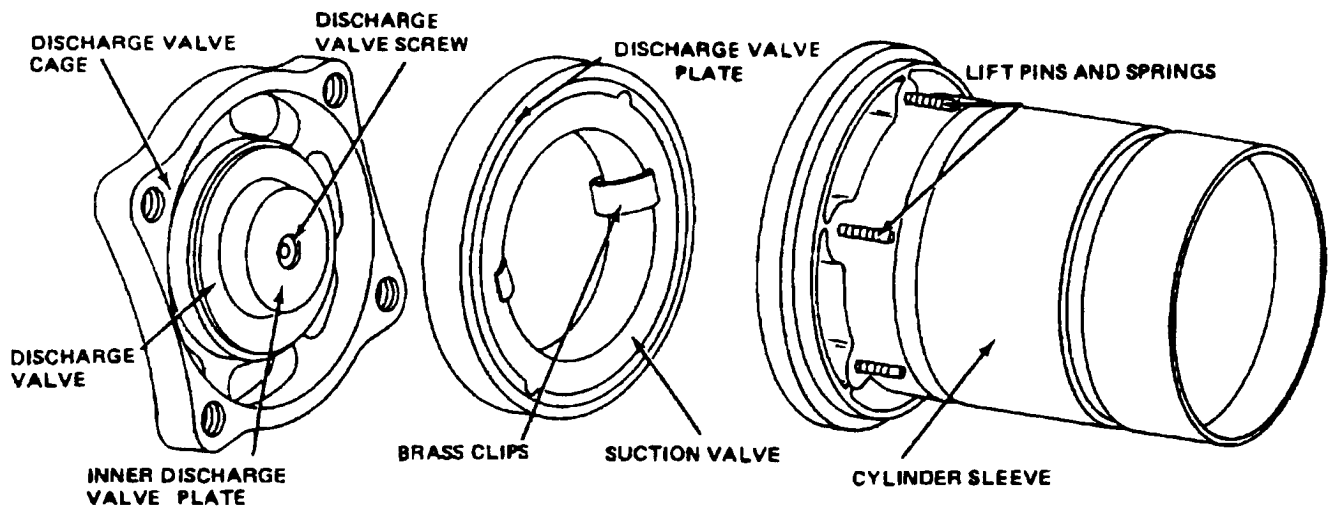


Figure 516-3-82. Valve and Cylinder Sleeve Assembly

3. Assemble the discharge valve cage assembly.
 - a Insert discharge valve springs in their recesses in the valve cage. Set the discharge valve in place with valve guides in register with recesses in the valve cage.
 - b Insert the discharge valve screw with beveled gasket through the inner discharge valve plate and the discharge valve cage. Then bolt the assembly together using the self-locking nut. Torque the self-locking nut to 20-21 foot pounds.
4. Install the suction valve spacer gasket and set the discharge valve plate, with suction valve clipped in place, on the spacer gasket. Then remove the two brass clips.
5. Holding the discharge valve plate in place, set the valve cage assembly on the valve plate and bolt the entire assembly (cylinder sleeve, valve plate, and valve cage) to the housing using capscrews and lockwashers.

516-3.2.23.6.4 Pistons and Connecting Rods. To remove the pistons and connecting rods, refer to [Figure 516-3-83](#) and proceed as follows:

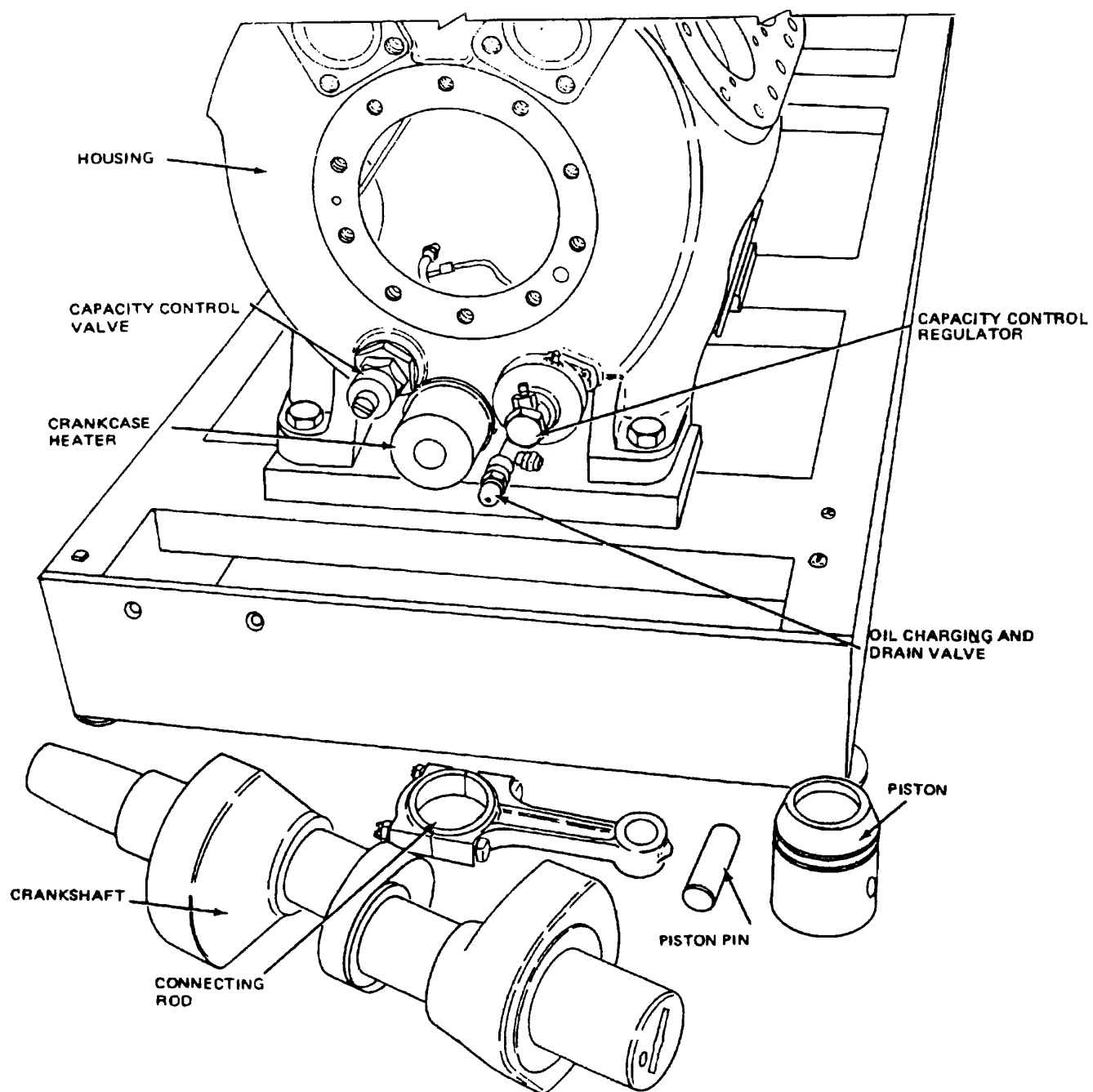


Figure 516-3-83. Removing Pistons, Connecting Rods, and Crankshaft

1. Pump down the compressor and drain the oil from the crankcase.
2. Remove either crankcase hand-hole cover plate.
3. Rotate the crankshaft until connecting rod bolts are conveniently located. Then loosen nuts and remove the lower half of the connecting rod.
4. Rotate the crankshaft until the crank pin is out of the way; then, pull the piston and connecting rod assembly down and remove the assembly from the compressor through the crankcase hand-hole. Keep each rod assembly together and mark each cylinder accordingly to be sure each rod is reinstalled in its original location.

NOTE

Piston and rod assemblies cannot be removed through the top of cylinder sleeves because the width of the connecting rod is greater than the inside diameter of the cylinder sleeve.

5. Remove the piston pin retaining ring then push the piston pin out of the piston.
6. Remove piston rings.
7. Clean, dry, and oil all parts.

516-3.2.23.6.5 Install Pistons and Connecting Rods. To install piston and connecting rod assemblies, refer to [Figure 516-3-83](#) and proceed as follows:

1. Each piston is equipped with two piston rings. The plain (compression) ring sits in the upper groove and the ventilated (oil) ring sits in the lower groove. Install the ventilated ring first, then the plain ring. Use copper or brass strips under rings and spread rings only enough to slide them down over the piston.
2. Set the piston with its top surface down on a bench. Insert the small end of the rod into the piston and slide the piston pin into position. The pin has a sliding fit into the piston and rod. Install the piston pin retaining rings.
3. Remove the lower half of the connecting rod bearing and insert the piston and rod assembly up into the cylinder sleeve from which it was removed. The lower end of the cylinder liner is chamfered to permit easy entrance of the piston and rings.
4. Clean and oil crank pins. Then place the rod over the crank pin, insert proper connecting rod bolts in each rod, and install the lower bearing half. There are no shims or liners between the upper and lower halves of the rod. Stampings on both halves shall be alike, however, and on the same side of the rod. Turn the shaft by hand after each rod is fastened to make sure there is no binding.
5. Clean the crankcase, install the handhole cover plate with gasket, and charge the compressor with oil.
6. Evacuate the compressor.

516-3.2.23.6.6 Crankshaft and Bearings. To remove the crankshaft and main bearings, refer to [Figure 516-3-83](#), [Figure 516-3-84](#), and [Figure 516-3-85](#). Proceed as follows:

1. Pump down the compressor and drain the crankcase.
2. Disconnect the compressor drive.
3. Remove the oil pump assembly as outlined in paragraphs [516-3.2.14.2](#) through [516-3.2.14.5](#).

4. Remove the shaft seal assembly as outlined in paragraph 516-3.2.26.3.
5. Remove piston and connecting rod assemblies as outlined in paragraph 516-3.2.23.6.3.
6. Remove capscrews that secure the pump end bearing head to the housing and remove the bearing head (Figure 516-3-84).
7. Carefully pull the crankshaft out of the compressor through the opening for the pump end bearing head.
8. The pump end thrust collar will come out with the pump end bearing head, but the seal end collar will probably remain in place on the inboard end of the seal end main bearing. Remove both thrust collars from main bearings. A roll pin prevents the collars from turning with the crankshaft (Figure 516-3-84).
9. Using the bearing replacing tool (Figure 516-3-85), pull worn bearings out, and pull new bearings into place. Main bearings are of split sleeve, steel-backed babbitt construction and are pressed into their respective housings at the factory. Figure 516-3-86 illustrates the use of the bearing replacing tool to remove the pump end main bearing and install the seal end main bearing. Since the outboard opening of the pump end bearing head is smaller than the diameter of the bearing, the pump end bearing shall be removed and replaced through the inboard opening (Figure 516-3-84). To remove the pump end bearing, use the bearing bar illustrated in Figure 516-3-86. When replacing either bearing, the bearing tube is used only for removing the bearings. The seal end bearing may be removed or replaced through either the inboard or outboard bearing head opening, since either opening is larger in diameter than the bearing.

NOTE

When pulling new main bearings into place, inboard ends of both bearings shall protrude 1/16 inch beyond the bearing head. This 1/16-inch surface serves as a locating seat for the inside circumference of the thrust collar. Position the bearings within their housing so that the semicircular port in the end of each bearing is located inboard and at the top.

10. Coat bearings with clean refrigerant compressor oil and install thrust collars. Be sure roll pins are in place.

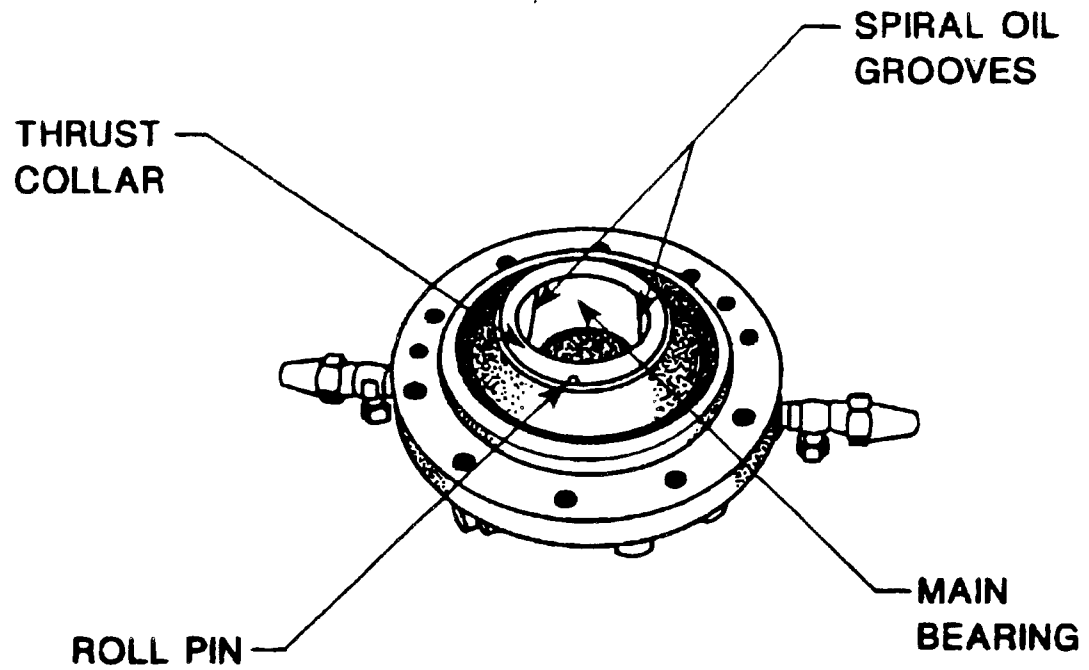


Figure 516-3-84. Inside Pump End Bearing Head

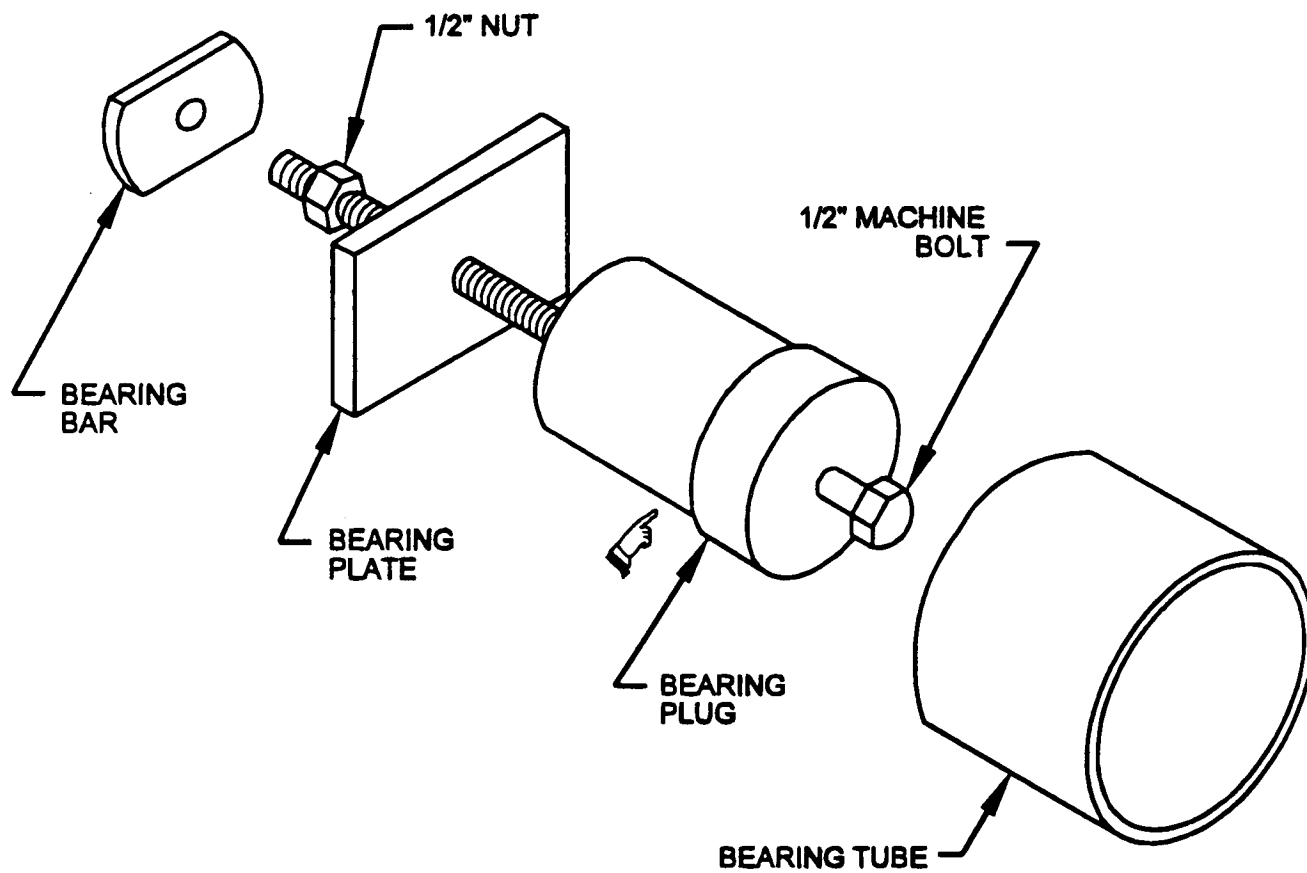


Figure 516-3-85. Bearing Replacement Tool

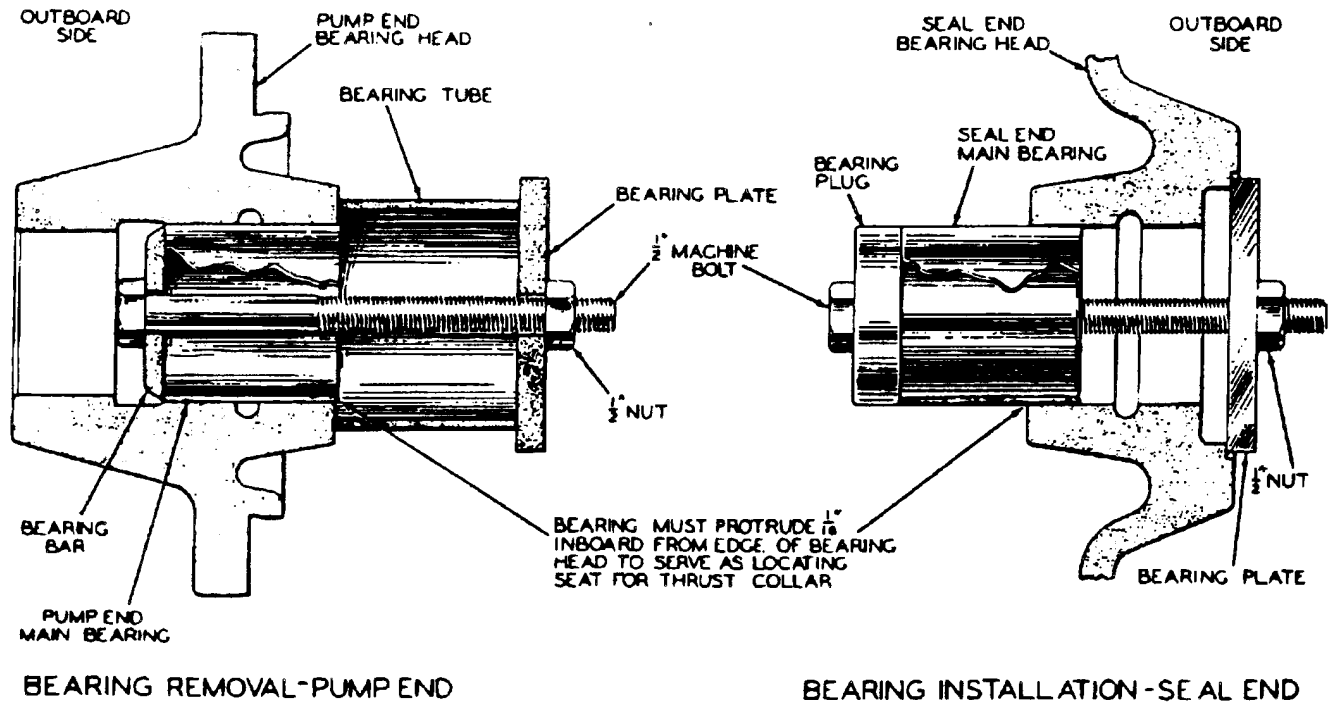


Figure 516-3-86. Replacing Main Bearings

11. Carefully install the crankshaft through the opening for the pump end bearing head. Then install the pump end bearing head with its thrust collar in place.
12. Rotate the crankshaft by hand to be sure it does not bind; then check the axial thrust clearance with a dial indicator. This clearance should be 0.015 to 0.020 inch.
13. Install piston and connecting rod assemblies as outlined in paragraph [516-3.2.23.6.4](#).
14. Install the shaft seal assembly (paragraph [516-3.2.26.1](#) or [516-3.2.26.3](#)).
15. Install the oil pump assembly (paragraphs [516-3.2.14.2](#) through [516-3.2.14.5](#)).
16. Reinstall the compressor drive.
17. Charge the compressor with oil, then evacuate the compressor.

516-3.2.24 CRANKSHAFT SEAL. The crankshaft oil seal is one of the most important components of a refrigerating compressor. It prevents leakage of refrigerant and oil from the system. The seal will perform satisfactorily if extreme care is taken in installing it and if the manufacturer's design, materials, and tolerance are used. Avoid substitutions as the shaft seal is too important an element.

516-3.2.24.1 Reciprocating Compressor Shaft Seal Leakage Criteria. It is desirable to have no measurable shaft seal leakage, but some oil leakage is acceptable. The criteria for scheduling a replacement of a shaft seal is as follows:

- a. Whenever refrigerant leakage can be detected at the shaft seal, replace the shaft seal at the next available time. Compressors that have not been operated for a week or more may experience refrigerant leakage at the seal

because the seal is dry. In this case, operate the compressor as needed, inspect for oil leakage, and reinspect for refrigerant leakage after it has been shut down for an hour.

NOTE

The shaft seal is satisfactory if the oil leakage rate is less than 1 drop of oil every 5 minutes. This leakage rate applies when the air-conditioning or refrigeration plant is operating under steady-state conditions (not fluctuating on capacity control).

- b. The plant may be operated without any restrictions if the oil leakage rate is greater than 1 drop of oil every 5 minutes, but less than 1 drop of oil every minute. Monitor the plant's oil level every 2 hours and add oil periodically to maintain the proper oil level. Replace the shaft seal at the next available time.
- c. If the oil leakage rate is continuous and greater than 1 drop of oil every minute, operate the plant only when no other plant is available. During operation, monitor the compressor sump oil level and shaft seal oil leakage. If the oil leakage rate exceeds 12 drops of oil every minute, the shaft seal could fail completely at any time, resulting in total loss of compressor lubrication. Oil will have to be added at least once per day, as required, to maintain proper oil level. Replace the shaft seal as soon as possible.

NOTE

An oil leakage rate of 12 drops every minute corresponds to 1-1/8 quarts of oil lost per day, while 60 drops every minute corresponds to 5-1/2 quarts of oil lost per day.

NOTE

The leakage rate for a new seal might exceed an acceptable rate until it has a chance to wear in. After seal replacement, the leakage rate for the first 50 hours of operation is not cause for alarm unless it exceeds 15 drops per minute. Monitor shaft seal leakage for the first 50 hours of operation.

516-3.2.25 CARRIER CRANKSHAFT SEAL. The crankshaft oil seal in all current Carrier 5F and 5H compressors is a sleeve type with rotating bellows and integral seal seat. This seal is the service replacement for all earlier seal assemblies. [Figure 516-3-87](#) shows types I and II of this design for 5F20 through 5H126 compressors. Earlier rotating bellows-type seals are shown in [Figure 516-3-88](#) and [Figure 516-3-89](#) and the stationary bellows-type seal is shown in [Figure 516-3-90](#). When removing the stationary bellows-type seal, tap the bellows frame with a plastic hammer if the seal spring pressure does not force the bellows clear of the housing. Observe the following steps before installing the seal:

- a. Be sure pump end bearing head is in place for proper positioning of seal on crankshaft.
- b. Be sure shaft extension, especially edges of the keyway, are free of sharp edges and nicks. Also, the shaft shall be clean and free of rust. Polish the shaft with crocus cloth.
- c. Check seal assembly to be sure the bellows is properly in place and is clean.
- d. Apply compressor oil to seal assembly, making sure that the bellows and carbon ring are completely saturated.

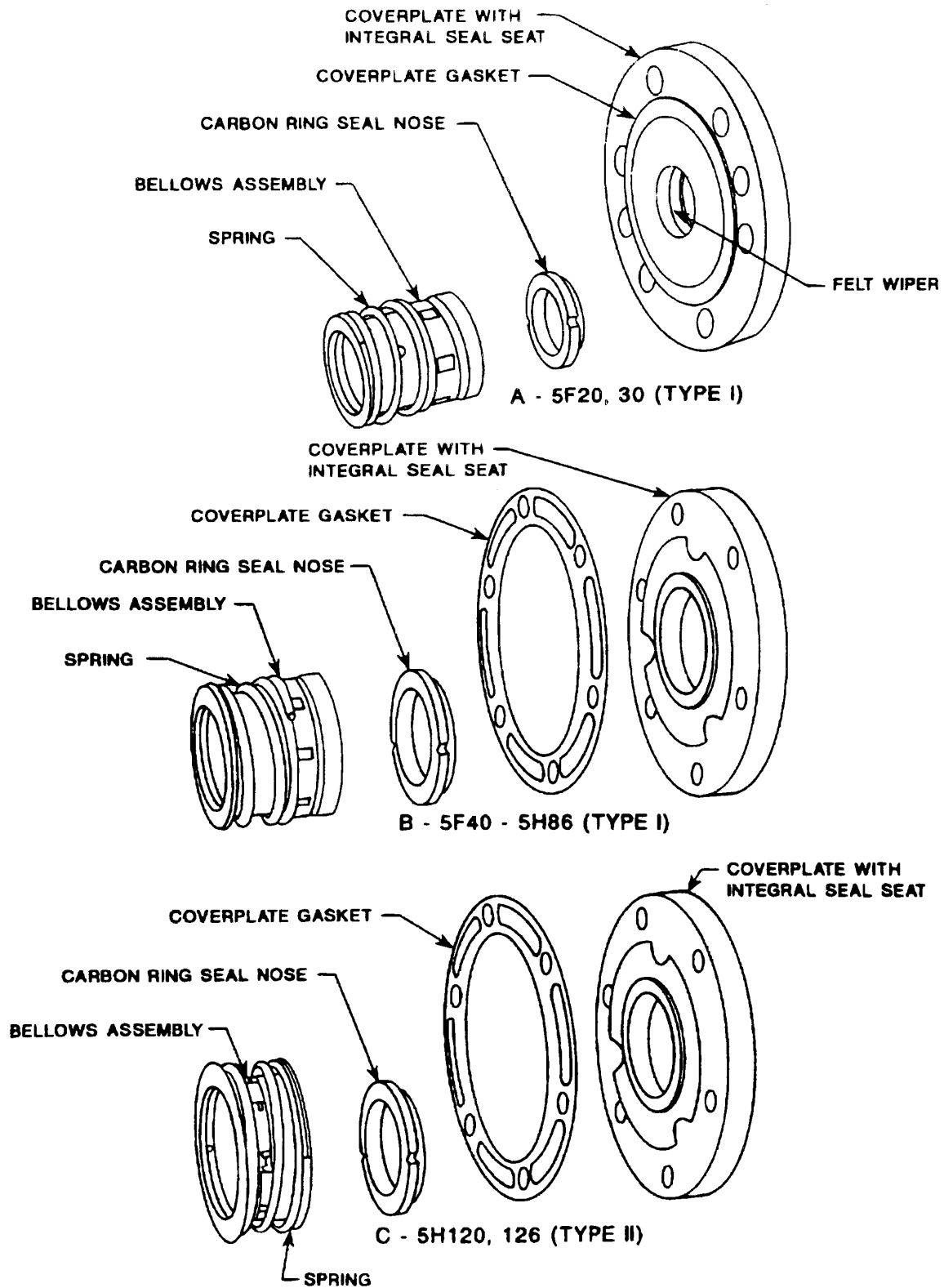


Figure 516-3-87. Service Replacement Seals - Carrier

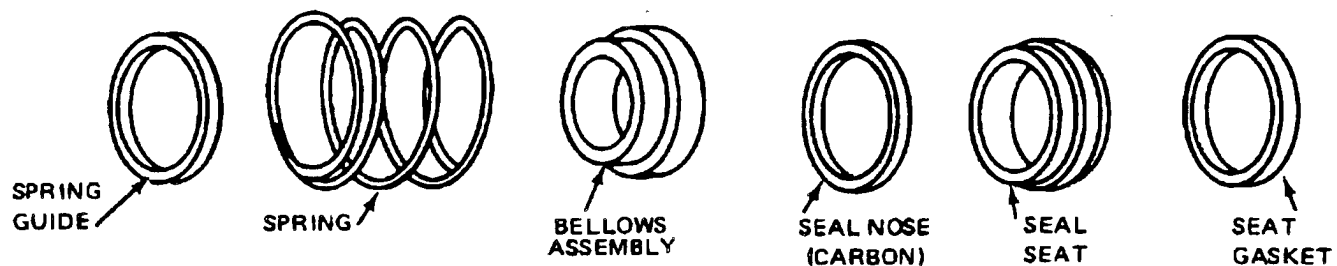


Figure 516-3-88. Rotating Seal with Insert Seal Seat - Carrier

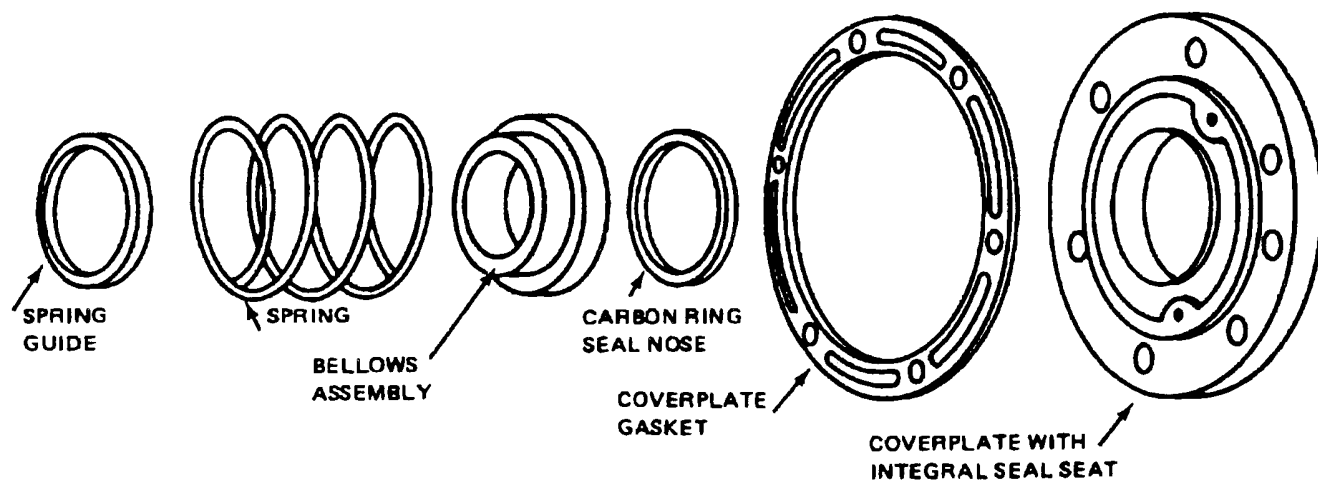


Figure 516-3-89. Rotating Seals with Integral Seal Seat - Carrier

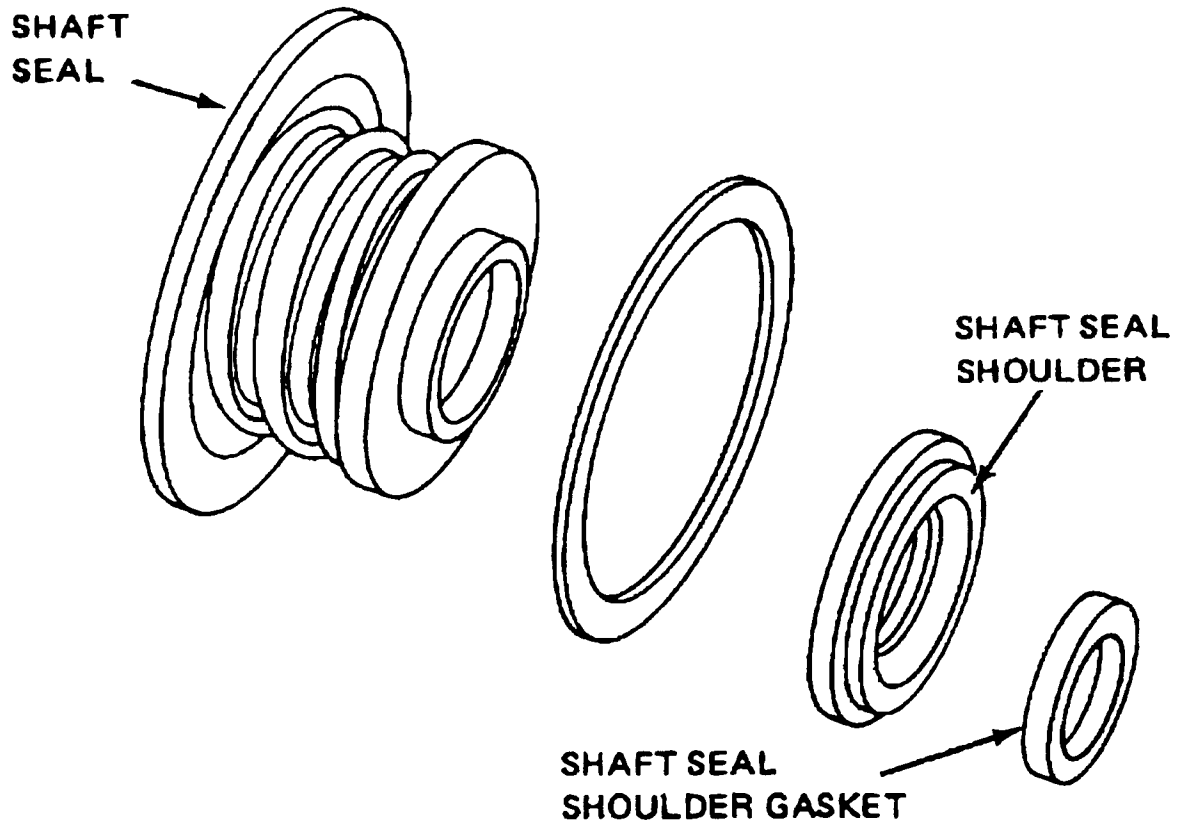
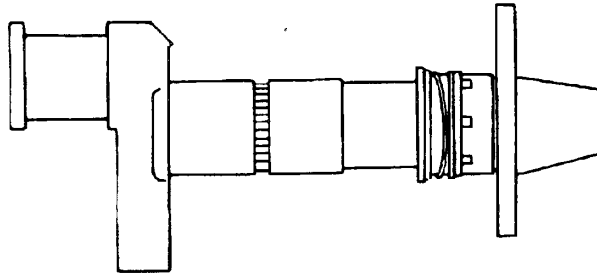


Figure 516-3-90. Stationary Bellows Seal - Carrier

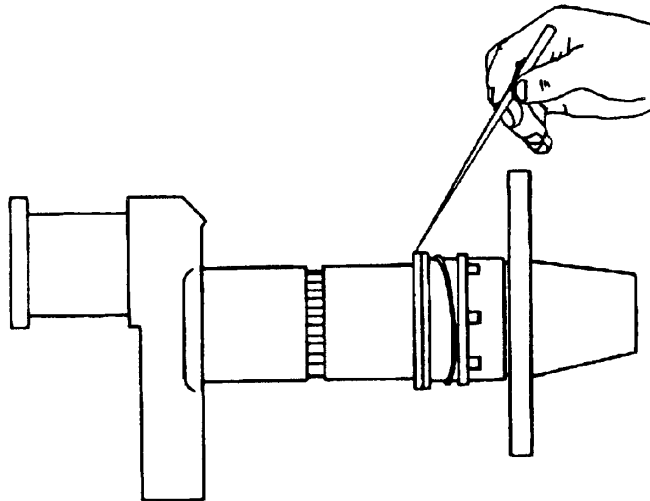
516-3.2.25.1 For installation, refer to steps 1, 2, and 3 in [Figure 516-3-91](#).

CAUTION

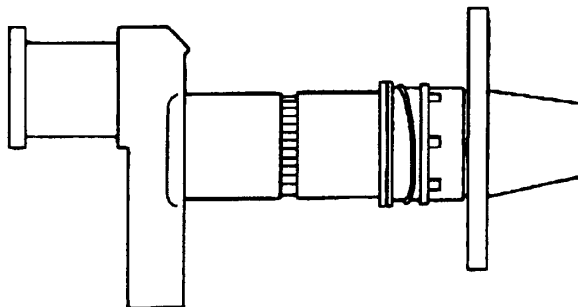
Do not attempt to repair or replace seal components. Replace complete seal assembly with current sleeve type. The bellows assembly of the service replacement seal shall not be taken apart.



STEP 1 - Lubricate shaft and neoprene bellows (with compressor oil only) where it contacts shaft. Slide seal assembly onto shaft until neoprene starts to grasp the shaft.



STEP 2 - Using seal coverplate, push seal assembly on crankshaft until spring guide is tight against shaft shoulder. (Do not use coverplate bolts to push seal into position.) Remove coverplate being careful not to damage carbon washer.



STEP 3 - Be sure that driving band lugs are positioned in center of seal retainer shell slots. Lubricate carbon washer and seal seat. Reinstall coverplate, drawing bolts down evenly to prevent damage to carbon washer.

Figure 516-3-91. Installation of Service Replacement Rotating Type Seal - Carrier

516-3.2.26 YORK CRANKSHAFT SEAL. The crankshaft seals on York compressors vary from compressor to compressor.

516-3.2.26.1 York R Series Compressor Crankshaft Seal. The York R series compressor 3-3/4 by 2-3/4 is equipped with a bellows-type shaft seal (Figure 516-3-92 and Figure 516-3-93). This seal consists basically of a rotating lapped carbon seal ring which seals against the lapped surface of the stationary seal cover plate, a Teflon (DuPont Trademark) shield, a neoprene bellows, and a spring-loaded retainer assembly. Spring pressure seals the neoprene bellows to the compressor crankshaft, causing the entire seal assembly to rotate with the crankshaft. An oil line taken directly from the compressor oil pump, ensures that the seal operates flooded in oil at all times. The shaft seal cavity is fitted with an oil pressure relief valve to relieve oil back to the compressor crankcase. To replace the R series compressor shaft seal, proceed as follows:

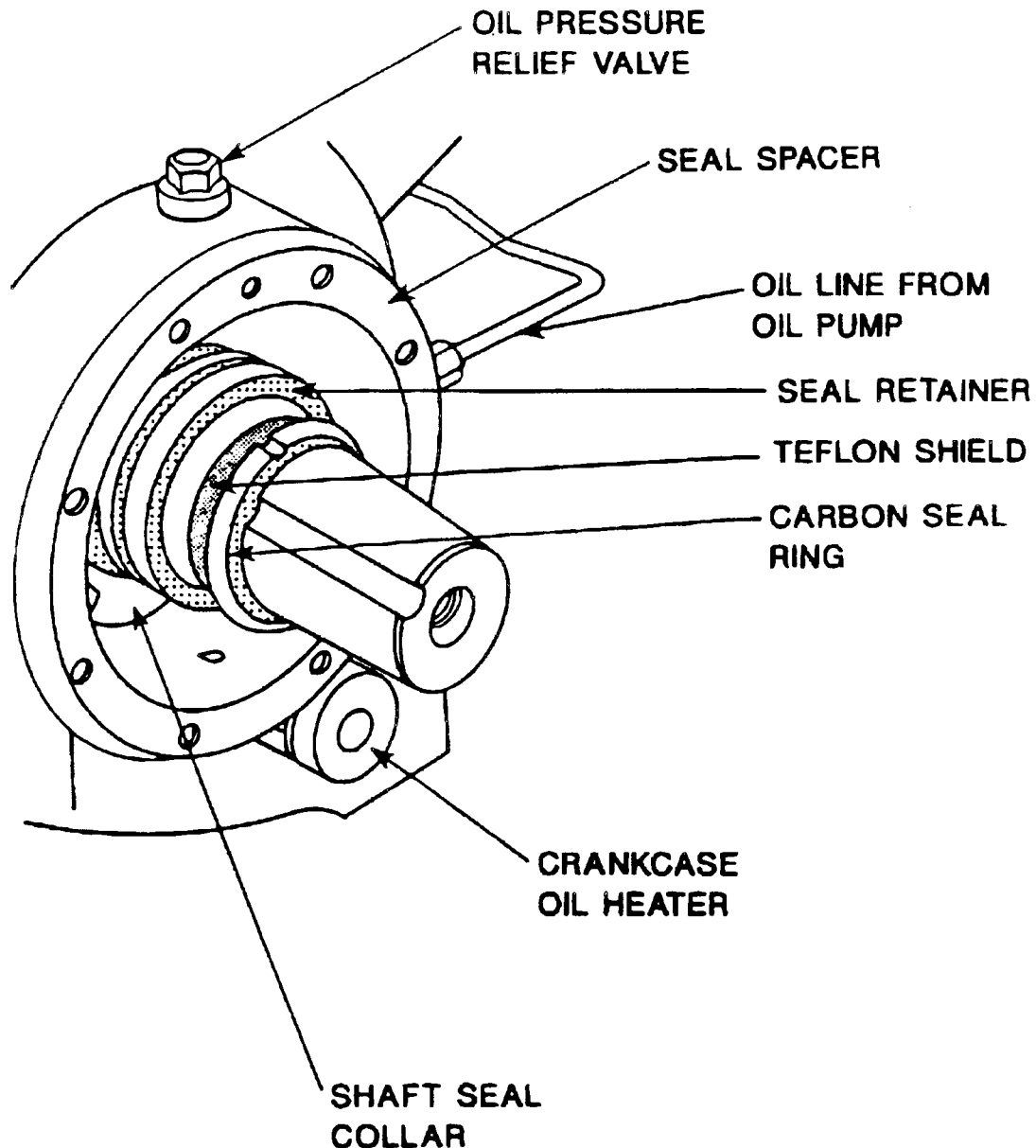


Figure 516-3-92. Compressor Shaft Seal - York R Series

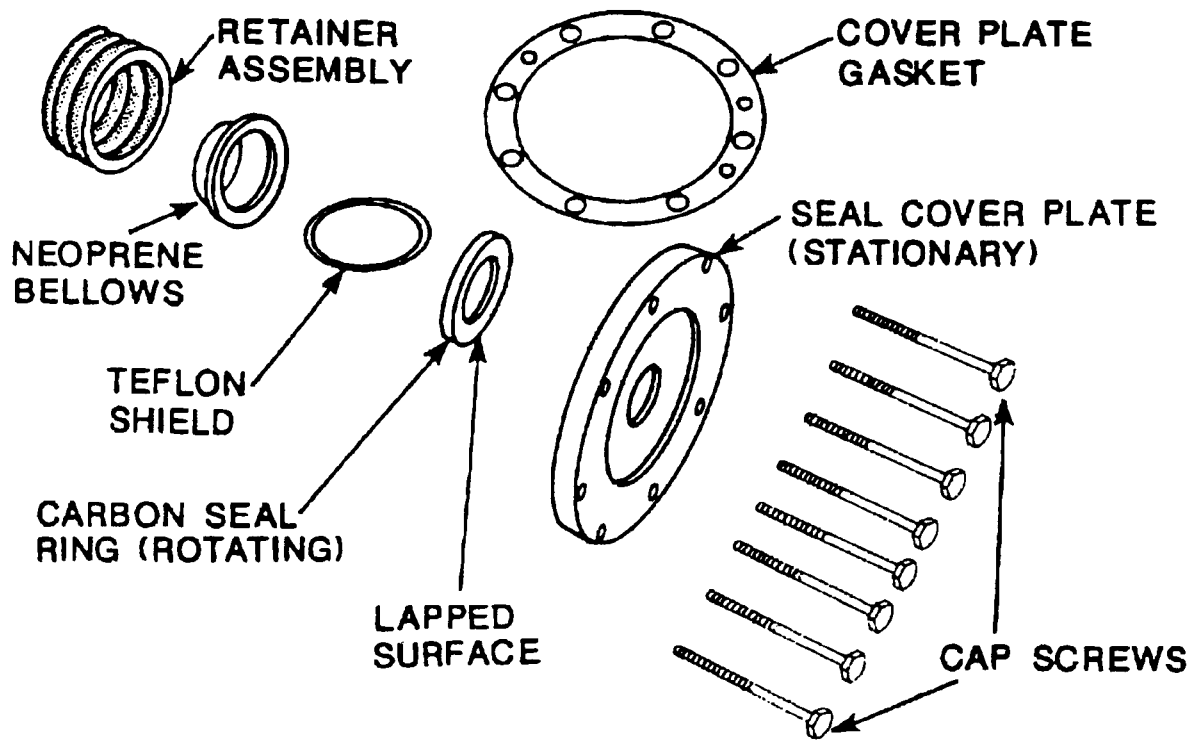


Figure 516-3-93. York Compressor Shaft Seal - Exploded View

1. Recover the refrigerant from the compressor.
2. Rotate the crankshaft so that the keyway is at the top. Remove the compressor half of the flexible coupling or the drive belt pulley. Remove the crankshaft key.
3. Loosen seal cover capscrews to allow the oil to drain from the seal cavity. Place a container under the seal cavity to prevent this oil from dripping on the foundation on deck.
4. Remove the eight capscrews holding the seal cover plate and the seal spacer to the compressor housing. Remove the seal cover plate, being careful not to damage the crankshaft. The seal spacer is positioned by two roll pins and need not be removed.
5. Using the York seal puller (part no. 364-37059), pull the seal assembly out of the compressor.

NOTE

Be sure to pull the seal assembly by the back flange.

6. Inspect the shaft seal oil supply line and fittings to see that they are not plugged or restricted.
7. To install the new seal assembly, oil the crankshaft and the neoprene bellows well and slide the retainer assembly with the neoprene bellows in place onto the crankshaft until it contacts the shaft seal collar. Compress the retainer assembly to see that it operates freely.
8. Oil the teflon shield and carbon seal ring. Carefully place the carbon seal ring with the Teflon shield in position inside the retainer assembly. Be sure notches on the outside diameter (OD) of the carbon seal ring match projections on the retainer assembly and that the lapped surface faces outward.

9. When installing a new carbon ring, always install a new cover plate. Apply oil to the lapped faces of the carbon seal ring and the seal cover plate.
10. Install the gasket, seal cover plate, and capscrews. The lapped surface of the cover plate will contact the lapped surface of the carbon seal ring before the cover plate will contact the seal spacer. Evenly tighten capscrews by drawing down opposite and alternate pairs ([Table 516-3-5](#)).
11. Reinstall drive components.
12. Evacuate the compressor.

516-3.2.26.2 York G Series Compressor Crankshaft Seal. Original compressors, furnished during various years, involved several crankshaft seal designs. Various crankshaft seals were designated as Y-49, Y-51, and Y-53. The Y-49 and Y-51 were early design seals. The Y-53 was used on all compressors with a number higher than 696 ([Figure 516-3-15](#)). It is not known which seals are installed in the compressors in various ships or which ships have converted their compressors to a later design. However, each will be described to aid personnel in identifying what is installed and to assist in maintenance.

516-3.2.26.2.1 York Y-49 Shaft Seal. This shaft seal was originally installed in compressors with external oil reservoirs. It is not known if this type of compressor was installed in any Navy system. However, a description of this Y-49 seal is given for information. The Y-49 shaft seal is a double-diaphragm seal designed to maintain a tight oil seal rather than a tight gas seal. It is, therefore, necessary to keep seal surfaces flooded at all times. [Figure 516-3-94](#), [Figure 516-3-95](#), and [Table 516-3-7](#) show parts of this seal and their order of assembly. The outer seal assembly (13) is called the shaft seal and the inner seal assembly (11) is called the oil seal. The shaft seal collar (6) is locked to the shaft with the steel ball and threaded collar rings (9) and rotates with the crankshaft. All other parts in the seal assembly are stationary because they are fastened between gasketed surfaces to the bearing head. This double diaphragm seal is balanced and self-compensating for all internal (crankcase) and external (atmospheric) pressures.

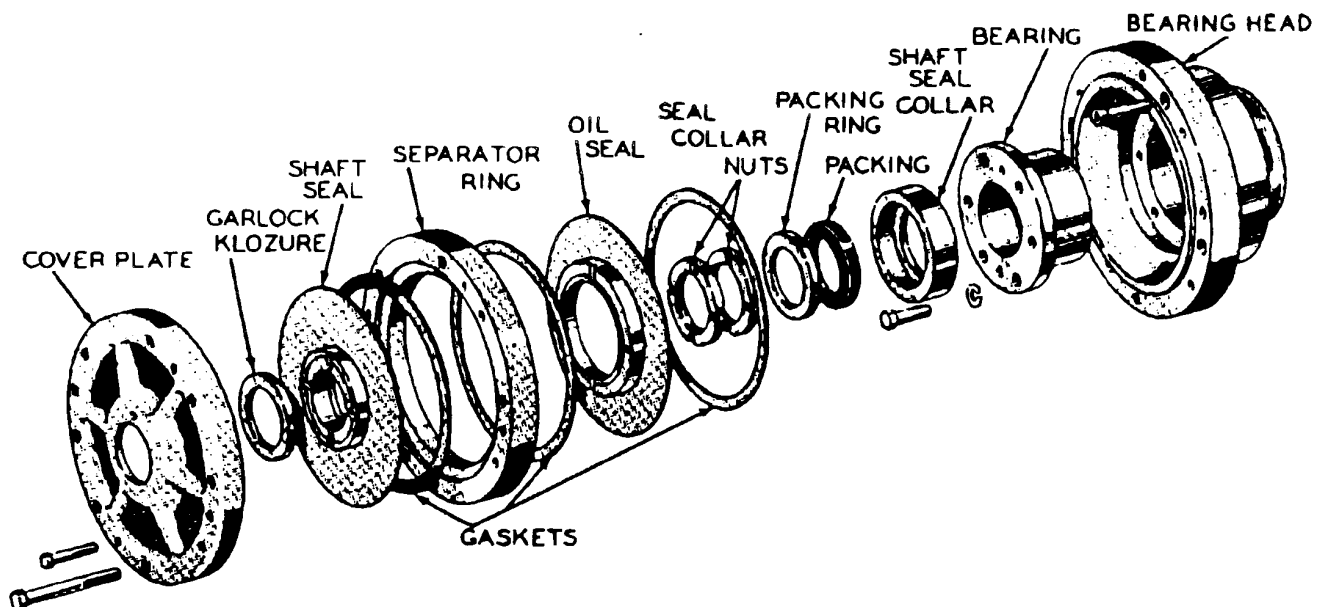


Figure 516-3-94. York Y-49 Shaft Seal - Exploded View

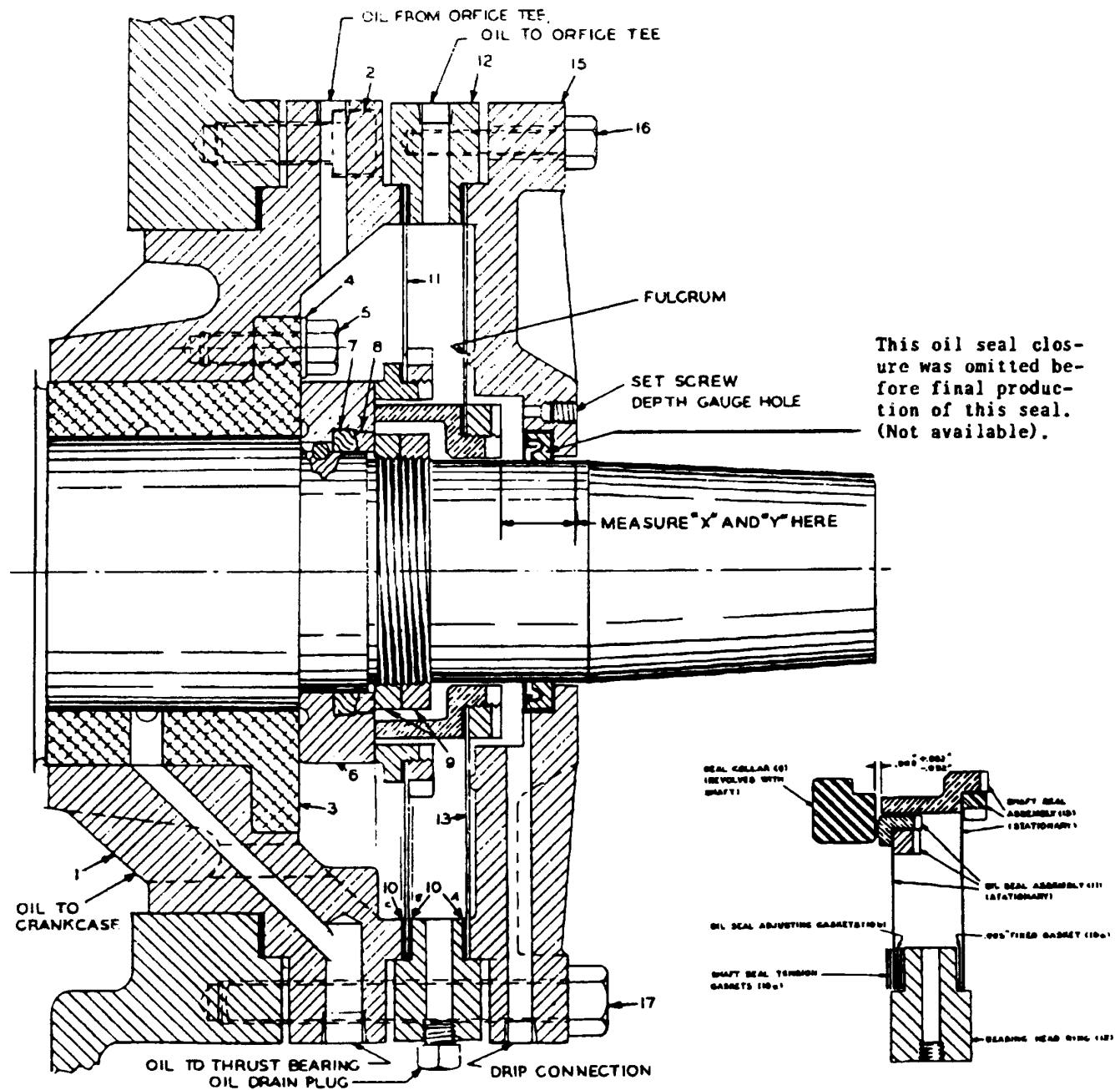


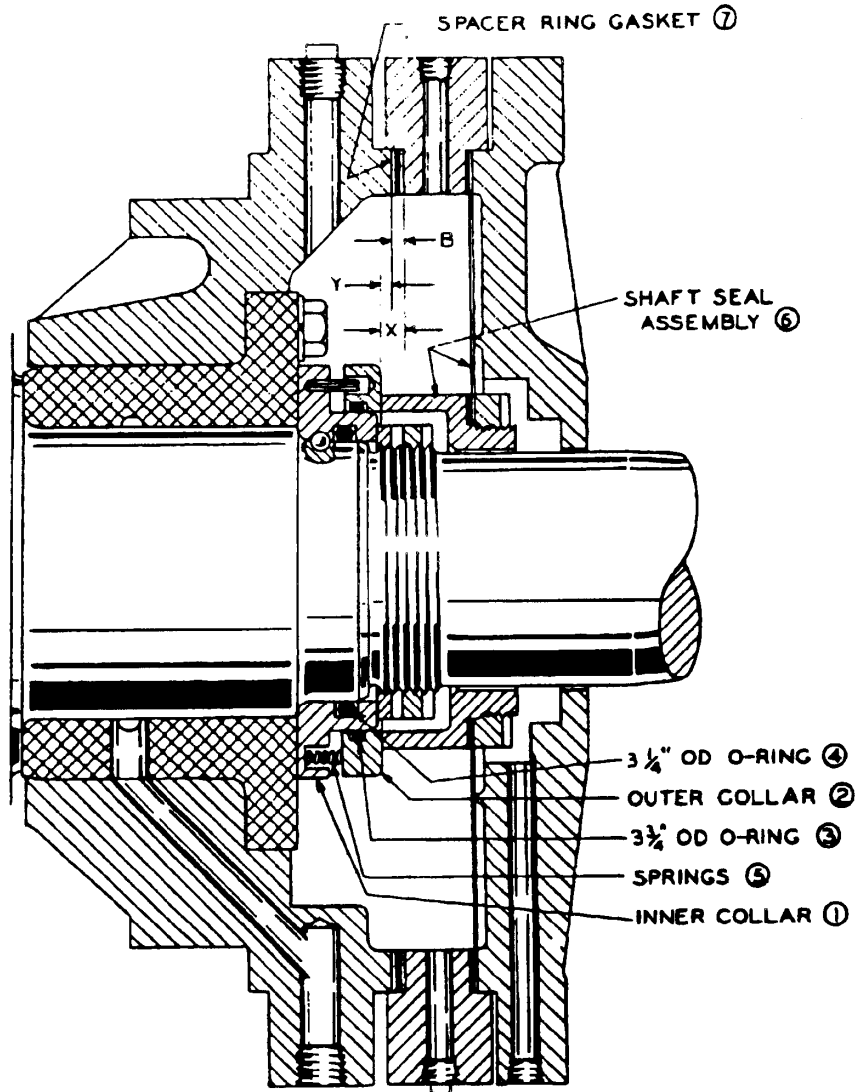
Table 516-3-7. YORK Y-49 SHAFT SEAL - PARTS LIST

Item No.	Part Name	Part No.
1	Thrust Bearing Head	64-292PL
2	Thrust Bearing Head Capscrew	21-2590P
3	Thrust Bearing	64-324PL
4	Thrust Bearing Washer (6 required)	21-5247P
5	Thrust Bearing Capscrew (6 required)	21-1483P
6	Shaft Seal Collar	64-342PL
7	Shaft Seal Collar Packing	28-1720PK
8	Shaft Seal Collar Packing Ring	64-343PK
9	Shaft Seal Collar Nuts	64-313PK
10	Diaphragm Gasket 0.006 in. thick	70-3806PK
10	Diaphragm Gasket 0.010 in. thick	70-3805PK
11	Oil Seal Assembly	64-339SL
12	Seal Separator Ring, less 1/8-in. NPT Plug	64-338PL
13	Shaft Seal Assembly	64-335SL
15	Seal Cover Plate	64-334PL
16	Cover Plate to Sep Ring Capscrews (4 required)	21-2751P
17	Cover Plate to Housing Capscrews (8 required)	21-1599P

516-3.2.26.2.2 On assembly, the fulcrum bears against the shaft seal diaphragm (13). The force it exerts on the diaphragm depends on the thickness of the gaskets (10) used. This initial tension tends to bend the seal diaphragm and, at the same time, forces the end surface of the shaft seal ring against the inner finished surface on the shaft seal collar. The oil seal ring inner surface bears against the outer-finished surface of the shaft seal collar. The force this exerts on the collar depends on the thickness of the gaskets (10) used at the bearing head. Shaft seal and oil seal rings, which are stationary, bear against two finished surfaces on the shaft seal collar which is rotating. The space between the oil seal diaphragm and bearing head is filled with gas from the crankcase at crankcase pressure. The space between oil seal and shaft seal diaphragms is filled with oil at crankcase pressure from the oil reservoir.

516-3.2.26.2.3 Pressures acting on both sides of the oil seal diaphragm are always equal; both the oil and the gas remain at crankcase pressure. If the crankcase pressure increases, the oil pressure in the oil chamber also increases. With this increase in oil pressure, the oil force against the larger area of the seal diaphragm tends to tip the shaft seal diaphragm about the fulcrum and counteract the pressure on the other side of the fulcrum, which tends to decrease the seal face pressure. When the crankcase pressure is below atmospheric pressure, the contact pressure at the outer surface of the collar increases by the action of the external pressure, as the external pressure acts on the shaft seal ring and diaphragm. This is the same as increasing the initial tension and thereby increasing the contact pressure at the shaft seal collar. Oil under pressure is piped to the oil reservoir and seal chamber from which it flows to the shaft seal ring, thus providing lubrication for rubbing surfaces. By means of the oil seal ring, this oil is retained in the space between two diaphragms, backing up through the oil reservoir into the crankcase. An orifice is provided in the fitting in the oil line from the seal chamber to the reservoir, which prevents the oil from siphoning out when the compressor is idle. Thus, the oil reservoir maintains a reserve supply of oil to seal rubbing surfaces during shutdown periods.

516-3.2.26.2.4 York Y-51 Shaft Seal. The Y-51 shaft seal, which replaced the Y-49 shaft seal, is a single diaphragm type with a two-piece collar, the outer portion of which is spring-loaded and full floating. Two rubber O-rings replace the collar packing used on the original design. [Figure 516-3-96](#) and [Figure 516-3-97](#) show sectional and exploded views of the Y-51 shaft seal.



Item No.	Part Number	Part No.
1	Inner Collar with Locking Pin	64-4306SL
2	Outer Collar	64-4277PL
3	3-3/4 in. OD O-ring	14-649P
4	3-1/4 in. OD O-ring	14-648P
5	Helical Springs	29-4715PK
6	Shaft Seal Assembly	64-335SL
7	Gasket, 0.006 in.	70-3806PK
7	Gasket 0.010 in.	70-3805PK
7	Gasket, 0.013 in.	70-6177PK

Figure 516-3-96. York Y-51 Shaft Seal - Sectional View and Parts List

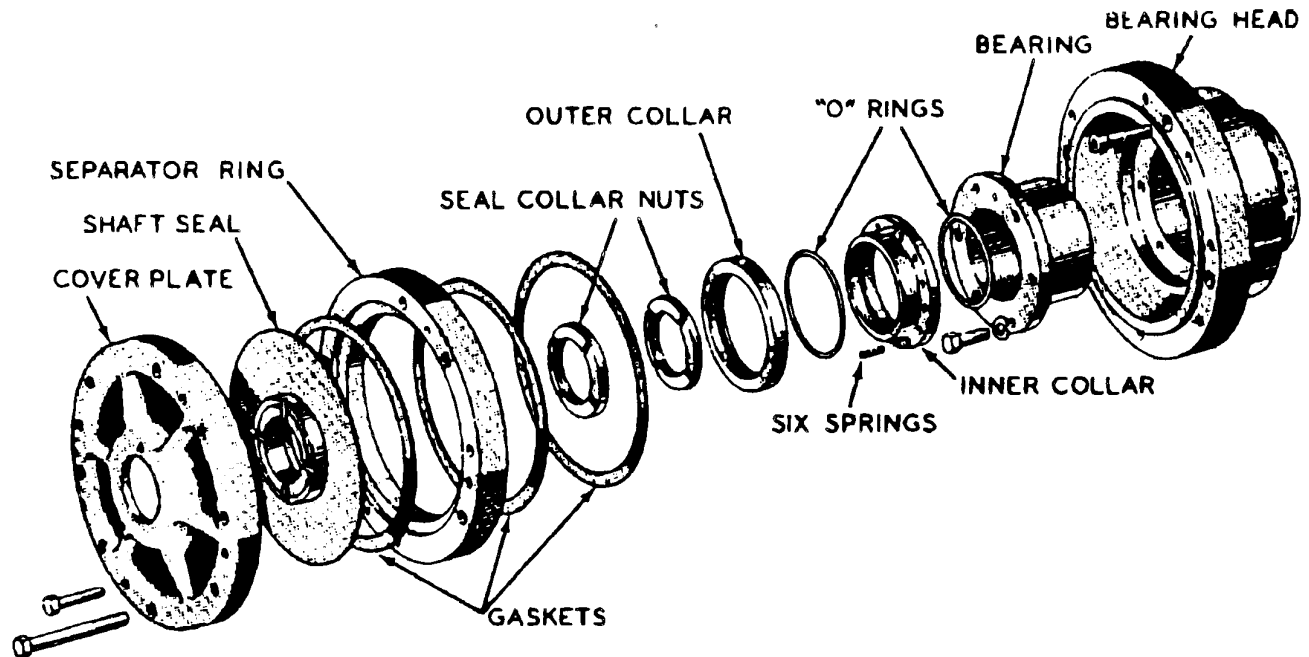


Figure 516-3-97. York Y-51 Shaft Seal - Exploded View

516-3.2.26.2.5 Y-51 Seal Operation. The seal collar assembly is locked to the crankshaft by the steel ball and therefore rotates with the shaft. The shaft seal assembly is stationary. On assembly, the fulcrum bears against the shaft seal diaphragm and the force that it exerts on the diaphragm depends on the thickness of the gaskets used. This initial tension forces the end surface of the shaft seal ring against the finished surface on the outer shaft seal collar. The space between the diaphragm and the bearing head is filled with oil, at slightly above crankcase pressure, from the oil pump. If the crankcase pressure increases, the oil pressure in the oil chamber also increases. With this increase in oil pressure, the oil force against the larger area of the seal diaphragm tends to tip the diaphragm about the fulcrum and increases the pressure of the shaft seal against the outer seal collar. When the crankcase pressure is below atmospheric pressure, the contact pressure between the shaft seal ring and the outer collar increases due to the atmospheric pressure on the outer side of the diaphragm. Therefore, the seal is gastight and is balanced for all external (atmospheric) and internal (crankcase) pressures. Because lapped contact surfaces are separated by a film of oil, the seal is practically frictionless. Because the outer seal collar is full floating on 12 small springs (5), it always rides against the seal ring with full contact. Since the Y-51 shaft seal is a flooded-type seal, it is necessary to have the shaft seal oil space completely filled with oil. This automatically happens during continuous or intermittent operation, but during a prolonged shutdown period, it will be necessary to ensure a flooded seal before startup. With this type of seal, carefully watch a seasonally operated compressor for shaft seal leakage during shutdown. Place an empty quart can under the seal drain tube during the off-season. Before the compressor is started for its normal running period, check the can to determine the amount of seal leakage. Charge an equal quantity of clean oil into the shaft seal by a hand oil pump attached to the oil-charging valve.

516-3.2.26.2.6 Adjust Y-51 Seal Tension. If the seal leakage is excessive, replace the seal or readjust the tension. The shaft seal tension cannot be checked unless the cover plate, separator ring, and shaft seal assembly are removed. The seal tension shall be 0.090 inch and is adjusted by adding or removing spacer ring gaskets. To adjust the shaft seal proceed as follows:

1. Pump down the compressor, close stop valves, recover any remaining refrigerant, and remove the flywheel or flexible coupling hub from the crankshaft.
2. Remove the plug from the bottom of the separator ring to drain the oil from the seal. Opening the oil-charging valve will speed up this operation.
3. Remove the oil lines from the side and top of the separator ring and then remove the cover plate, separator ring, and shaft seal assembly as one unit.
4. Examine running faces of the shaft seal assembly and outer collar (6 and 2) for dirt, grit, scratches, cracks, or excessive wear.
5. If faces show any of the defects just mentioned, replace the worn part or parts.
6. If faces appear to be free from defects, adjust the shaft seal tension. This may be all that is needed to correct the shaft seal leakage. Be certain that the clearance on the thrust bearing does not exceed 0.006 inch. Excessive shaft end play can cause seal failure.
7. To adjust the seal tension proceed as follows:
 - a With the cover plate, separator ring assembly face up, lay a straightedge across the running face of the seal and with a depth gauge and straightedge, measure the height of the seal face above the undercut gasket surface on the separator ring. Make sure that the diaphragm is seated firmly on the fulcrum of the cover plate. Record this as dimension X.
 - b With the straightedge and depth gauge, measure the depth of the outer collar face below the gasket surface on the bearing head. Do not apply pressure on the collar. Take two or three readings, depressing the collar between each one. Record the average of these readings as dimension Y.
 - c To find the thickness B of the ring gaskets needed, use the following formula:

$$B = X - (Y + 0.090 \text{ inch})$$
 0.090 inch is the shaft seal tension required.
 - d For example, assuming that the reading for dimension X is 0.246 and Y is 0.112 inch, use the formula as follows:

$$B = X - (Y + 0.090 \text{ inch})$$

$$B = 0.246 \text{ inch} - (0.112 \text{ inch} + 0.090 \text{ inch})$$

$$B = 0.246 \text{ inch} - 0.202 \text{ inch}$$

$$B = 0.044 \text{ inch}$$
 The average gasket thickness B required is 0.044 inch.
 - e The thickness of gaskets in this example would be 0.044 inch. Make up the required thickness by using 0.006-, 0.010-, and 0.013-inch lead gaskets.

516-3.2.26.2.7 Replace Y-51 Shaft Seal. To replace any shaft seal parts, follow the procedure in paragraph [516-3.2.26.2.6](#), steps 1 through 6, and proceed as follows:

1. After the cover plate-separator ring assembly has been removed, remove the seal collar assembly by unscrewing the locking nut and collar nut.
2. Relap the outer collar running surface if necessary.
3. Assemble collar parts as shown in [Figure 516-3-96](#), using clean new oil on all parts.
4. Make sure the O-ring (4) is in its recess in the inner collar (1).

5. With the inner collar laying on a flat surface, place the 12 springs (5) in their sockets, making sure that they are properly seated.
6. Assemble the outer collar (2) [with its O-ring (3) in place] to the inner collar, being careful not to cut or jam the O-ring. Be sure that the locking pin on the inner collar coincides with the recess in the outer collar.
7. Depress the outer collar on springs to be sure that it is free to move.
8. If necessary, remove the sharp corner from the shoulder of the crankshaft with a file so that the O-ring will not be damaged when the collar is being pushed into position. Clean all filings from the shaft and the bearing head recess.
9. Pull the shaft all the way toward the seal end and install the collar assembly, making sure that it is locked to the shaft by the ball key and its thrust side is bearing against the shoulder of the shaft.
10. Apply the collar nut and the locking nut, pulling them up. Rotate crankshaft several revolutions by hand and check the thrust clearance between the collar and thrust bearing (0.003 to 0.006 inch).
11. If the shaft seal assembly needs replacing, clean the cover plate and the separator ring and assemble with a new shaft seal (6) and a 0.006-inch lead gasket. Pull the four bolts tight.
12. Place the required number of gaskets (7) on the separator ring and assemble the seal to the bearing head, pulling bolts up evenly and lightly.
13. Reconnect oil lines to the side and top of the separator ring.
14. Replace the drain plug in the bottom of the separator ring and charge 1-quart of oil into the seal oil space with a hand pump connected to the seal oil charging valve. This is necessary to ensure a flooded seal during startup.
15. Reassemble the coupling or flywheel and open stop valves.

516-3.2.26.2.8 The compressor is now ready for operation. Keep a close check on the seal for a short period. If excessive leakage occurs (more than 20 drops per minute) for an extended period, it will be necessary to recheck the assembly. Do not be alarmed if there is no sign of oil drip.

516-3.2.26.2.9 York Y-53 Shaft Seal. Subsequent to the use of Y-49 and Y-51 shaft seals, York introduced the Y-53 shaft seal. At the same time York recommended that all compressors equipped with Y-49 and Y-51 shaft seals be converted to use the Y-53 shaft seal. Currently York has recommended the use of an improved John Crane shaft seal on G series compressors with Y-53 shaft seals. These shaft seals, as well as the conversions, are described herein for guidance when converting one of these compressor crankshaft seals and to help determine the stage of conversion since modification on top of modification has been made by York. The Y-53 style shaft seal is a single, spring loaded, balanced seal, simple in design and using no diaphragms ([Figure 516-3-98](#) and [Figure 516-3-99](#)). A cast-iron shaft seal collar with rubber O-ring is secured to the crankshaft by a steel ball and two locking nuts, thereby rotating with the crankshaft. A carbon shaft seal ring with rubber O-ring, loaded by eight small helical springs, is locked to the cover plate by a roll pin. This assembly is stationary. The lateral movement of the shaft seal ring allows the surfaces of the carbon ring and cast-iron collar to always be in contact. Lapped contact surfaces are separated by a film of oil. This oil, slightly above crankcase pressure, is supplied by the oil pump and floods the cavity between the cover plate and bearing head. The two rubber O-rings perform an important function in sealing off possible leak paths along the shaft and through the cover plate; thus, they shall be carefully handled and properly applied.

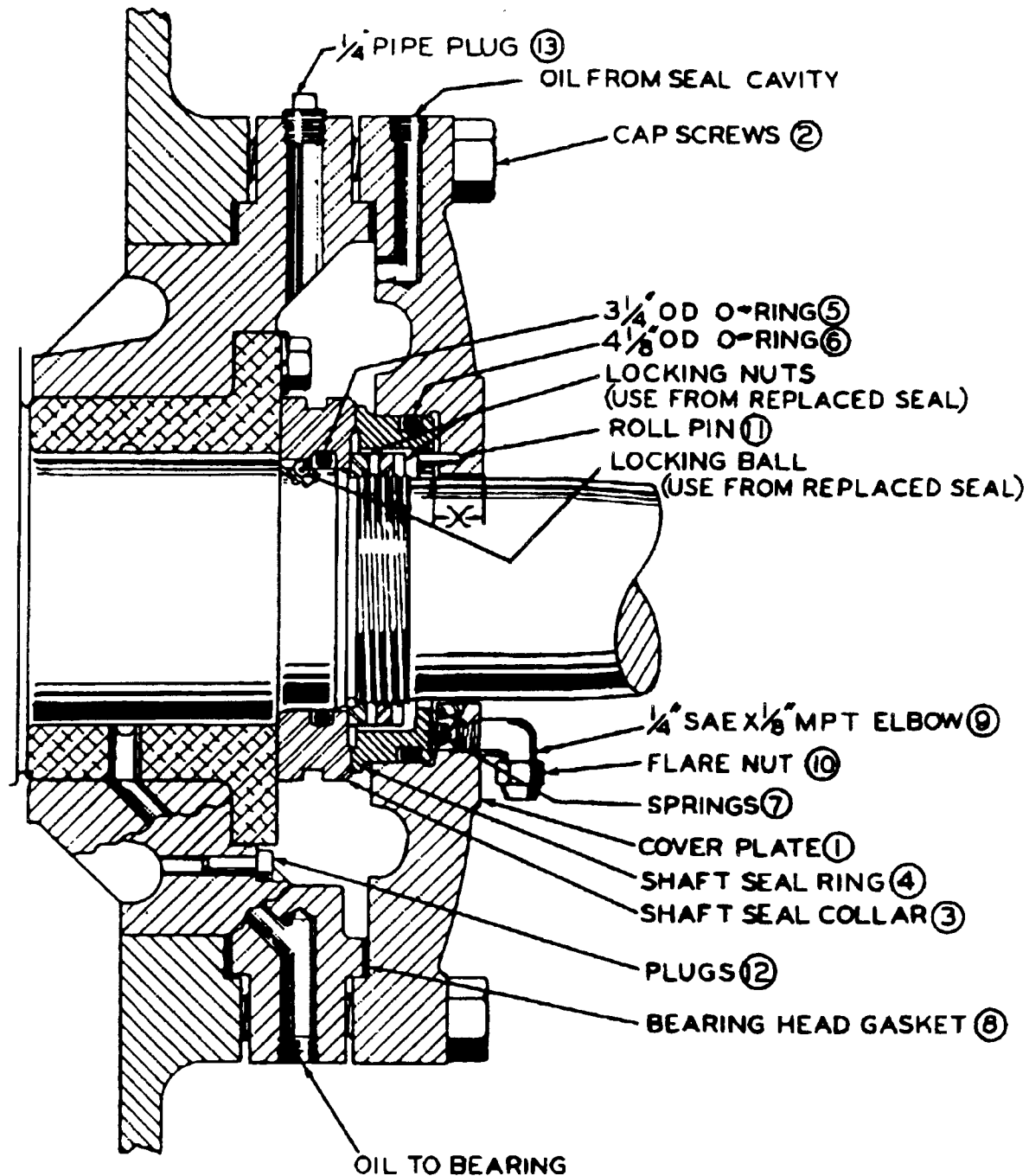


Figure 516-3-98. York Y-53 Shaft Seal - Sectional View

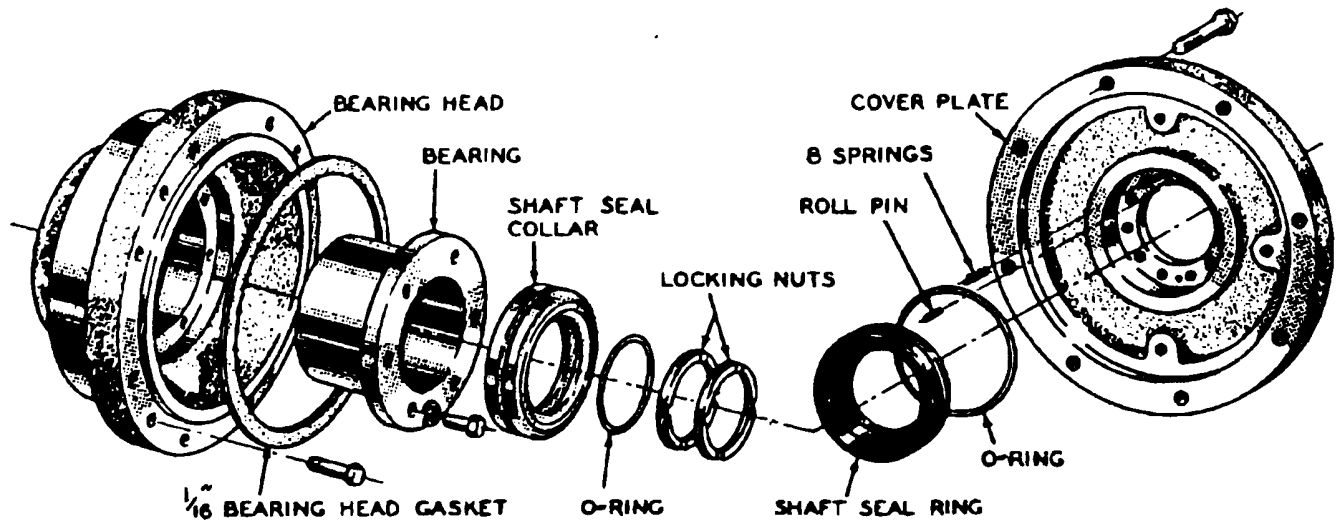


Figure 516-3-99. York Y-53 Shaft Seal - Exploded View

516-3.2.26.2.10 Y-53 Shaft Seal Conversion. To convert the original Y-49 shaft seal or the modified Y-51 shaft seal to the Y-53 shaft seal, shaft seal conversion kit 064-05434 is available. The kit is made up of two separate packages. Items 1 through 7 in the parts list (Table 516-3-8) are required for converting a Y-51 shaft seal and items 1 through 19 are required for converting a Y-49 shaft seal. The unused package of parts remaining from the conversion of a Y-51 shaft seal should not be returned to York for credit. The following steps 1 through 7 are illustrated in Figure 516-3-98 and Figure 516-3-99. Steps 14 through 16 are used to make changes to the oil piping when converting from a Y-49 to a Y-53 seal (Figure 516-3-100). To install the Y-53 seal for the conversion on compressors having a Y-49 seal, refer to Figure 516-3-100 and Figure 516-3-101 and proceed as outlined in steps 1 through 16. To install the Y-53 seal on compressors having a Y-51 seal, omit steps 5 and 14.

Table 516-3-8. Y-53 CONVERSION KIT PARTS LIST

Item No.	Quantity Per Kit	Part Name	Part No.
1	1	Plate, Cover	64-6366PM
2	8	Screw, Cap, Hex Head	21-9204P
3	1	Collar, Shaft Seal	64-4739PL
4	1	Ring, Shaft Seal	64-14031
5	1	O-ring, 3-1/4 in. OD	28-7420
6	1	Quad-ring, 4-1/8 in. OD	28-7421
7	8	Spring, Helical	29-4010P
8	1	Gasket, Bearing Head, 1/16 in.	28-824P
9	3	Elbow, 1/4-in. SAE x 1/8-in. MPT	23-1258P
10	1	Nut, Flare, 1/4 in.	21-5675P
11	1	Pin, Roll	29-4290P
12	2	Plug, Bearing Head, Brass	64-4279PK
13	1	Plug, Pipe, 1/4 in.	23-1972P
14	1	Elbow, 1/4-in. SAE x 1/4-in. MPT	23-4729P

Table 516-3-8. Y-53 CONVERSION KIT PARTS LIST - Continued

Item No.	Quantity Per Kit	Part Name	Part No.
15	1	Union, 3/8-in. SAE x 1/4-in. MPT	23-1308P
16	1	Union, 1/4-in. SAE x 1/4-in. MPT	23-1306P
17	1	Tee, 1/4 in.	23-4334P
18	1	Nipple, Pipe, 1/4 in.	70-675PK
19	3 ft.	Tubing, 1/4 in.	03-235P

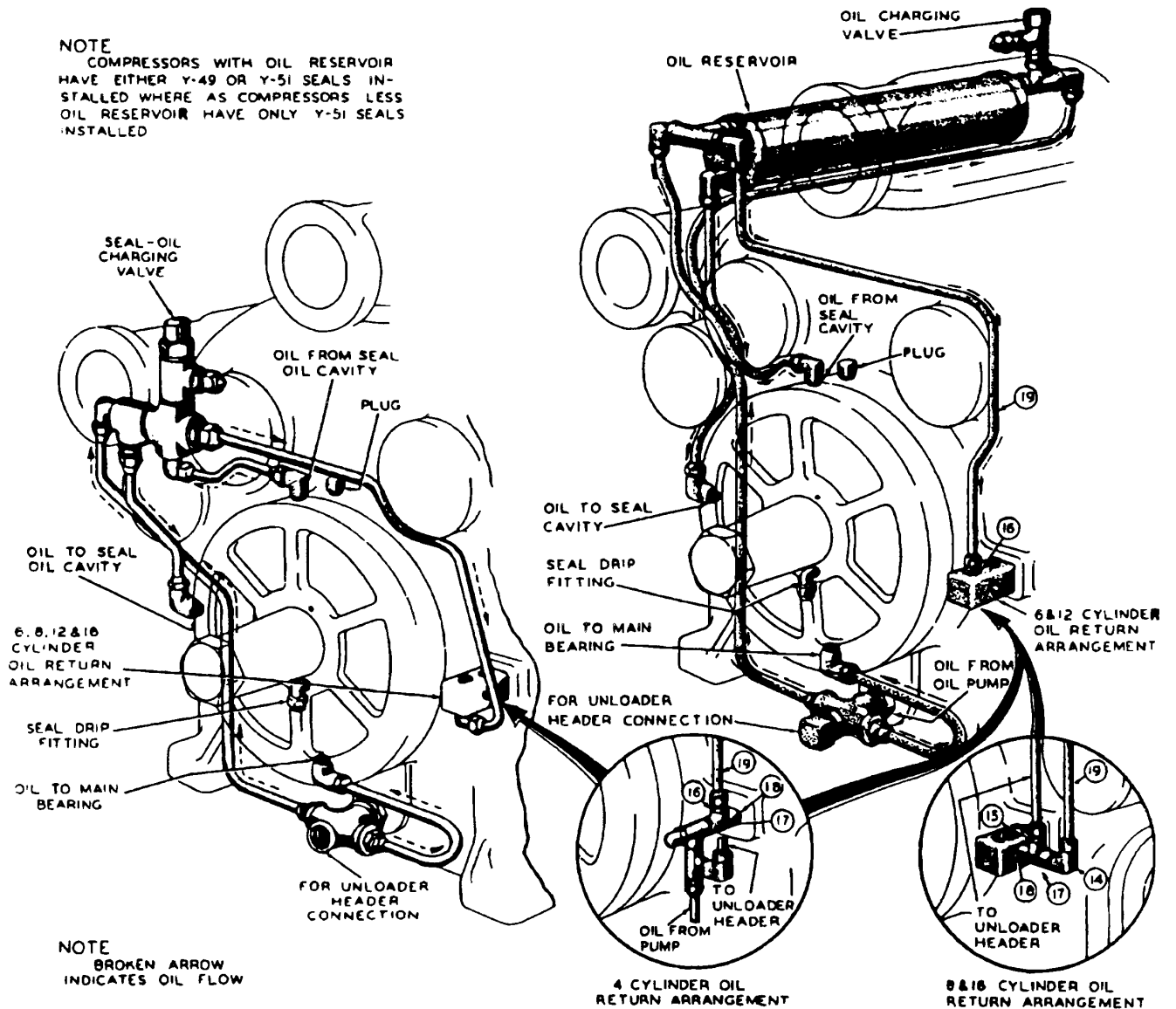


Figure 516-3-100. Shaft Seal Oil Piping for Converting a Y-49 Shaft Seal to Y-53 Seal

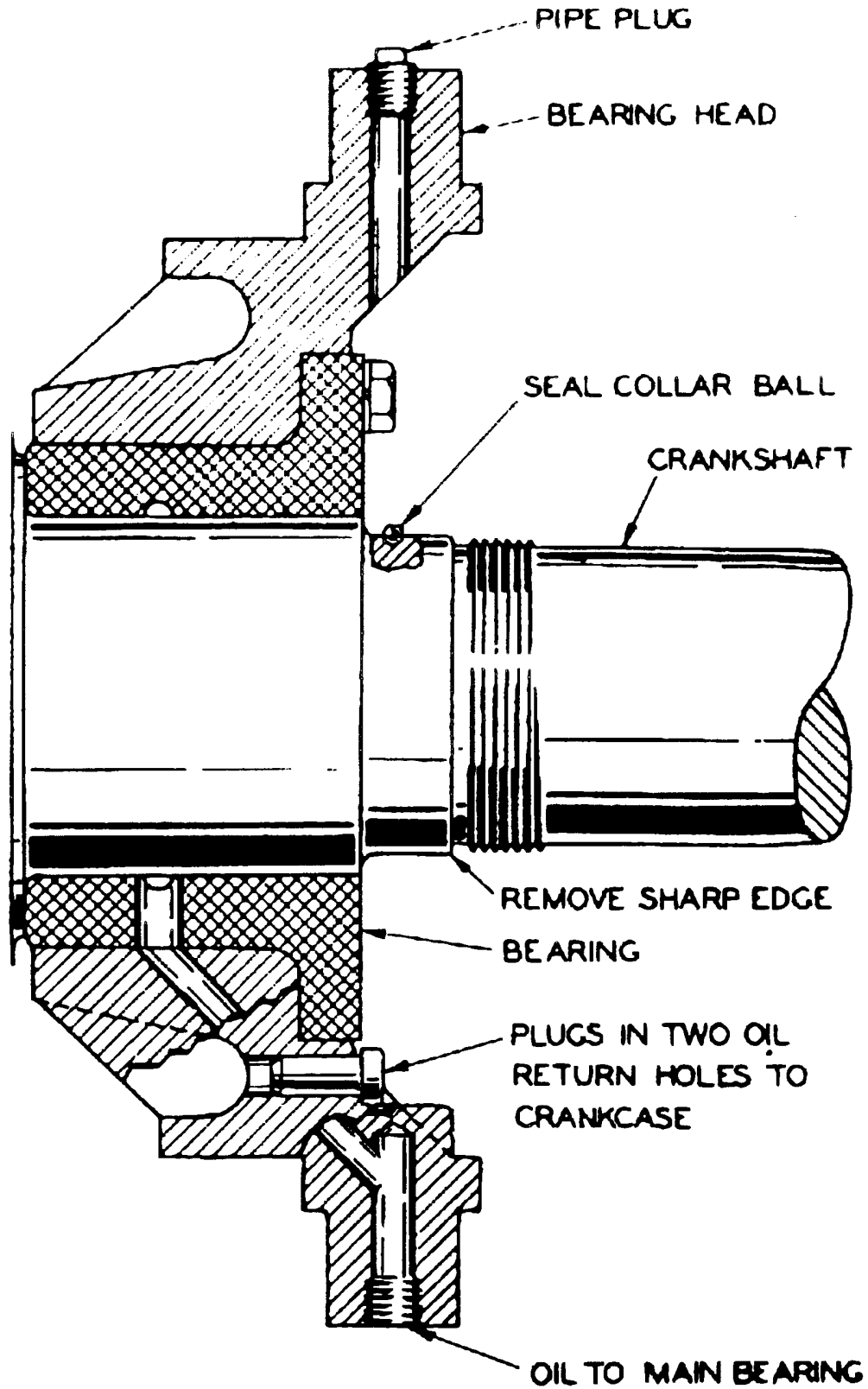


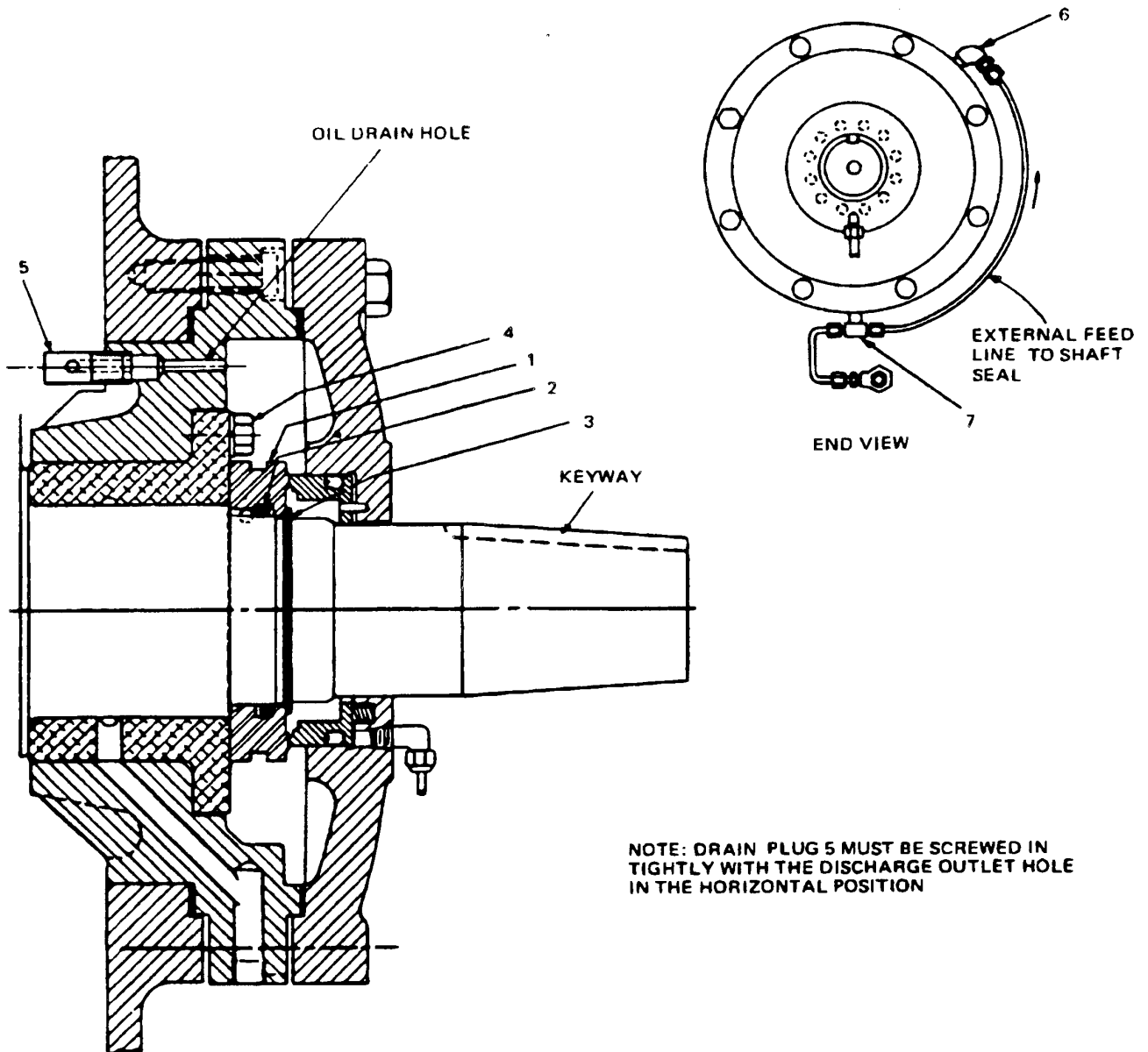
Figure 516-3-101. Shaft Seal Removed

1. Pump down the compressor, close stop valves, recover any remaining refrigerant, and remove the flywheel or flexible coupling hub from the crankshaft.
2. Remove the plug from the bottom of the separator ring and drain the oil from the seal oil cavity. Opening the oil-charging valve will speed up this operation.
3. Remove the shaft seal following the procedure outlined in paragraph 516-3.2.26.1.
4. Remove the elbow from the top of the bearing head and replace with the 1/4-inch pipe plug from the bottom of the separator ring.
5. Plug the two oil drain holes in the bottom part of the bearing head. Two brass plugs (12), are furnished for this purpose. Place these plugs in drain holes and drive them in snugly. Clean off any brass shavings that may have scraped off these plugs when driven into place. When driving brass plugs into place, be careful to avoid hitting the machined bearing head gasket surface (Figure 516-3-98).
6. With a file, remove the sharp corner from the shoulder of the crankshaft so that the O-ring will not be damaged when the collar is pushed into position. Clean all filings from the shaft and the bearing head recess. The compressor should now appear as it is in Figure 516-3-101.
7. Place the 3-1/4 inch OD O-ring (5) in its recess in the shaft seal collar (3). Pull the crankshaft all the way toward the seal end and install the shaft seal collar (3), making sure that it is locked to the shaft by the locking ball and its thrust side is bearing against the shoulder of the shaft. Apply the original collar nut and locking nut, pulling them up tight. Be certain the thrust clearance remains the 0.003 to 0.006 inch originally allowed. Push the shaft toward the pump end.
8. Screw elbow (9), with flare nut (10), in the hole provided on the face of the new cover plate (1). Place the cover plate on a horizontal surface with spring holes face up. Place the eight springs (7) in their sockets, leaving every third hole empty, on 12-hole cover plates. Place the roll pin (11) in the hole provided in the cover plate.
9. Place the 4-1/8 inch OD O-ring (6) in its recess in the shaft seal ring (4) and place this assembly in the cover plate (1), being careful not to cut the O-ring. Be sure that the locking pin in the cover plate enters its proper hole in the shaft seal ring and that springs are properly seated. Depress shaft seal ring to be sure that it is free to move. Place the 1/16-inch bearing head gasket (8) on the cover plate assembly.
10. Make sure the contact surfaces of the shaft seal collar (3) and shaft seal ring (4) are free from all foreign particles. Apply oil to these surfaces.
11. Assemble the cover plate assembly, with gasket in position, to the bearing head using capscrews (2) provided in the kit. Draw the bolts up evenly and tightly. Place a 1/4-inch plug (13) in the top of the bearing head as shown in Figure 516-3-98 and Figure 516-3-100.
12. After the assembly is complete, measure X (distance from outside of cover plate to shaft seal ring, Figure 516-3-98) through the 9/64-inch hole in the cover plate using a depth gauge. This dimension shall be 0.612 inch + 0.012 inch.
13. Reconnect the oil lines to the side and top of the new cover plate (1).
14. Using the 1/4-inch tubing and fittings (13 to 19), make a new connection from the orifice tee on the oil reservoir to the unloader oil return manifold (Figure 516-3-100).
15. Since this is a flooded-type seal, it will be necessary to fill the seal oil cavity with oil. On compressors having an oil reservoir, disconnect the reservoir oil line at the unloaded oil return manifold. Charge oil into the reservoir with a hand pump until oil is forced from the open connection. On compressors having a seal-oil charging valve, connect a hand pump to this valve and charge 1 quart of oil into the seal oil cavity.
16. Be sure all oil line joints are properly made, then reassemble the coupling or belt wheel.

516-3.2.26.2.11 The compressor is now ready for operation. Keep a close check on the seal for a short period. Do not be alarmed if there is no sign of oil drip; for the Y-53 shaft seal, leakage is relatively low. Only 10 to 15 drops per day might be observed at the elbow (9) on the face of the cover plate. A piece of drain tubing may be attached to the elbow if desired.

516-3.2.26.2.12 John Crane Shaft Seal (York G Series). This procedure covers the installation of an improved bellows type, the John Crane seal, on G-series and Y-53 compressors. Conversion is recommended on all compressors having a history of seal failure problems. The seal consists of a rotating lapped carbon seal ring, which seals against the lapped surface of the stationary seal cover plate, a Teflon shield, a neoprene bellows, and a spring-loaded retainer assembly. Spring pressure seals the neoprene bellows to the compressor crankshaft, causing the entire seal assembly to rotate with the crankshaft. The John Crane seal conversion kit can be installed only on compressors that use a tapered retaining ring to lock the shaft seal collar to the crankshaft. It cannot be used on compressors that have the shaft seal collar locked to the crankshaft by threaded lock nuts. To use the conversion kit on a belt drive unit, it is necessary to remove 1/2 inch from the flywheel hub on the compressor side to prevent interference between the hub and shaft seal cover bolts. To install the conversion seal kit on an existing compressor proceed as follows:

1. Close suction and discharge stop valves.
2. Close the valve in the return line from the oil separator, if an oil separator is installed.
3. Recover the refrigerant from the compressor.
4. Before disassembly of any kind is started, pull the compressor motor main disconnect switch and deenergize the control circuit.
5. Rotate the crankshaft so that the crankshaft keyway is at the top. Remove the compressor half of the flexible coupling or the flywheel and remove the key from the crankshaft keyway.
6. Loosen cover plate capscrews to allow the oil to drain from the seal cavity. Place a container under the seal to prevent this oil from dripping on the foundation or deck. Remove the oil supply tubing ([Figure 516-3-102](#)).



LEGEND

Item No.	Description
1	Collar, Shaft Seal
2	Ring, O
3	Ring, Retaining
4	Screw, Cap, Bearing
5	Plug, Drain (5-5/32" Orifice-1/8" NPTM)
6	Elbow
7	Tee

Figure 516-3-102. Shaft Seal Assembly - Cross-Sectional View

7. Remove the cover plate capscrews and slide the cover plate and carbon seal ring off the crankshaft. These parts are not used with the conversion kit.
8. Using a special retaining ring plier tool, carefully expand the retaining ring and remove it from the shaft. Such a tool is made by Waldes Kohinoor Inc., Long Island, NY and is available under York part no. 029-08590. Remove the shaft seal collar, and using care not to damage the shaft or lose the ball, remove the collar-locking ball from its pocket in the crankshaft. After a thorough cleaning with solvent, examine running faces of the shaft seal collar for marks, grooves, scratches, cracks, or excessive wear. These indicate the need for replacement.
9. Before shaft seal parts are installed, it is necessary that all parts, including the shaft and shaft seal cavity, be thoroughly cleaned. For this purpose, use an approved safety solvent and a brush to apply it to seal cavity surfaces rather than a cloth. Rinse seal parts in solvent and allow to air-dry.
10. Inspect the shaft seal external oil feed line and fittings to see that they are not plugged or restricted. Also check the oil return hole in the bearing head and its drilled plug to be sure that no obstruction exists.

NOTE

Figure 516-3-102 shows the current arrangement of the shaft seal oil system. Some early compressors were made with an identical arrangement except that the oil drain hole was 3/32 inch in diameter and the drilled plug was not used. If shaft seal difficulty is being experienced on these early compressors, it is recommended that the oil drain hole be enlarged to 5/32 inch diameter or the plug be replaced with the new plug, York part no. 064-24444.

11. Place the shaft seal collar locating ball in its pocket in the crankshaft. Insert the O-ring in the recess in the shaft seal collar and put the collar in position on the shaft. Use care to avoid damaging the O-ring. Make sure the recess in the inner bore of the collar fits over the locating ball (Figure 516-3-103).

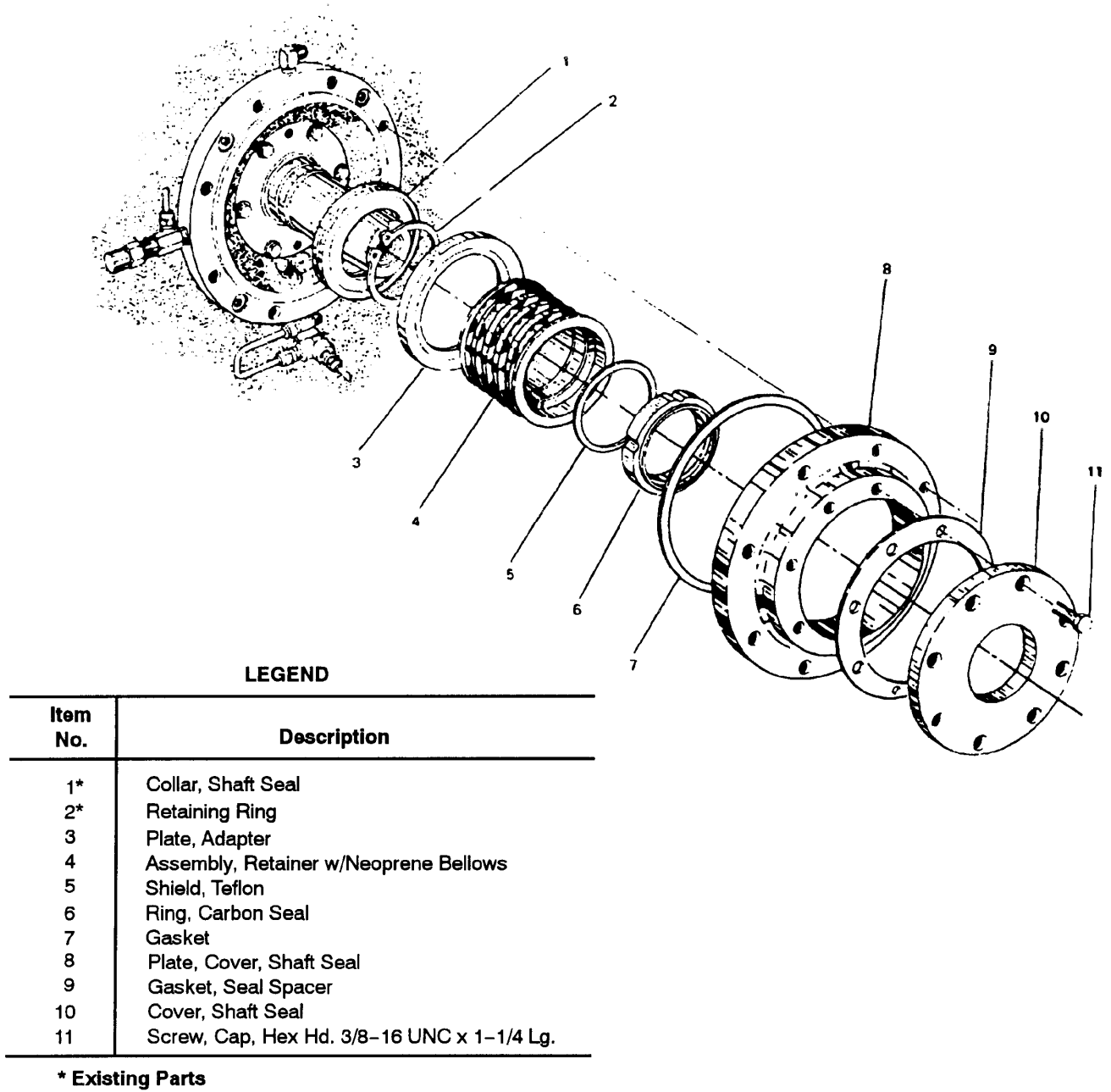
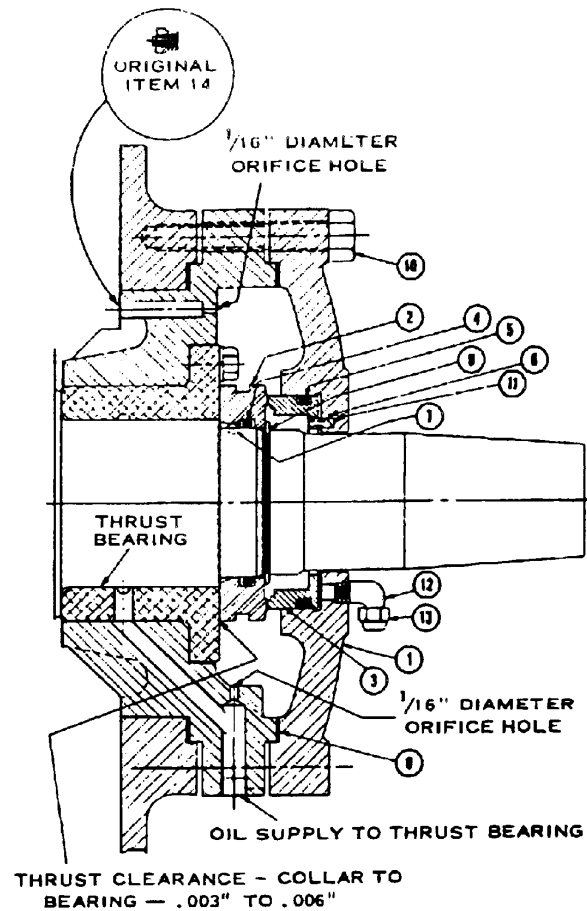


Figure 516-3-103. John Crane Conversion Shaft Seal - Exploded View

12. Pull the crankshaft outward as far as it will go. Clean the retaining ring groove and install the retaining ring, using the special plier tool. The inner circumference of the retaining ring is beveled. Install the ring with the beveled edge toward the outside of the compressor and with the retaining ring groove clean. Avoid scratches or damage to the running face of the shaft seal collar.
13. Using a new gasket and existing capscrews, install the cover plate. Draw capscrews down alternately and evenly to 75 foot-pounds torque.
14. Install the adapter plate. The flange of the adapter plate fits over the shaft seal collar installed in step 11.
15. Oil the crankshaft and the neoprene bellows well. Slide the retainer assembly with the neoprene bellows in place onto the crankshaft until it contacts the adapter plate. Compress the retainer assembly to see that it operates freely.
16. Oil the Teflon shield and carbon seal ring and carefully place the carbon seal ring with the Teflon shield in position inside the retainer assembly. Be sure the notches on the OD of the carbon seal ring match the projections on the inside diameter (ID) of the retainer assembly.
17. Apply oil to lapped faces of the carbon seal ring and the seal cover.
18. Install the gasket, seal cover, and capscrews. Due to the action of the spring-loaded retainer assembly, the lapped surface of the cover will contact the lapped surface of the carbon seal ring before the cover will contact the plate installed in step 13. Tighten capscrews evenly by drawing down opposite and alternate pairs.
19. Connect the oil supply line.
20. Reinstall drive components (see limitations for belt drive units).

516-3.2.26.2.13 York G Series Shaft Seal Design Changes. York has made several design changes that affect shaft seals. These are outlined in the following steps, indicating a progression of changes. A change to the crankshaft is also indicated since the change in the shaft affects the shaft seal. This is of particular interest to maintenance personnel when obtaining replacement parts. The design changes are as follows and may be incorporated in existing compressors at the time a shaft seal replacement is made.

- a. Beginning with compressor serial no. P0075493 (compressor no. 10013), manufactured 20 May 1964, the quantity of tension springs (6, [Figure 516-3-104](#)), has been changed from 8 to 12. The shaft seal spring change is applicable to all compressors equipped with the Y-53 style shaft seal or the Y-53 shaft conversion kit. To install these springs, a new shaft seal cover plate (part no. 064-06366; 1, [Figure 516-3-104](#)), containing 12 holes for springs, can be used to replace the original cover plate. Also, it is possible to have four additional holes drilled in the existing cover plate at a machine shop. Do this work carefully, locating the new holes so that the 12 holes will be evenly spaced. Use 12 springs when reinstalling the cover plate.
- b. Beginning with compressor serial no. P0081170 (compressor no. 10037), manufactured 1 June 1964, the shaft seal pressure relief valve (formerly item no. 14, [Figure 516-3-104](#)) has been eliminated, and a 1/16-inch orifice hole drilled in the bearing head as shown in [Figure 516-3-104](#). Compressors no. 7966 to no. 10037 were equipped with the shaft seal relief valve. The following field change, therefore, is applicable only to these compressors. Proceed as follows:



Item No.	Number Required	Description	Drawing Part Number
1	1	Cover Plate	064-06366
2	1	Collar	064-04739
3	1	Ring, Carbon	064-14031
4	1	Gasket, O-ring	028-07420
5	1	Gasket, Quad Ring	028-07421
6	12	Spring, Helical	029-04010
7	1	Ball, 3/16 in. Diameter	029-01845
8	1	Gasket, Bearing Head	028-00824
9*	1	Ring, Retaining	029-09214
10	8	Screw, Cap. Hex.-Hd 1/2 in. - 13 UNC x 3-1/4 Lg.	021-09204
11	1	Pin, Roll Pin 1/8 x 1/2 in. Lg.	029-04290
12	1	Ell, 1/4-in. SAW x 1/8-in. M.P.T.	023-01285
13	1	Nut, 1/4-in. Flare	021-05675

*Retaining ring must always be installed with the bevel on its inner circumference facing toward the cover plate.

Figure 516-3-104. Shaft Seal Assembly - Retaining Ring Type

- 1 Remove the shaft seal and its bearing head.
 - 2 Remove the relief valve from the bearing head.
 - 3 Drill a 1/16-inch hole through a 1/8-inch male pipe thread (MPT) hex socket pipe plug.
 - 4 Install the drilled plug in place of the relief valve and reassemble the compressor.
- c. Shaft seal oil piping - Beginning with compressor no. 7467, manufactured 10 July 1961, the external shaft seal oil piping, except for the oil feed connection at the bottom of the bearing head, was eliminated. Oil is now fed to the shaft seal cavity from a 1/16-inch-diameter orifice hole, which is drilled at the upper end of the large feed hole at the bottom of the bearing head, from which oil is supplied to the thrust bearing (Figure 516-3-104). High-pressure oil from the compressor oil pump is then fed (at reduced pressure after leaving the orifice hole) to the shaft seal cavity. With the cavity filled, this oil is returned to the crankcase through the relief valve (14, Figure 516-3-104), which is set at 7-1/2 to 15 psig. This valve is located on the crankcase side of the bearing head. With the compressor running, the shaft seal collar (2) and the carbon shaft seal ring (3) are continuously submerged in oil at higher than crankcase pressure, thus ensuring proper lubrication of the rubbing surfaces.
- d. Crankshaft - Beginning with compressor no. 7977, crankshafts for all 3-3/4 inch x 3-inch compressors have been modified to eliminate the threads for locknuts that secured the shaft seal collar (2, Figure 516-3-104) to the crankshaft. Before compressor no. 7977, this change was made on about fifty 3-3/4 inch x 3-inch compressors of various cylinder numbers. The following applies:

NOTE

Measure shaft seal collars (York part no. 064-04739) purchased before October 1961 to determine whether they can be used with the new style crankshaft with the Truarc ring. The distance between the face of the recess adjacent to the sealing face of the collar and the back of the collar should be +0.856 inch to 0.860 inch (Figure 516-3-104). If the distance or collar thickness is greater or less than this, use the collar only with the old design, locknut type crankshaft.

- 1 The shaft seal collar is now held against the shoulder by means of a spring-type retaining ring (9, Figure 516-3-104; York part no. 029-09214), which fits into a groove in the crankshaft. The shaft seal collar is anchored to the shaft by means of a steel ball, and the refrigerant seal between the collar and shaft is provided by means of the O-ring (4). Note that the retaining ring (9) is provided with a beveled edge on the inside.
- 2 circumference. Install the ring with the beveled edge toward the outside of the compressor as shown. Since the thrust clearance of the compressor (0.003 to 0.006 inch) is established by the retaining ring, it is essential that the crankshaft be pulled all the way out when this ring is installed and that all parts be thoroughly clean. Use care to prevent damage to the O-ring gasket (4).
- 3 New replacement crankshafts ordered from York will be of the new design (retaining ring type) described above. When a new crankshaft is installed, also install the new modified carbon ring described in step e.

CAUTION

The original carbon shaft seal ring for the locknut-type crankshaft cannot be used with the new retaining ring-type crankshaft.

- e. Use the modified carbon shaft seal ring, York part no. 064-14031, (3, Figure 516-3-104) with the retaining ring-type crankshaft described in step d. The modifications are as follows:
- 1 Added a counterbore to allow clearance for the shaft seal retaining ring (9).

- 2 Changed the ring material to make it suitable for use with R-12 and R-22.

NOTE

The cover plate depth gauge hole for checking the seal tension (thickness of cover plate gasket) has been deleted since the dimension found is always within the limits stated in this paragraph when all new seal parts are installed and gasket 028-00824 is used.

- f. Installing shaft seal collars with locknut type shaft - During the installation of a shaft seal collar to the crankshaft, service personnel should always rotate the crankshaft and pull the shaft towards the outside. This will allow the collar to be seated properly over the steel-locking ball and the shoulder on the shaft. Collar locknuts may then be tightened before the collar is forced against the thrust bearing, which sometimes locks the crankshaft. After locknuts have been tightened, rotate the crankshaft and pull towards the outside. Then check the thrust clearance.

516-3.2.26.3 York Compressor F Series 2-5/8 by 2-1/4 - Crankshaft Seal The original (obsolete) shaft seal consists of a stationary carbon seal ring that is kept in constant contact with the face of a rotating cast-iron shaft seal collar by means of a spring (Figure 516-3-105). When the shaft seal requires replacement and signs of abnormal wear or damage to running faces are present, look for a definite reason for the condition. Seal failure is usually the result of faulty lubrication due to the condition of the crankcase oil. Dirty or broken down oil is generally caused by one or both of the following conditions:

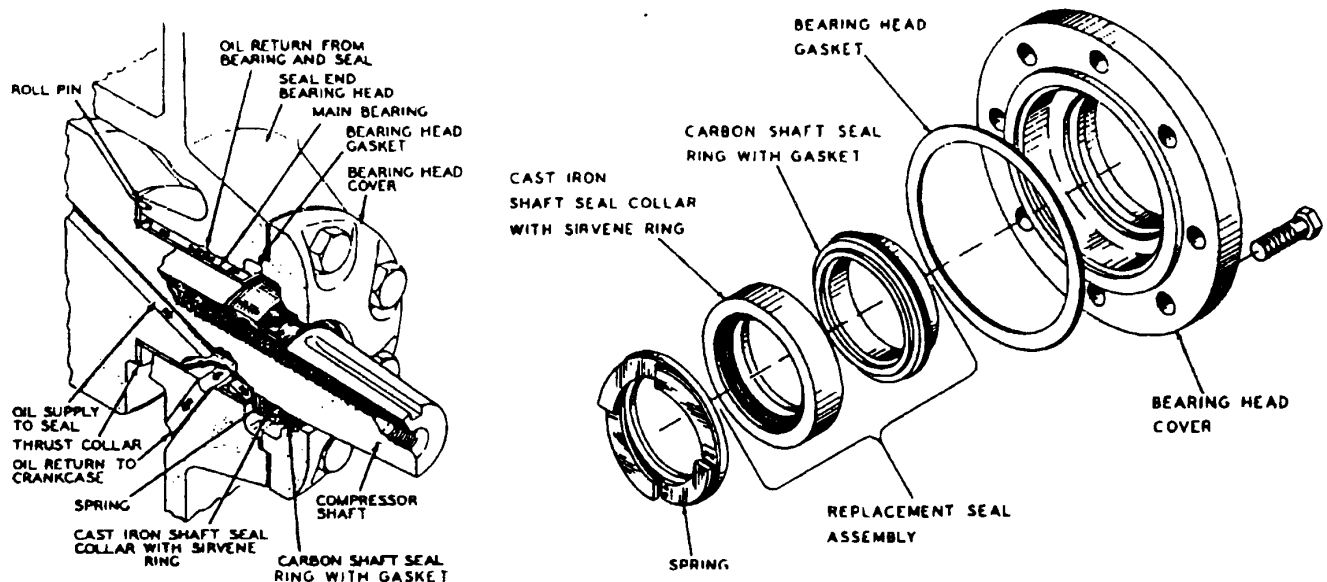


Figure 516-3-105. Shaft Seal and Bearing Head Assembly

- a. Dirt in the system. Dirt usually enters the system during installation or repairs. After a period of operation, any dirt will eventually accumulate in the compressor crankcase and some of this will concentrate in the shaft seal chamber. When the oil contains grit, it is only a matter of time until the highly finished running faces become damaged, causing failure of the shaft seal.
- b. Moisture in the system. Moisture frequently causes an acid condition in the lubricating oil. Oil in this condi-

tion will not provide satisfactory lubrication and will promote failure of compressor parts. If the oil in the crankcase is discolored, gritty, or broken down, thoroughly clean the crankcase. If the presence of moisture is suspected (indications of corrosion, sludge, or copper plating on compressor parts), use a system drier when the compressor is put into operation.

516-3.2.26.3.1 To remove a leaking shaft seal, refer to [Figure 516-3-105](#) and proceed as follows:

1. Pump down the compressor.
2. Remove the compressor drive (flywheel or coupling).
3. Back out capscrews that secure the bearing head cover to the bearing head and remove the bearing head.

NOTE

Since the seal chamber remains flooded with oil at all times, place a container under the seal to catch this oil when the bearing head is removed.

4. Remove the shaft seal ring and its gasket. These parts may come out with the bearing head cover.
5. With a rotating motion, pull the seal collar, with its Sirvene ring, off the shaft.
6. Remove the shaft seal spring.
7. Remove the bearing head gasket.

516-3.2.26.3.2 Install Replacement Shaft Seal. The replacement seal assembly is a bellows type shaft seal. When replacing a leaking shaft seal, the complete assembly (ring and collar) should always be replaced.

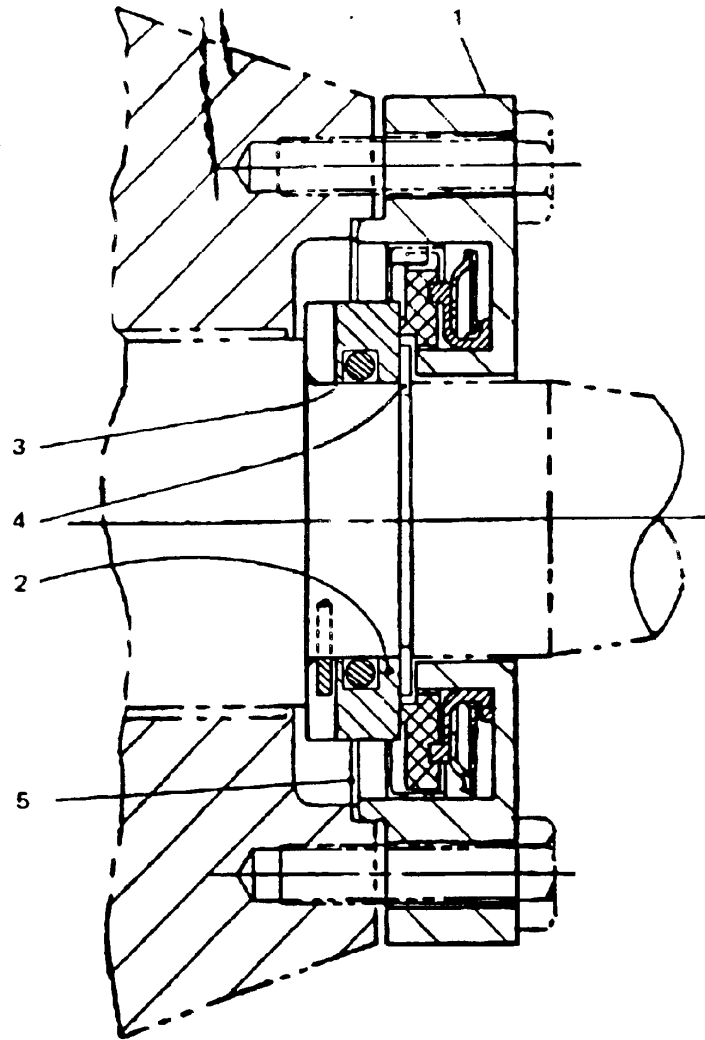
516-3.2.26.3.2.1 Shaft seal replacements are available for the original 2-5/8 x 2-1/4 compressor shaft seals. Compressors using these shaft seals fall into one of three categories as described herein:

- a. Compressors (designated by AF) equipped with a shaft seal using a leaf-type spring. The seal cover plate on these compressors has a rather flat dome on the outside.
- b. Compressors (designated by BF or early F32S, F62S, and F92S) equipped with a balance-type shaft seal. The seal cover plate on these compressors had a raised center on the outside.
- c. Later design F32S, F62S, F92S and FS53, FS62, and FS92 compressors equipped with a Brummer (bellows-type) shaft seal. The cover plate on this seal is perfectly flat on the outside.

NOTE

Parts are no longer available for the seals described in categories a and b. If a new seal is required, convert the compressor to the replacement shaft seal.

516-3.2.26.3.2.2 Install Brummer Shaft Seal. The replacement Brummer shaft seal consists of the parts shown in [Figure 516-3-106](#). The Brummer seal will fit all existing 2-5/8 inch compressors. However, compressors falling into category a of paragraph [516-3.2.26.3.2.1](#) will require modifications to the crankshaft, per [Figure 516-3-107](#), if not already modified. To install a replacement Brummer shaft seal, proceed as follows:



Item No.	Description	Part No.
	Shaft Seal, Complete	365-24327
1	Seal, Shaft	029-13635
2	Collar	065-09573
3	Seal, O-Ring	028-09306
4	Ring, Retaining	029-07100
5	Gasket	070-03357

Figure 516-3-106. Brummer Replacement Shaft Seal - Cross-Sectional View

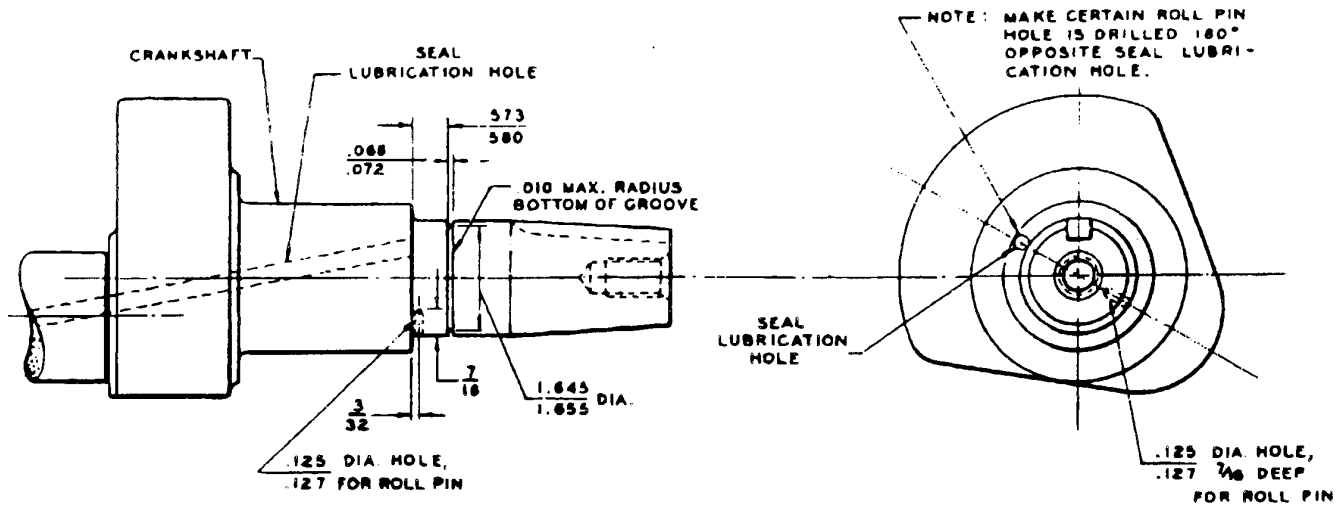


Figure 516-3-107. Retaining Ring Groove and Roll Pin Hole

1. Before opening the compressor for repairs, close suction and discharge stop valves. Recover the refrigerant from the compressor.
2. Remove the compressor drive (flywheel or coupling, and key).
3. Remove capscrews that hold the shaft seal cover plate to the bearing head and remove the cover plate.

NOTE

Since the seal remains flooded with oil at all times, place a container under the seal to catch this oil when the cover plate is removed.

4. Remove existing shaft seal parts.
5. Clean the shaft seal chamber and flush it with an approved safety solvent.
6. Coat the O-ring and collar with clean compressor oil and carefully slide them onto the crankshaft. Be sure that one of the grooves on the back of the collar fits over the roll pin.
7. Carefully fit the retaining ring into its groove in the crankshaft, being careful not to damage the crankshaft or the seal collar.
8. Oil the bellows and the face of the seal ring well and slide the assembly with the new gasket onto the shaft. Do not touch sealing surfaces and be sure the carbon is not chipped or cracked.
9. Compress the cover plate to see that it operates properly.
10. Install cover plate capscrews and tighten them evenly by drawing down opposite and alternate pairs. Proper torque is 30 foot-pounds.
11. Reinstall the compressor drive (flywheel or coupling).
12. Be sure compressor is filled to the correct level with the proper oil. Evacuate the compressor and test for leaks.

516-3.2.26.3.3 Install John Crane Shaft Seal (York 029-22359). John Crane replacement shaft seal is a replacement for the original 2-5/8 x 2-1/4 compressor face type (obsolete) shaft seal or the Brummer bellows type shaft seal. To replace the seal proceed as follows:

1. Isolate the compressor and recover the refrigerant from the compressor.
2. Remove the compressor drive (flywheel or coupling and key).
3. Remove capscrews that hold the shaft seal cover to the bearing head and remove the cover plate. ([Figure 516-3-108](#)).

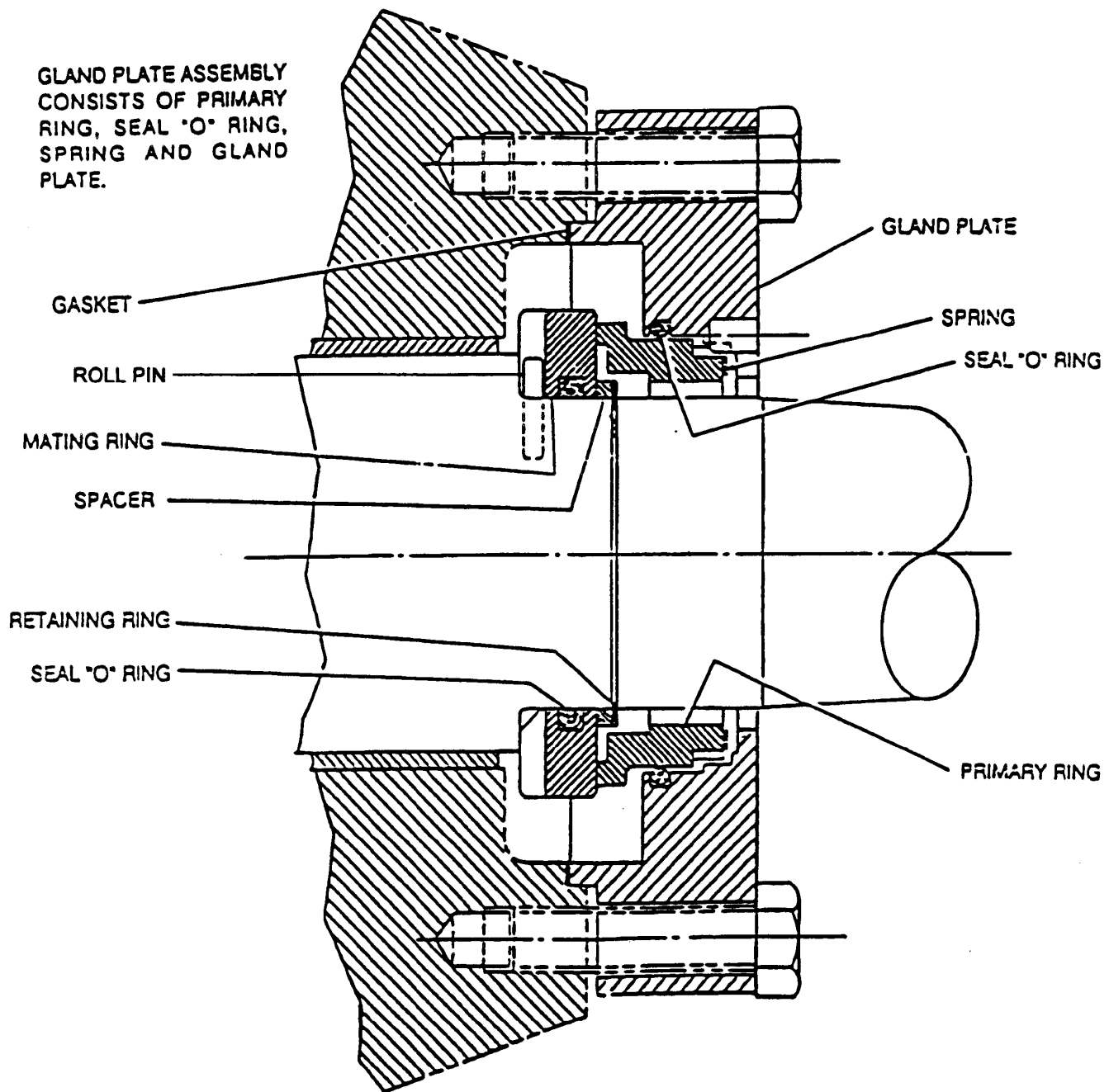


Figure 516-3-108. Cross Section-John Crane Replacement Shaft Seal (York Part No. 629-20956)

NOTE

Since the seal remains flooded with oil at all times, place a container under the seal to catch this oil when the cover plate is removed.

4. Remove existing shaft seal parts. (Figure 516-3-108)
5. Remove roll pin from the crankshaft by gripping it with a pair of side cutters and using a screw driver to pry it from the shaft. (Figure 516-3-108)
6. Clean the shaft seal chamber and flush it with an approved solvent.
7. Clean the crankshaft of any foreign material such as paint, grease, or dirt.
8. Install filler ring in the retaining ring groove. (Figure 516-3-109)
9. Oil the "O" ring in the mating ring and place the mating ring in the gland plate with the lapped surface facing toward the primary ring. (Figure 516-3-109)
10. Oil the crankshaft and I.D. of the rubber bellows. Slide the spring holder, spring and bellows assembly onto the shaft. (Figure 516-3-109)

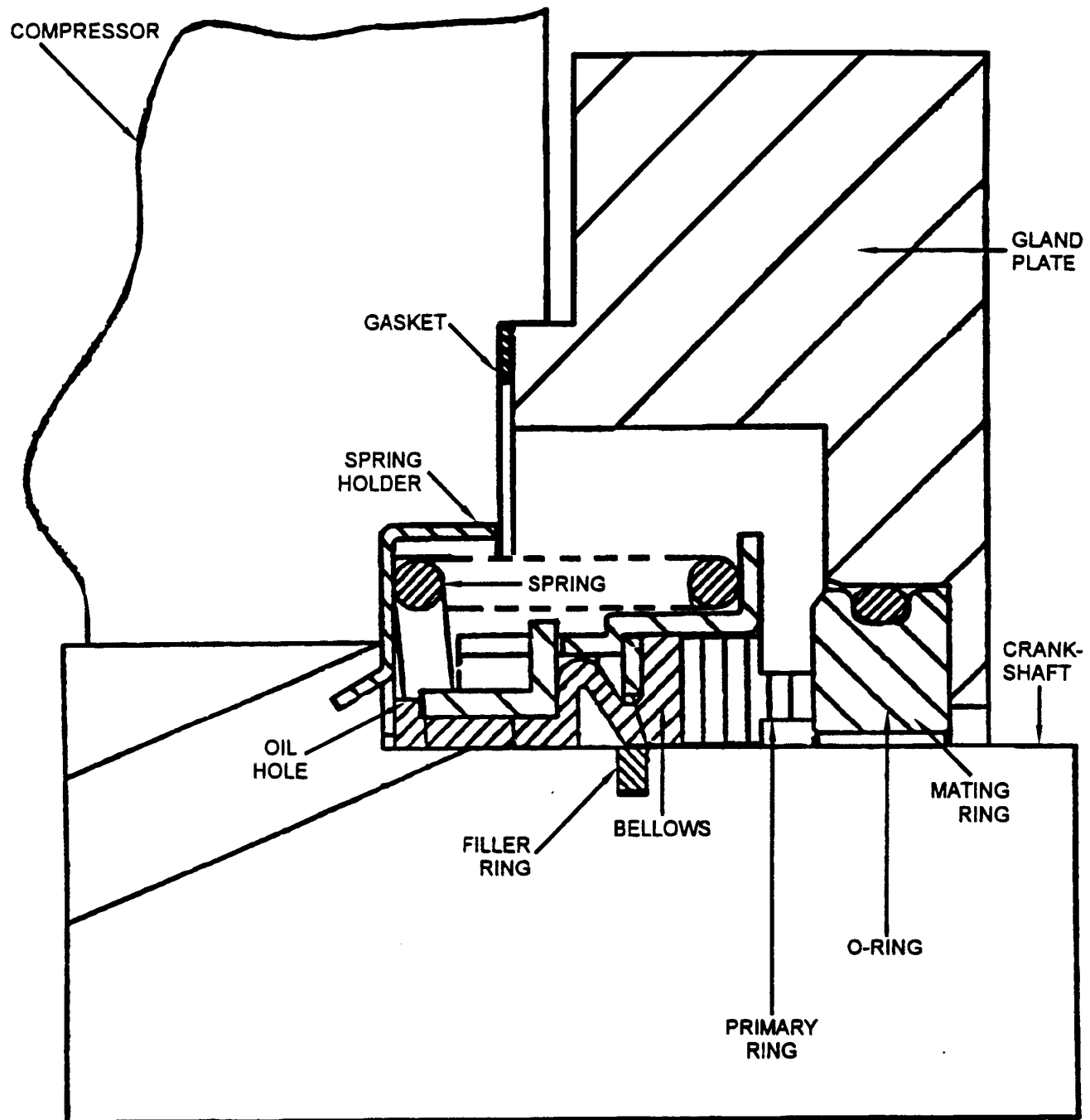


Figure 516-3-109. John Crane Bellows Type Shaft Seal (York Part No. 029-22359)

NOTE

Ensure the tab in the spring holder is engaged in the oil hole of the crankshaft and the spring holder is flat against the crankshaft shoulder. (Figure 516-3-109)

11. If the bellows assembly can not be pushed into place by hand, the gland plate with the mating ring can be used to push the bellows into place. Use two (2) 3/8-16UNC x 3-1/4 inch long threaded rods and two (2) nuts. Thread the rods into opposite housing holes. Place the gland plate and seal assembly over the rods and use the nuts to push the seal and gland plate into place.
12. Remove the two (2) threaded rods and gland plate.
13. Apply oil to the lapped surfaces of the carbon ring and mating ring.
14. Install gland plate gasket and gland plate. Secure with the original eight (8) 3/8 inch cap screws. Torque cap screws to 34 - 40 ft/lbs.
15. Reinstall coupling hub to the compressor shaft and couple motor and compressor or install flywheel and belts.

516-3.2.27 COMPRESSOR DRIVE. Current compressors are designed for a maximum nominal speed of 1,800 rpm. These compressors are driven by a motor either through V-belts or flexible coupling. Belt drives may be used because of a space problem or to match a specific compressor capacity; that is, the lower the speed, the lower the capacity. In either case, proper alignment of compressor and motor shafts is extremely important for trouble-free operation of the compressor unit.

516-3.2.28 V-BELT DRIVE. To ensure long life and satisfactory operation of V-belts, the motor pulley and the flywheel shall be in exact alignment and belts shall be under proper tension.

516-3.2.28.1 Remove Belts, Pulley, and Flywheel.

1. Loosen motor adjusting bolts and move the motor to eliminate all of the belt tension.
2. Remove all belts, one belt at a time, outer belt first.
3. Remove motor pulley and compressor flywheel using the appropriate pullers. (Refer to the equipment technical manual.)

516-3.2.28.2 Install and Align the V-belts.

1. Before aligning the drive, find the magnetic center of the motor rotor. This may be done by running the motor idle and measuring from the inside face of the motor pulley to some fixed point on the motor frame. Maintain this distance during the alignment procedure. Another method of maintaining the motor shaft at the correct axial position during alignment is to run the motor idle and scribe a mark on the motor shaft adjacent to the motor bearing housing. Then keep at the marked location during the alignment procedure.
2. Clean motor and compressor shafts and bore of flywheel and motor pulleys with fine emery cloth.
3. Install the motor pulley and compressor flywheel. See that keys are nicely fitted along side and that the pulley and flywheel are tightly installed on the shafts.

CAUTION

Never stretch a belt over motor or flywheel pulley grooves as this procedure may permanently injure the belt. Always loosen the motor on base and place belts in grooves without stretching, then move motor back to correct position.

4. Slide motor forward on its rails and install belts.
5. Move motor back into place with adjusting bolts until the belt slack is taken up.
6. Line up the flywheel and motor pulley with straightedge or string. The shafts shall be parallel and the grooves in the same line as shown in [Figure 516-3-110](#). [Figure 516-3-111](#) shows angular and parallel misalignment. Alignment can also be checked by placing a length of round rod in the belt grooves. Correct parallel misalignment by sliding the motor pulley on its shaft. Correct angular misalignment by loosening motor hold-down bolts and turning motor frame.

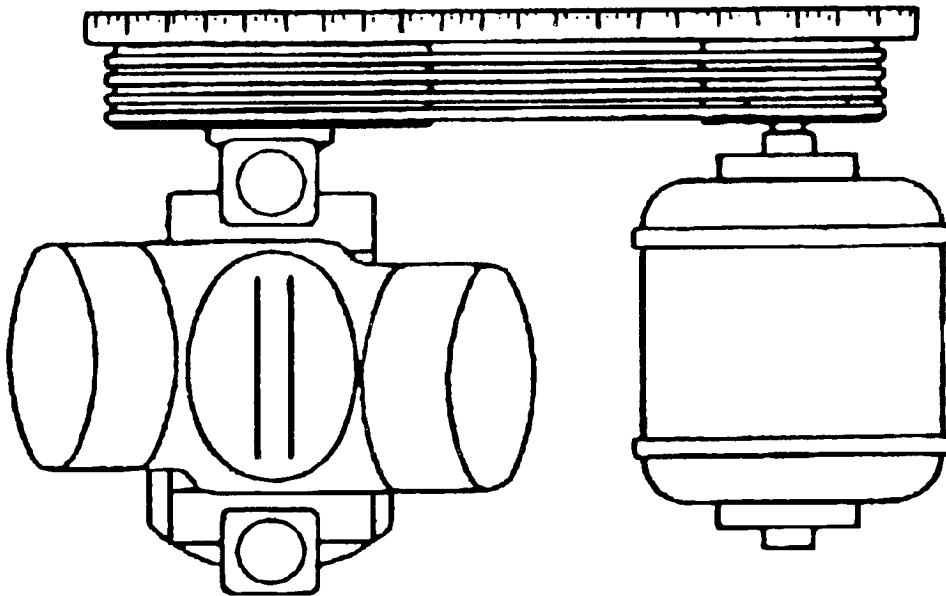
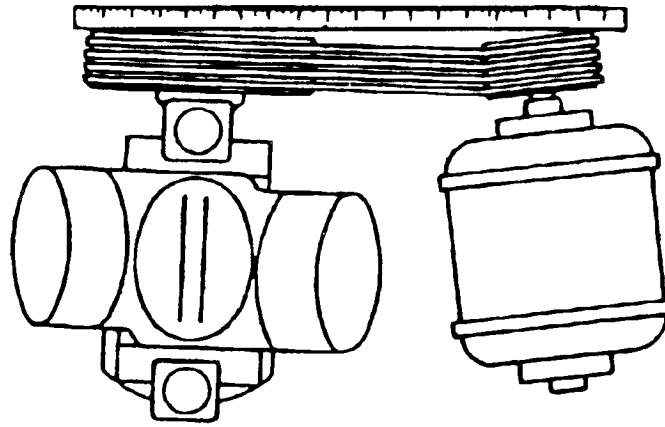
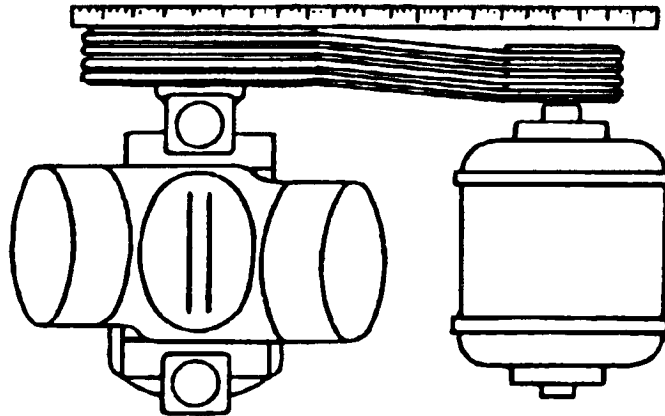


Figure 516-3-110. Correct Belt Placement



ANGULAR MISALIGNMENT



PARALLEL MISALIGNMENT

Figure 516-3-111. Belt Drive Misalignment

7. Adjust belt tension by turning adjusting screws and sliding motor on its rails, or by using the belt-tightening device if provided. Where two screw adjusters are provided, make certain that equal adjustment is applied at both points. Tighten belts just enough to prevent slippage. One method of determining the correct belt tension is to loosen belts just enough so they slip when the motor is started (the belt squeals) and then tighten them just enough to eliminate the slippage. Some operators judge belt tension by the amount a single belt can be depressed at the center of the span with the pressure of one finger. Experience is needed to judge tension in this way. As a guide, a heavier belt with a 24-inch span should deflect about 3/4 to 1 inch. Lighter belts or longer spans should deflect proportionately more. Follow manufacturer's detailed instructions in technical manuals, when available, for particular compressors. A belt that is too loose will cause slippage, rapid wear, and deterioration often to the extent of burning. A belt that is too tight will cause excessive wear of the belt and both the main compressor bearings and the motor bearings. In extreme cases, it may cause a bad seal leak.
8. Install a belt guard to cover the flywheel, motor pulley, and belts. Do not operate motor and compressor without belt guard in place. Serious injury can result from contact with moving parts.
9. When replacement of one belt of a multiple V-belt is necessary, install a complete new set of matched belts. Belts stretch considerably during the first few hours of operation. Replacement of a single belt will upset the load balance among new and old belts and be a potential source of trouble. It is better practice to run the unit with a defective belt removed than to attempt to operate a new belt in conjunction with two or more seasoned belts.
10. Order replacement V-belts in matched sets for the particular service intended.
11. Keep V-belts, motor pulley, and compressor flywheel dry and free of oil. Never use belt dressing.

516-3.2.29 FLEXIBLE COUPLING DRIVE. If it is determined that the compressor and motor shafts are misaligned, realign the shafts. Misalignment can cause vibration, excessive flexible coupling wear damage, or compressor seal failure. Tools required for alignment are a straightedge, a scribe, a steel rule graduated to 1/64 inch, and a dial indicator. The use of a dial indicator for coupling alignment is the more accurate method. The illustration and procedure presented herein is for a typical coupling. Other types of couplings are in use; however, the procedure is essentially the same. See the technical manual for specific details and permitted misalignment tolerances. The following instructions make up the dial indicator method of alignment.

1. Disassemble the coupling, as shown in [Figure 516-3-112](#), where a typical flexible coupling is illustrated.

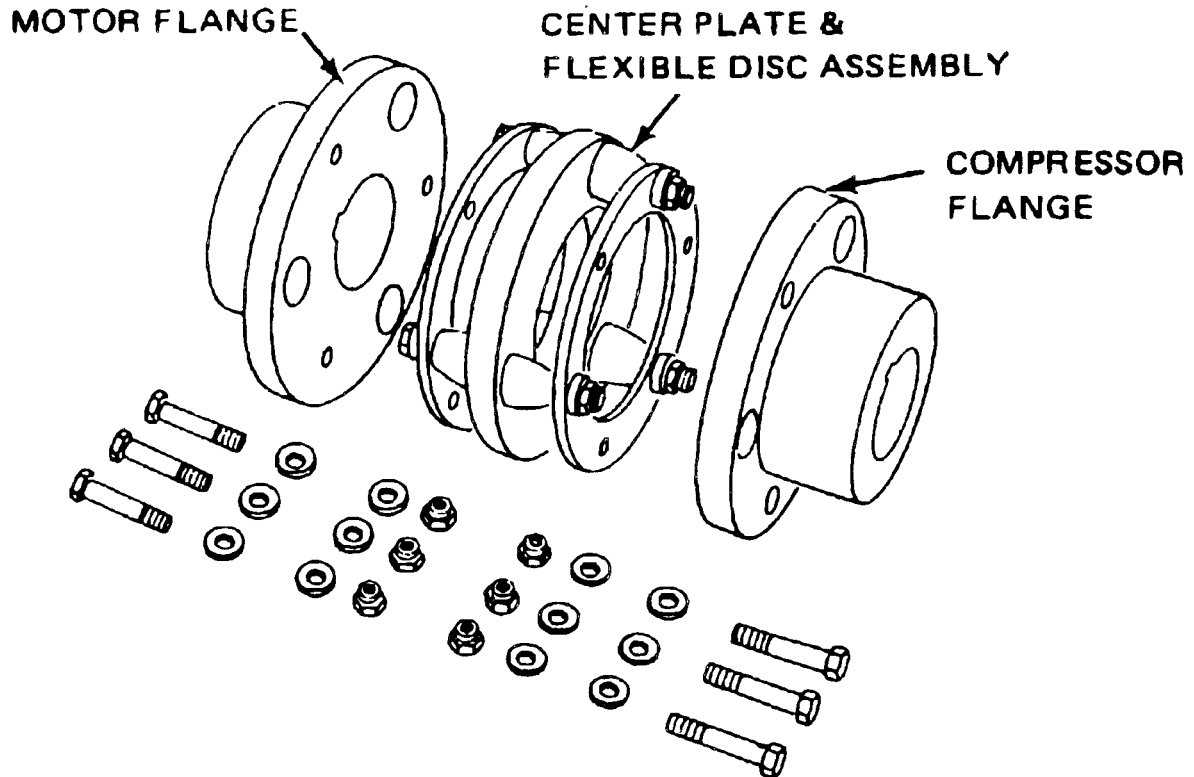


Figure 516-3-112. Typical Flexible Coupling Dismantled

2. Clean compressor, motor shafts, and coupling flanges. Remove all burrs. Tighten compressor holddown bolts. Leave motor holddown bolts loose enough to permit adjustment during alignment.
3. Fit the compressor coupling flange to the compressor crankshaft. The flange has a tapered bore and keyway. It is most important it fit properly on the tapered crankshaft without wobble. Correct any irregularities that might cause an imperfect fit. To ensure proper fit, proceed as follows:
 - a Blue the shaft and slide the flange on without the key in place. Apply moderate pressure against the flange and rotate it slightly back and forth a few times. Remove the flange and check both the shaft and the flange bore surfaces for high spots. Use an extra fine grit stone to dress down any high spots. Do not use a file. Reblue the shaft and repeat the operation until all high spots are gone and there is no detectable wobble. Wipe the shaft and bore clean.
 - b Without the key in place, slide the flange onto the shaft as far as it will go. Use moderate pressure but do not jam it on. Scribe lightly around the shaft at the back end of the flange. Also note the position of the shaft end with respect to the flange face. It should be approximately 1/8 inch below the face. Then remove the flange.
 - c Place the key in the keyway and again slide the flange onto the shaft as far as it will go. If the flange does not stop in the same position as in step 2, the key is causing the misfit and shall be carefully dressed down until the fit is correct. After the flange is in place, install the bolt and washer provided with the compressor. Tighten the bolt securely. Do not use the bolt and washer to force the flange into place. On some compressors the washer has a projection that engages the channel in the hub.
4. Fit the motor flange to the motor shaft, using the same procedure described for the compressor flange.
5. Start the motor and scribe a line adjacent to the motor bearing house to locate running position of the arma-

ture (Figure 516-3-113). If the motor cannot be started, measure the amount of end play in the motor shaft. Set the motor shaft at half this measurement and mark its position. The coupling is to be aligned with the motor shaft in this running position.

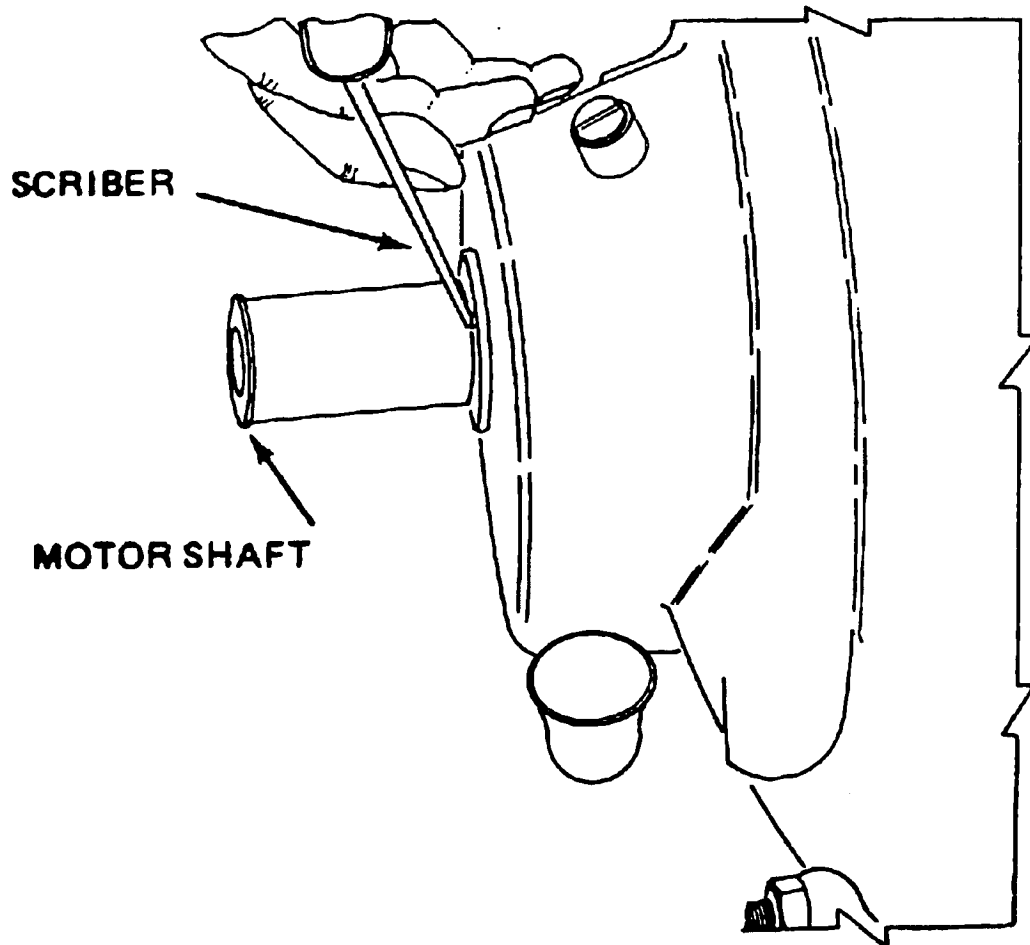


Figure 516-3-113. Scribing a Line to Locate Running Position of Armature

6. The position of the compressor crankshaft shall be against the pump end thrust bearing or against the seal end thrust bearing, depending on the operating crankshaft position. Determine the proper position of the crankshaft (check equipment technical manual). The crankshaft shall be in that position (pump end or seal end) before proceeding with the alignment procedure. If the operating crankshaft position cannot be determined, measure the crankshaft end play, set the crankshaft at half this measurement, and mark its position. Then align the coupling with the crankshaft in that position.
7. Reassemble the coupling and make a preliminary adjustment of the flange spacing, dimension E (Figure 516-3-114). Refer to the equipment or coupling technical manual for required flange spacing. After adjustment of dimension E, tighten motor flange setscrews.
8. Move and shim the motor until dimension E is correct and the same within 1/64 inch when measured at four positions 90 degrees apart, and until edges of the flanges are in line when tested with a straightedge (Figure 516-3-114).

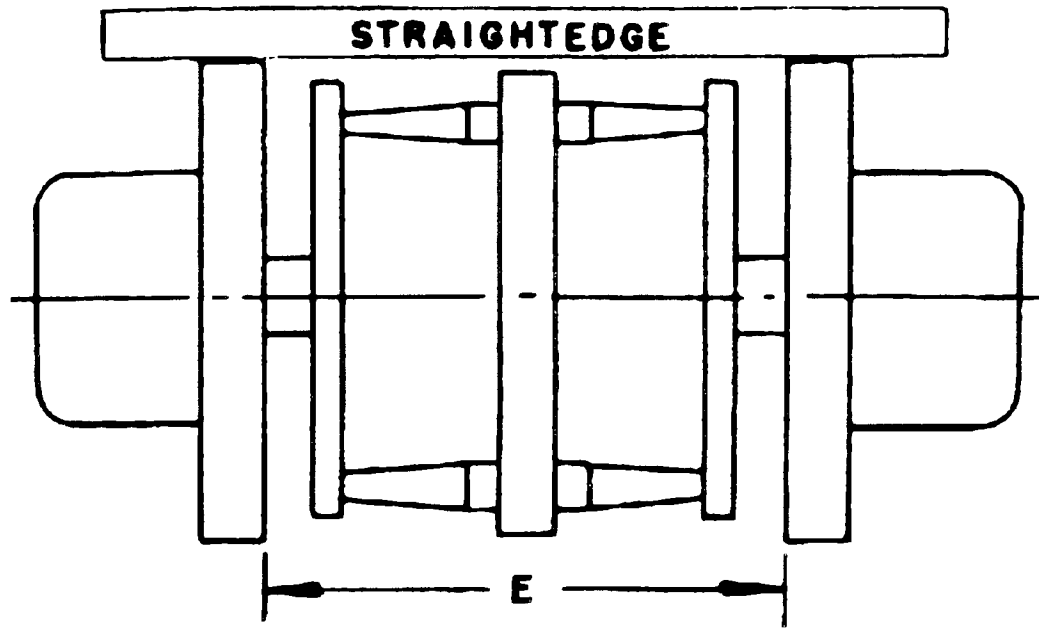


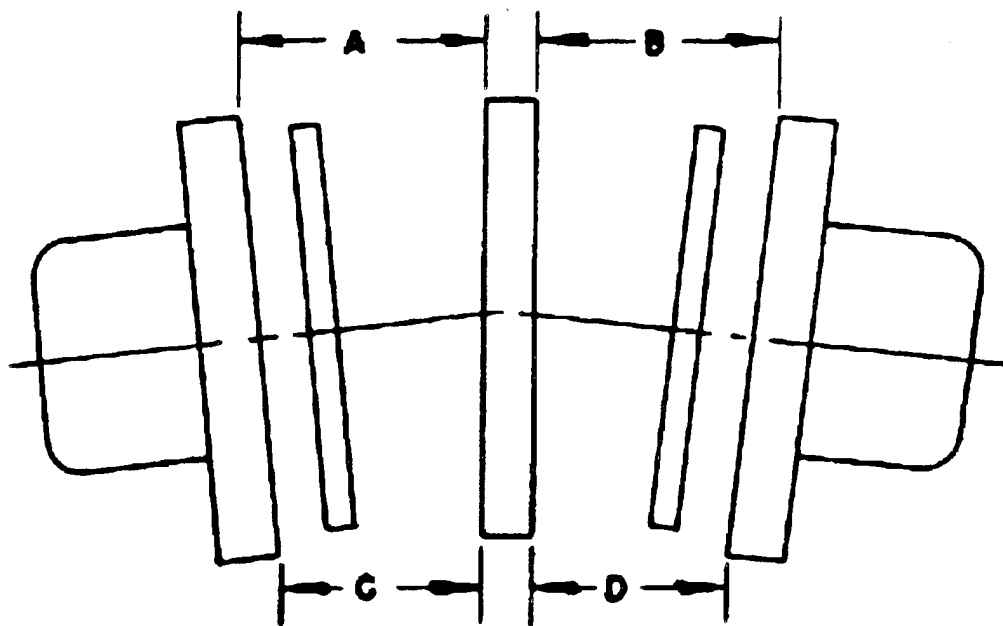
Figure 516-3-114. Preliminary Adjustment, Flexible Coupling

9. Tighten motor holddown bolts.

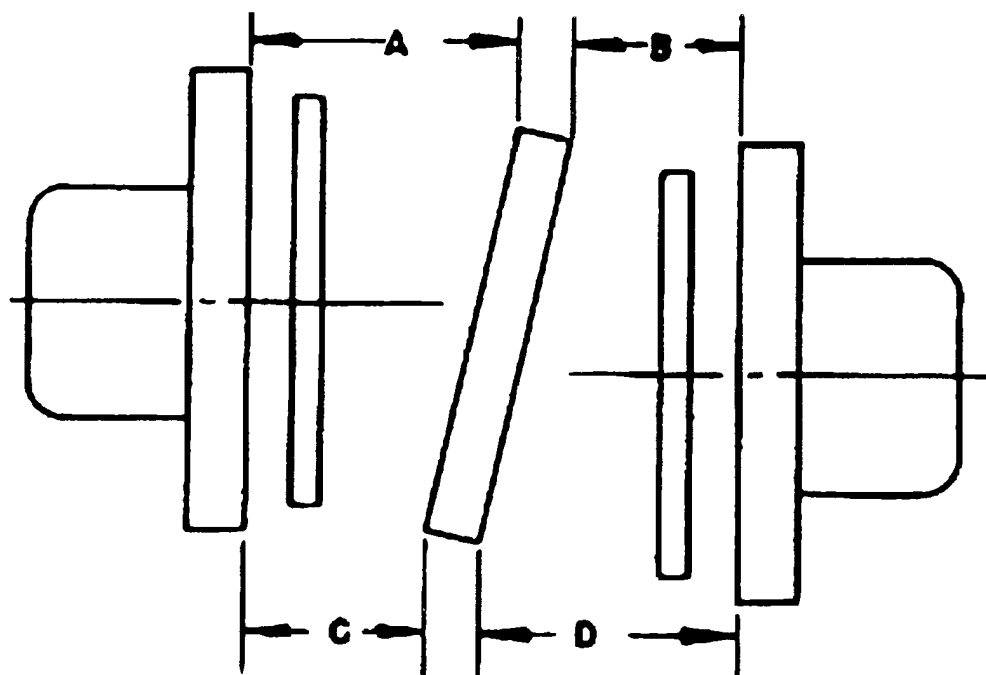
NOTE

The tolerances given here and in the following paragraphs are for general guidance only. When available consult the technical manual provided by the coupling or equipment manufacturer to determine tolerances required. Angular and parallel misalignment should not exceed 0.005 inch; but under no circumstances shall it exceed 0.010-inch total indicator reading.

10. For angular alignment ([Figure 516-3-115](#)), mount the dial indicator on the motor flange as shown in [Figure 516-3-116](#). Make certain that the indicator is securely clamped and that the entire assembly is rigid.



Angular Misalignment



Parallel Misalignment

Figure 516-3-115. Flexible Coupling Misalignment

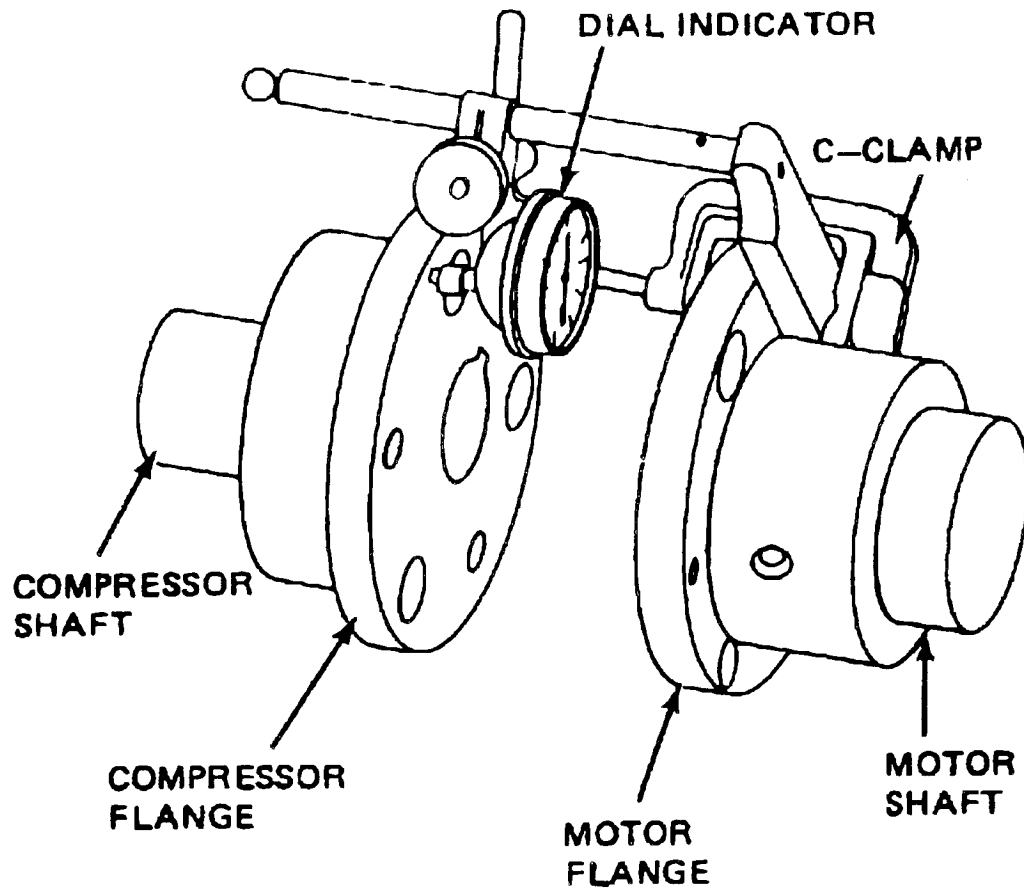


Figure 516-3-116. Dial Indicator Setup to Check Angular Alignment

11. Adjust the indicator so that its stem will contact the inside face of the compressor flange at all times while the indicator is being rotated through 360 degrees with the motor flange.
12. With the indicator at the top, set the dial to read zero at the pointer. Rotate the motor flange with the indicator and note readings at the top, bottom, and at each side. Push the motor shaft hard against its thrust bearing before each reading is taken. To correct any misalignment, tilt the motor up or down in the vertical plane or swing from one side to the other in the horizontal plane, in an amount approximately equal to one-half the difference between readings taken in respective planes. For example, the following is a typical set of indicator readings:
 - Top 0.000 inch
 - Bottom -0.020 inch
 - Right Side -0.010 inch
 - Left Side +0.030 inch
13. Shim up the two motor feet at the shaft end by approximately 0.010 inch and jack the bell end over to the right approximately 0.020 inch to bring the coupling into angular alignment. When the distance between flanges at their extreme diameter does not vary by more than 0.005 inch, the angular alignment is within recommended tolerance.
14. For parallel alignment ([Figure 516-3-115](#)), mount the dial indicator as shown in [Figure 516-3-117](#). Adjust the indicator so that the contact point will contact the periphery of the compressor flange while rotating the motor

flange through 360 degrees. If the flange is not circular, set the dial indicator to contact the coupling hub. Obtain readings as in step 1. For example, the following is a typical set of readings:

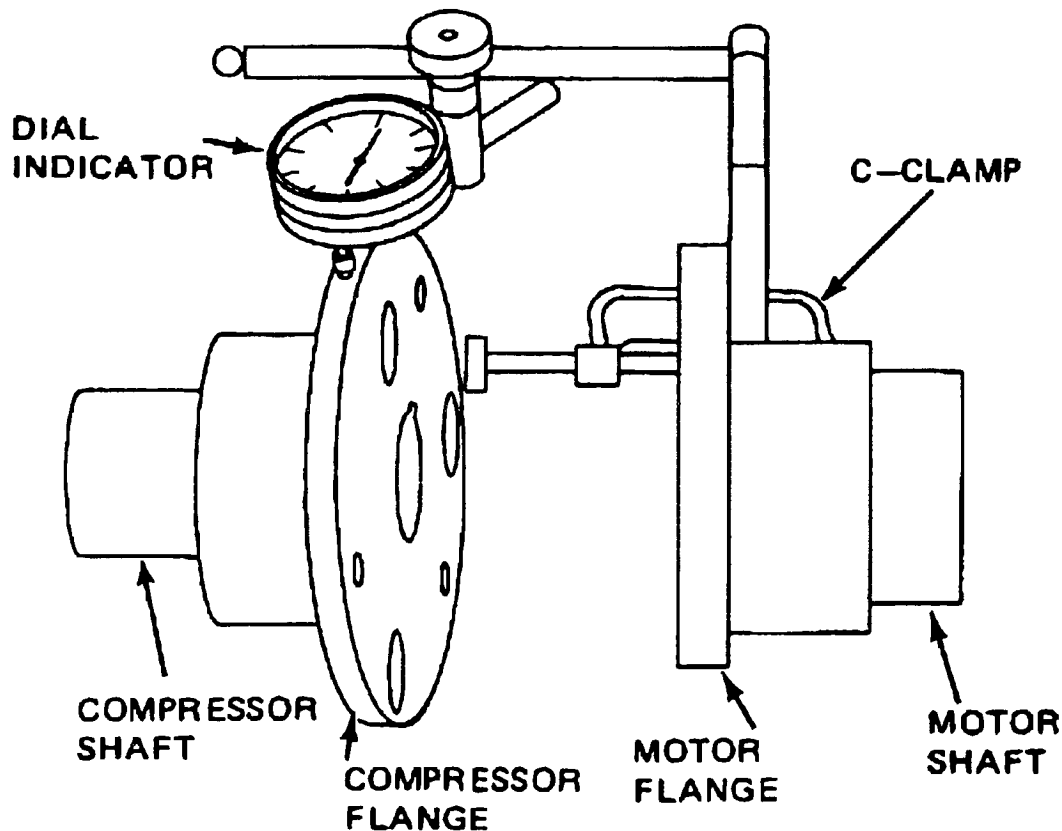


Figure 516-3-117. Dial Indicator Setup to Check Parallel Alignment

Top 0.000 inch

Bottom -0.020 inch

Right Side -0.010 inch

Left Side +0.030 inch

15. In this case 0.010-inch shims would be required under all four motor feet and the entire motor would have to be moved to the left by 0.020 inch, perpendicular to the shaft, to bring the coupling into parallel alignment. Parallel misalignment should not exceed 0.005-inch total indicator reading for two points 180 degrees apart. After correcting for parallel misalignment, make another check for the correct angular alignment. Tighten motor holddown bolts as soon as alignment is complete. Check alignment after tightening holddown bolts.
16. Loosen the setscrew in taper dowel pins. The length of the taper shall be at least twice the foot thickness. Slide the flange toward the motor to allow sufficient space to accommodate the coupling center plate and flexible disc assembly.
17. Set the motor shaft at its running position. Set distance E between flanges ([Figure 516-3-114](#)) and tighten the setscrew on the motor shaft.
18. Reassemble the coupling with the motor shaft at its running position and recheck the distance E between flanges.

WARNING

**Do not operate motor and compressor without the coupling guard in place.
Serious injury can result from contact with moving parts.**

19. Run the compressor until it reaches operating temperatures and then recheck the distance between flanges. The motor may be doweled to the base at this time as follows:
 - a After hot check and while the components are still at operating temperature, drill and ream two holes through diagonally, opposite motor and compressor feet and the base. Use a 9/32-inch-diameter drill and a no. 6 taper reamer.
 - b Secure the motor and compressor to the base with the no. 6 taper reamer.
 - c Fit the dowel so that at least 1/16 inch of the dowel is left above the foot. Coat dowels with white lead or other lubricant to prevent rusting, and tap the dowel lightly into position with a machinist's hammer.
 - d Be sure that all dowels are tight and that they do not bottom.

516-3.2.30 CONDENSER. The condenser is one of the most important components of the plant. While it appears simple with no moving parts, it nevertheless is a source of serious problems unless properly operated and maintained. Water-cooled condensers are of multipass shell and tube type with circulating water flowing through tubes. The refrigerant vapor is admitted to the shell and condensed on the outer surfaces of the tubes. The capacity of a water-cooled condenser is affected by the temperature of the water, quantity of water circulated, and temperature of the refrigerant gas. The capacity of the condenser will vary whenever the temperature difference between the refrigerant gas and the water is changed. An increased temperature difference or greater flow of water will increase the capacity of the condenser. The use of colder seawater may cause the temperature difference to increase. Variations in seawater flow or temperature will vary the refrigerant discharge pressure. A constant discharge pressure is desirable for satisfactory operation of the expansion valve in reciprocating units. Modulation of seawater flow is required to maintain relatively constant refrigerant discharge pressure. A seawater regulating valve, actuated by the compressor refrigerant discharge pressure, is installed in the condenser seawater outlet to maintain the constant refrigerant discharge pressure. A seawater bypass valve is provided around the automatic regulating valve in the event of valve failure.

516-3.2.30.1 Condensers installed in ships before 1952 were of many types and sizes. Shell diameters, numbers of tubes, tube lengths, and number of water passages were designed to suit the particular R-12 application. After 1952, a family of Navy standard condensers was established. The standard Navy design has been used and supplied by refrigeration manufacturers since that time. All applications are covered by 16 standard size condensers using only five shell diameters, six tube lengths, and one water passage design. These standard condensers are conservatively designed for a water velocity of 6 feet/second with an inlet water pressure of 25 to 35 psi. Any higher pressure increases water velocity above the design limit.

516-3.2.30.2 Condensers installed in old ships have plain (bare) tubes. All present condensers use finned tubes. A finned tube of the same diameter can be installed in a condenser with bare tubes. The finned tube for condensers is usually made with 19 fins per inch although some present condensers have 26 fins per inch. The additional fins increase the condenser capacity by a few percentage points. NEVER install plain tubes in a condenser with finned tubes as the capacity will be seriously reduced.

516-3.2.31 CONSTRUCTION. The condenser is constructed of a tube sheet brazed or welded to each end of a shell. Copper-nickel tubes are inserted through drilled openings in tube sheets and are expanded or rolled into tube sheets to provide a gastight seal. Condenser heads (water boxes) are bolted to tube sheets to complete the water side of the condenser.

516-3.2.31.1 Where dissimilar metals are used in parts of the condenser containing seawater and seawater piping systems, zinc anodes (wasting bars) are installed in condenser heads to minimize electrolytic corrosion of condenser parts in contact with the seawater. Where parts of the condenser containing seawater and seawater piping systems are essentially made of the same material, such as copper-nickel, zinc anodes (wasting bars) have not been required (except in nuclear ships). However, experience has dictated that zinc anodes are desirable and shall be used in all refrigeration condenser applications.

516-3.2.31.2 The condenser heads are provided with vent and drain connections so air can be vented from the water circuit and water can be drained for maintenance. A purge connection with a valve is located at the top of the condenser shell to allow manual release of any accumulated air in the refrigerant circuit. In new condenser installations in surface ships, a relief valve, a bursting disc upstream from the relief valve, and a sniffer valve between the relief valve and bursting disc will be installed to relieve excessive refrigerant pressure overboard. On each surface ship condenser, a cooling water failure switch is provided, which secures the compressor if cooling water fails. Pressure gauges and thermometers are also provided so that cooling water pressure and temperature can be monitored.

516-3.2.31.3 Reciprocating refrigerating plants in current submarines are limited to ship stores. For air-conditioning applications, where the vapor compression cycle applies, the centrifugal compressor is used. The condenser in submarine refrigerated ship stores uses the air-conditioning chilled water for condenser cooling. Since the chilled water system is a closed loop, the cooling water is returned back into the chilled water system. For water failure, a differential pressure cutout switch is required in this application. The construction of the condenser is a special design and generally includes the condenser and receiver in one shell. For this specialized application, see the applicable technical manual for details of construction and operation.

516-3.2.32 CONDENSER WATER SUPPLY. The circulating seawater for cooling refrigeration and air-conditioning condensers in most Navy ships is provided from some low-pressure seawater supply such as a pump in an auxiliary cooling water system on surface ships. If the seawater circulating pump fails, there is an emergency supply of seawater in the firemain that provides cooling water through a pressure-reducing valve or orifice to the auxiliary cooling water system serving the condenser. Some ship classes may not have a low pressure auxiliary cooling water system, but, may use the firemain directly or with a reducing valve. [Figure 516-3-118](#) shows a typical arrangement of a water-cooled condenser installed aboard ship.

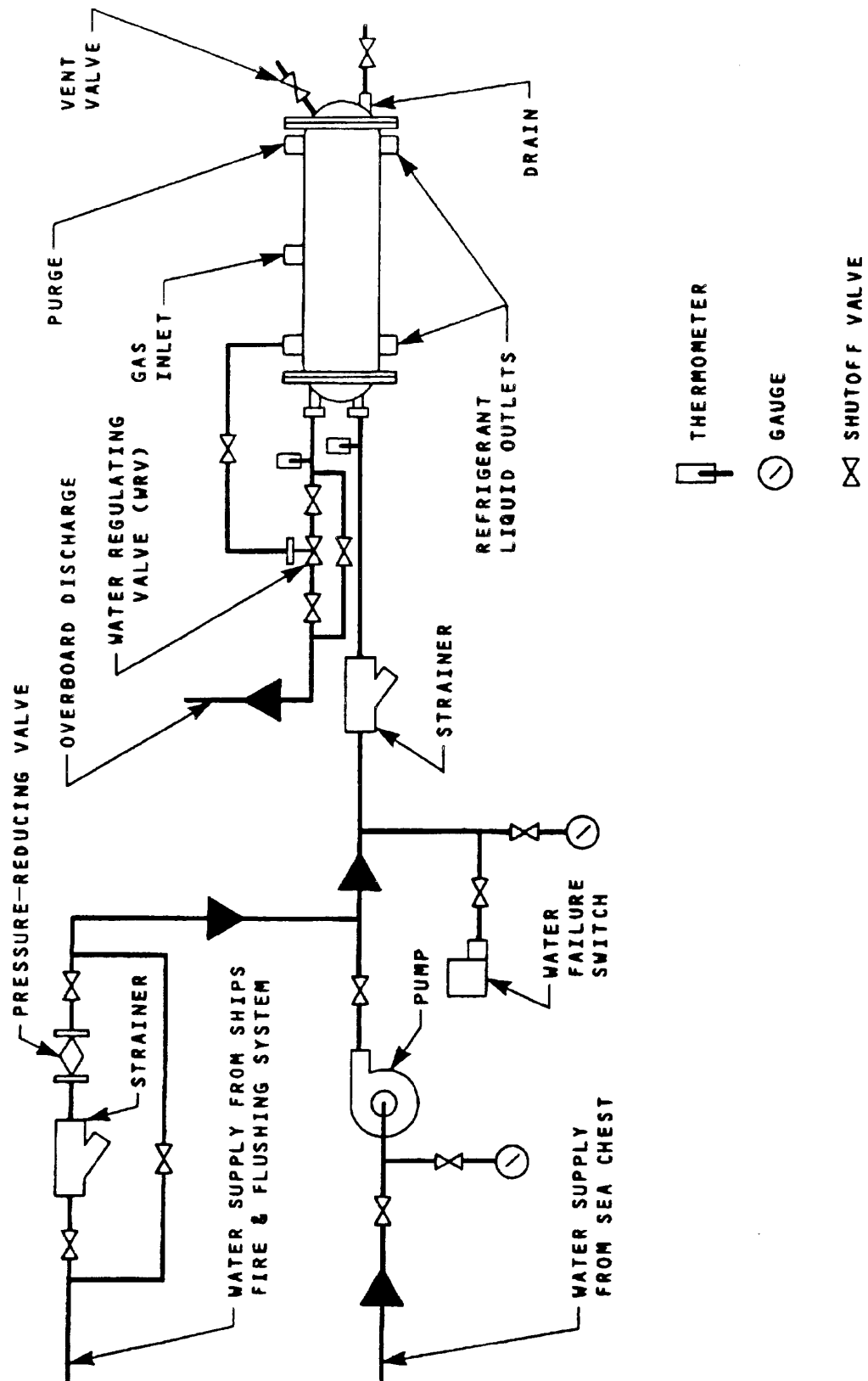


Figure 516-3-118. Condenser Piping Schematic

516-3.2.33 LIQUID RECEIVER. The in-line liquid receiver, which is made of steel material (nonferrous in older ships), accumulates the reserve liquid refrigerant to provide storage for off-peak operation and permit pumping down of the system. It also serves as a seal against the entrance of gaseous refrigerant into the liquid line. When stop valves are provided at each side of the receiver for confining the liquid refrigerant, a pressure relief valve is installed in the receiver-condenser equalizing line to protect the receiver against excessive liquid pressure which would occur if the receiver is completely filled with liquid refrigerant since liquids are virtually incompressible. If the pressure in the receiver should rise above the setting of the relief valve (about 225 psi for R-12 or R-134a), the relief valve will open and allow refrigerant to flow back into the condenser. Most receivers used in naval shipboard refrigerant systems have a magnetic liquid level indicator that shows the amount of liquid refrigerant in the receiver. In normal full-load operation the receiver should be approximately one-eighth full. As the load drops off, less refrigerant is being used in the cooling coils or water chiller and the liquid level will rise in the receiver. At maximum load conditions the plant should have a minimum amount of refrigerant in the receiver, that is, only enough to seal the outlets and prevent gaseous refrigerant from entering the liquid line. The receiver should be large enough to hold, as a minimum, the complete plant charge when it is necessary to pump down the entire system.

516-3.2.34 REFRIGERANT LIQUID LINE. The refrigerant liquid that accumulates in the bottom of the receiver is conveyed to cooling coils through the main refrigerant liquid line. A stop valve and thermometer are usually installed in this line adjacent to each receiver. Where the dehydrator is close to the receiver, shutoff valves in this piping arrangement may be used in place of a separate shutoff valve.

516-3.2.35 CHARGING CONNECTION. Most refrigerating plants installed aboard ship are arranged for charging liquid refrigerant into the system, when necessary, through a charging connection located just upstream from (ahead of) the dehydrator in the liquid line ([Figure 516-3-119](#)).

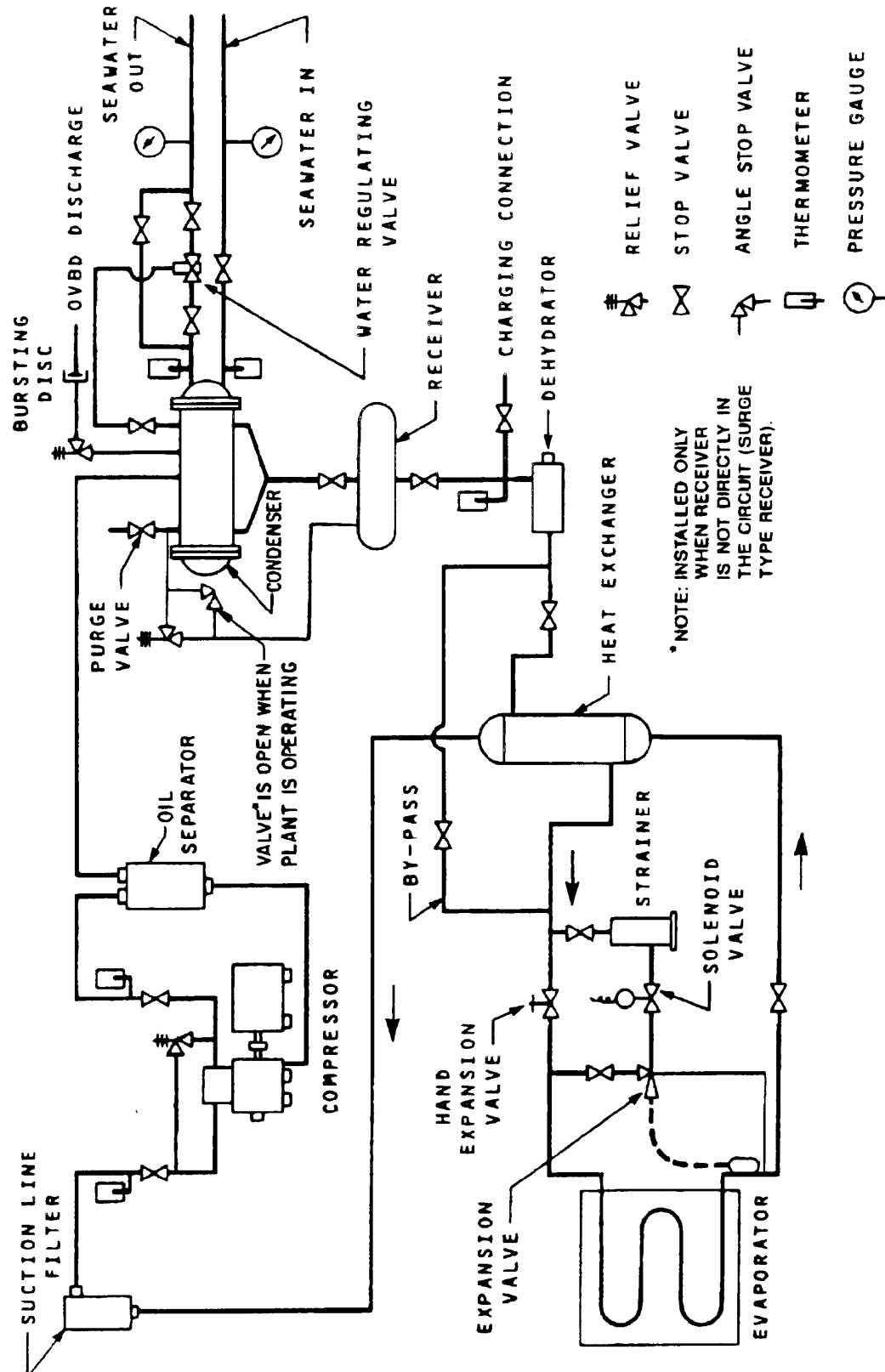


Figure 516-3-119. Refrigerant Piping Schematic

516-3.2.36 DEHYDRATOR. A dehydrator is provided in the refrigerant liquid line. To understand the purpose of a dehydrator it is necessary to review some of the principles involved:

- a. The refrigerant used in the system can hold moisture in the same manner that moisture is present in the atmosphere. Similarly, when the relative humidity of the moisture in the refrigerant exceeds 100 percent, the moisture will come out of solution and there is rain in the system. The amount of moisture that either the refrigerant or air can handle depends on the temperature of the refrigerant or the air. A cubic foot of air at 80° F will hold approximately 155.6 grains (1 pound equals 7,000 grains) of moisture. R-12 or R-134a at the same temperature will hold approximately 100 parts water per million parts refrigerant. Note that the units of measurements are not the same because of the considerably smaller amount of moisture that can be held by the refrigerant; therefore, a much smaller unit of measurement may be used. The fact that it is smaller emphasizes the importance of the presence of any moisture in the system. Since the release of water from refrigerant depends on its temperature, it is apparent that the entire system shall have a maximum absolute moisture content not in excess of the total solubility of water in the refrigerant at the lowest temperature in the cycle.
- b. The dehydrator is installed to adsorb moisture that may be in the refrigerant. A dehydrator cannot remove all the moisture in a system. However, an effective and properly sized dehydrator can reduce the moisture content to an acceptable level for R-12 or R-134a. The dehydrator used removes a sufficient amount of moisture to get the system below critical moisture content. For example, for a cooling coil with R-12 to be at -20° F, the amount of moisture in the system shall not exceed 3 parts per million (ppm) or else it will become free moisture. The free moisture would then freeze at the expansion valve orifice in the form of an ice coating or plug. However, if the dehydrator is large enough, or if the amount of water is small enough, the dehydrator will adsorb enough water so that the refrigerant and moisture will be at an equilibrium low enough to provide a dry system. If the dehydrator is too small or there is too much moisture present, another dehydrator or a larger dehydrator shall be used to remove the moisture. In a completely wet system, discard the refrigerant and dehydrate the refrigerant circuit by evacuation.
- c. A typical dehydrator is illustrated in [Figure 516-3-120](#). It consists of a cylindrical shell containing a moisture-adsorbing substance usually enclosed in a removable cartridge. Filters and strainers are provided at the ends of the dehydrator cartridge to prevent the passage of small particles of the drying agent into the system. The dehydrator is arranged to facilitate removal of the dehydrator cartridge for replacement of the drying agent through an end opening sealed by a cover plate. Activated alumina or silica gel are the drying agents generally used in naval installations. These agents have a high capacity to adsorb moisture per unit weight of material without dissolving or disintegrating in the presence of moisture, oil, or refrigerant. The adsorbing materials are provided in granular form enclosed in standard size, Navy-type replacement cartridges. Cartridge design should be such that there is a block filter on the exiting portion of the cartridge ([Figure 516-3-120](#)). This will reduce the quantity of loose desiccant material to fall out of the cartridge, which causes malfunction of other refrigerating system components. The cartridges are furnished in airtight hermetic containers. When opening a container, make sure that the material has not powdered or that an excessive amount of material has not fallen out of the cartridge. The activated alumina desiccant used with R-12 is incompatible with R-134a and should not be used. For R-134a a molecular sieve desiccant (UOP XH-7 or XH-9, or equal) should be used.

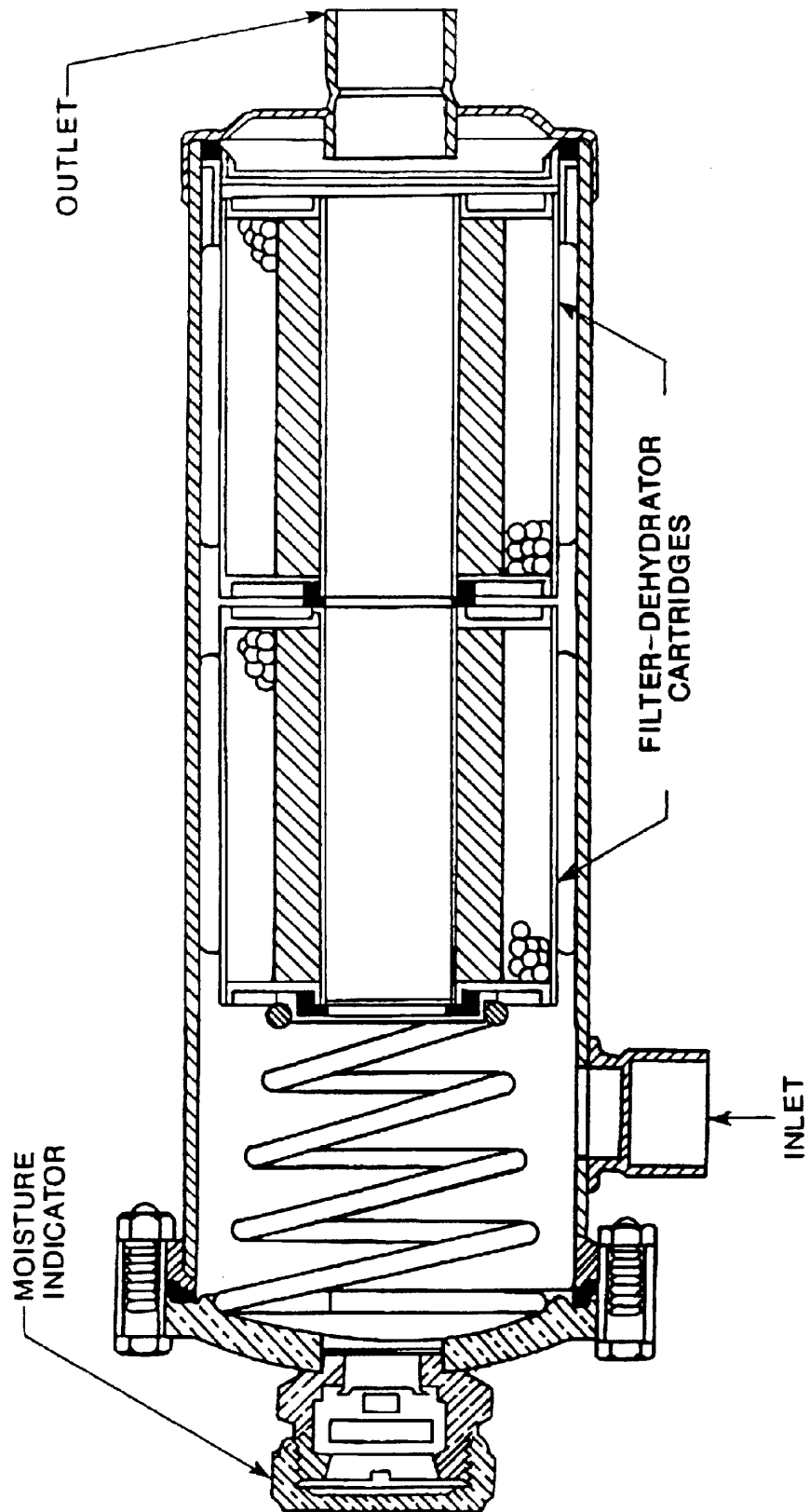


Figure 516-3-120. Filter-Dehydrator with Moisture Indicator

516-3.2.36.1 When installing new cartridges, take time to determine if the refrigerant flow through the dehydrator is from the side to the end or from the end to the side. This is to ensure that the correct safety cap assembly is used and is installed on the downstream of the cartridges. The direction of flow should be verified from the piping arrangement. An incorrectly fitting cartridge will bypass liquid refrigerant and dehydration will not occur. The dehydrator will continue to absorb moisture until the moisture content of the dehydrator cartridge and refrigerant reaches an equilibrium, or all possible moisture has been absorbed. The moisture indicator will show if the moisture level is safe or if the dehydrator cartridge should be replaced. Systems designed after 1960 have a dehydrator in-line all the time. In systems designed before 1960, the dehydrator was generally installed in a bypass line. Where the dehydrator is installed in a bypass line, use it when charging or adding liquid refrigerant to the system. It may also be used at regular intervals, such as one time every week for 24 hours, when the system is in operation. Except during charging or adding of refrigerant, use the dehydrator for at least 10 to 12 hours at a time so the complete system refrigerant charge passes through the dehydrator several times.

516-3.2.37 **MOISTURE INDICATOR.** All refrigerant systems should have a moisture indicator installed, either on the dehydrator cover or integral with an in-line sight flow indicator. Most dehydrators currently being installed have moisture indicators in the dehydrator cover. Indicators show the moisture content by changing color. When the indicator shows pink, the moisture level is too high; when it shows blue, the moisture level is satisfactory. The change in color is completely reversible with the change in moisture level. By checking the indicator, the plant operator can easily determine when to replace the dehydrator cartridge. [Figure 516-3-120](#) shows a dehydrator cover with the moisture indicator. The moisture indicator will react only to water vapor. Most moisture indicators used in Navy shipboard systems will be ruined if the moisture content of the refrigerant system is high enough to precipitate water. If free water comes in contact with the moisture indicator element, it will not register pink for wet, but will be light grey in color and will no longer change color. The moisture indicator elements, however, are replaceable. If there is enough moisture in the refrigerant system to ruin the moisture indicator element, determine the source of the moisture and take corrective action. New moisture indicators (Henry Valve Co., part no. MI-2Y and MI-3Y) are now available for use with the R-114 air-conditioning systems. MI-2Y and MI-3Y have different salt concentrations to more accurately reflect the acceptable moisture level in R-114 air-conditioning systems. Other vapor compressor refrigeration systems (R-11, R-12, R-134a, and R-22) should use the previously available moisture indicators (MI-2N and MI-3).

516-3.2.38 **SIGHT FLOW INDICATOR.** Many systems have a refrigerant sight flow indicator installed in the liquid line. The sight flow indicator is a special fitting provided with a gasketed glass port on each side and furnished with seal caps for protection when not in use. While a single port indicator may be used, the double port unit permits the use of a flashlight for background, where space is available, for a clearer view. The refrigerant may be viewed as it passes through to determine its condition with respect to the presence and amount of vapor bubbles. The existence of bubbles indicates an inadequate supply of refrigerant.

516-3.2.39 **MAIN LIQUID LINE SOLENOID VALVE.** A solenoid valve is installed in the main liquid line, upstream from any branch circuit where multiple coil circuits are used. Its function is to stop the flow of liquid refrigerant from the receiver when the compressor unit stops for any reason, except in normal operation under the influence of the suction line control. Such protective action is designed to prevent excessive flooding of the cooling coils or the low side of the system with refrigerant, which might result in the return of liquid to the compressor unit upon starting, causing possible compressor damage.

516-3.2.40 **LIQUID REFRIGERANT CONTROL.** The main refrigerant liquid line, downstream from the dehydrator and charging valve, carries the liquid refrigerant to the evaporator(s) or cooling coil(s). Evaporators (cooling coils) may be gravity wall-type, forced convection coils in refrigerated spaces, air-conditioning cooling coils, water chillers, or specially designed coils for various applications. The refrigerant from the main liquid line

is fed to each evaporator through a liquid flow control assembly. This assembly consists of a manual packless shutoff valve, strainer, solenoid valve, thermostatic expansion valve, and another manual shutoff valve. In ship stores refrigeration plants and cargo refrigeration plants, a bypass line equipped with a hand expansion valve is provided around the liquid flow control assembly. In some applications where there are multiple, parallel coil circuits serving one compartment, such as large refrigerated spaces, the control assembly is divided so that a combination of one strainer and one solenoid valve controls the refrigerant supply to several thermostatic expansion valves. Each expansion valve serves an individual coil circuit.

516-3.2.41 LIQUID STRAINER. In installing a refrigeration system, a certain amount of foreign matter, such as scale from welding or brazing, metal chips, dust, and dirt from other operations, may enter the piping system. Since the refrigerant piping system forms a closed circuit, particles of foreign matter will remain in the system unless trapped or removed. Although the system should be thoroughly cleaned before placing it into operation, it is possible that some foreign matter may remain or may be introduced into the system by charging it with contaminated refrigerant dirty oil while making system repairs or by the failure of system parts. The liquid strainer removes and traps such foreign matter from the refrigerant before it passes through the solenoid and expansion valves and clogs them, or from where it could enter the compressor system and do further damage.

516-3.2.41.1 Strainers consist of fine mesh metal screen in a housing similar to that used for the dehydrator ([Figure 516-3-120](#)). Certain types of expansion valve assemblies are provided with small conical or cylindrical strainers at the inlet connection furnished as a part of the valve assembly. In this case, a larger liquid strainer or filter is installed in the common liquid line to all cooling coils to prevent rapid clogging of the small strainers at the expansion valve inlet connection. In addition to strainers with fine mesh screens, filters with porous pads are often provided in a system to filter out foreign particles too small to be trapped by a strainer screen.

516-3.2.42 SOLENOID VALVE. The filtered liquid refrigerant is discharged through a solenoid-operated stop valve located between the strainer and the thermostatic expansion valve. The function of the solenoid valve is to stop the flow of liquid refrigerant to the evaporator when the medium being cooled (the conditioned space or water chiller) has reached the desired temperature, and to open permitting refrigerant to flow when cooling is required. The solenoid valve is electrically actuated by a thermostatic switch which is responsive to temperature changes in the space or water chiller being cooled. It may also be manually controlled by a toggle switch, depending on the application. [Figure 516-3-121](#) shows a cross-sectional assembly view of a typical solenoid valve. When the solenoid coil is energized, a magnetic field is produced that lifts the iron plunger and snaps the needle valve open. When the flow of current through the coil is interrupted, the weight of the plunger and valve stem shuts the valve. Since the closure of the valve depends on gravity for older design valves, it is necessary that the assembly be mounted in a vertical position with the coil above the valve body. Most current valves, however, are designed so that the valve can be installed in various positions. When direct current solenoid valves are used, a condenser or surge protector is connected across valve coil terminals to protect coil and switch contacts against the surge of current produced when the circuit is broken.

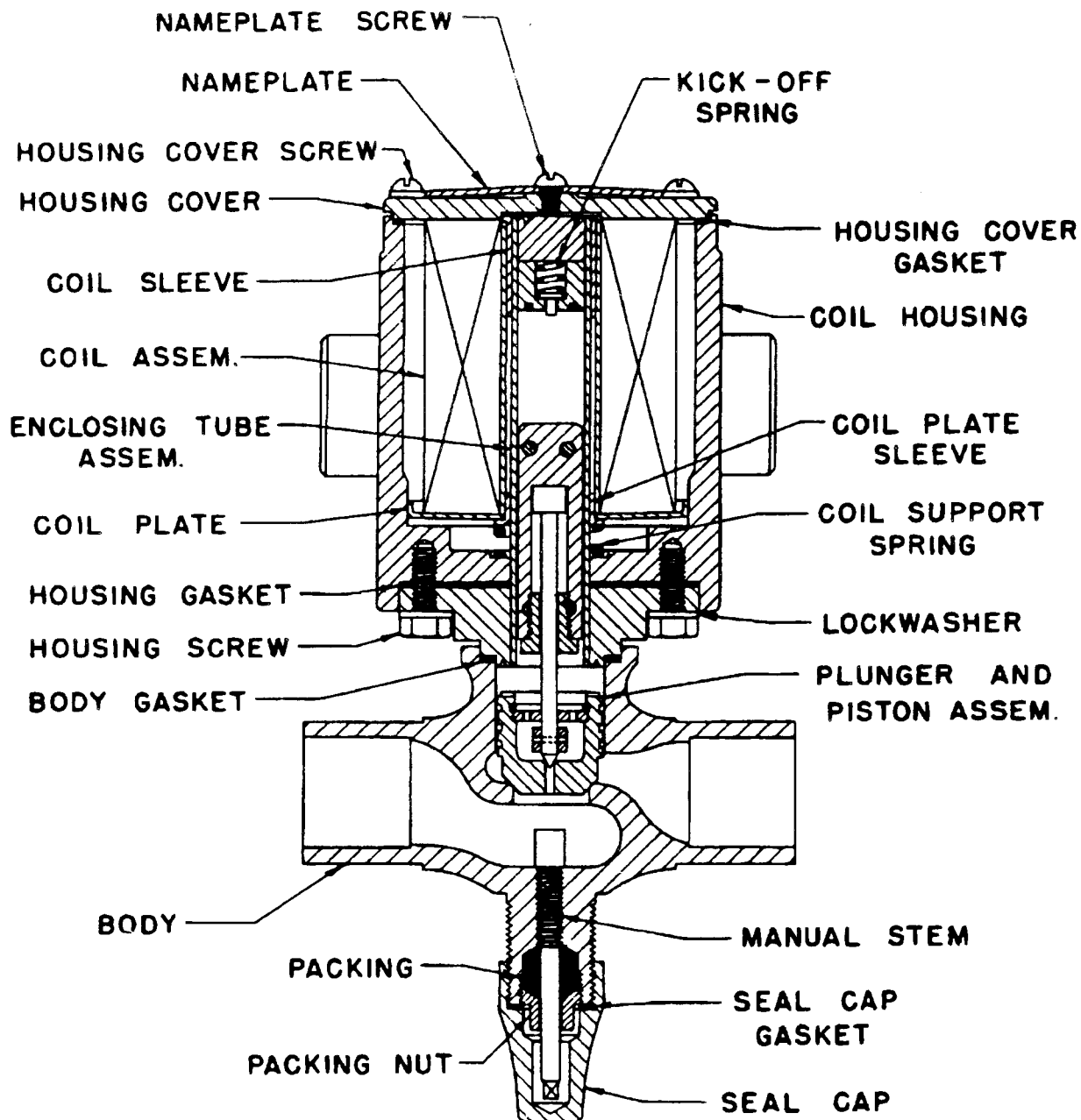


Figure 516-3-121. Solenoid Valve

516-3.2.42.1 The solenoid valve controlling refrigerant flow to cooling coils may be actuated by electric supply from the controller or from an outside source. Usually where a forced circulation cooling coil is involved, the solenoid valve coil takes its current supply from the electric supply to the fan associated with forced circulation cooling coils. This is a very desirable feature because if the fan is secured or fails, the solenoid is not energized and refrigerant is not supplied to the cooling coil, thus preventing possible slugging of refrigerant to the compressor.

516-3.3 TEMPERATURE AND PRESSURE CONTROLS

516-3.3.1 TEMPERATURE CONTROL. The solenoid valve control or thermostat makes and breaks the electric circuit through the solenoid, thereby controlling the flow of liquid refrigerant to the expansion valve. The construction of this control is generally similar to that shown in Figure 516-3-122. The thermostat bulb is located in that portion of the refrigerated compartment or water chiller where it will come in contact with average temperature conditions. The control bulb is charged with a fluid so that temperature changes in the bulb produce corresponding changes in the pressure of the actuating medium within the control bulb. These pressure changes are transmitted through the control tubing or capillary to the control power element to open or close the electric circuit. The control is adjusted to open contacts, and thus close the solenoid valve (stopping the flow of refrigerant to the cooling coil), when the temperature of the refrigerated space has reached the desired low point. As the temperature rises, the increase in bulb pressure closes contacts, causing the solenoid valve to open and permitting refrigerant to flow to the expansion valve.

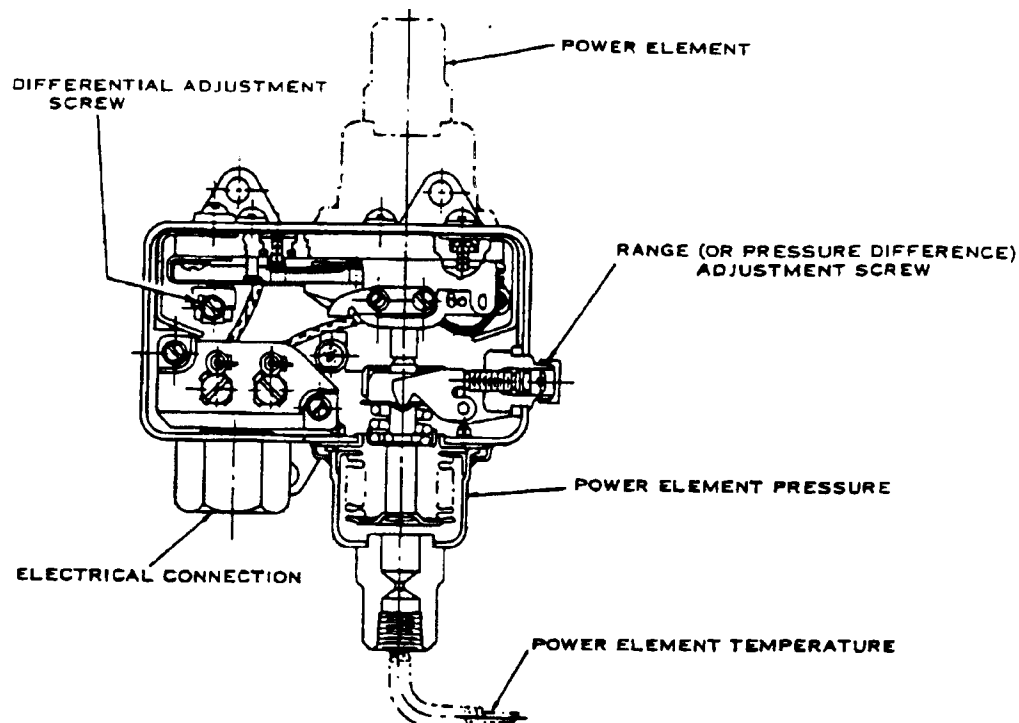


Figure 516-3-122. Thermostat Switch

516-3.3.2 PRESSURE CONTROL. A pressure control is similar in construction to the thermostat control except that instead of a capillary tubing and a bulb, the pressure control has a screwed connection for the pressure source to actuate the opening and closing of control contacts. Pressure controls can be either a differential control connected to two different pressure sources; high-pressure control, which opens on high pressure and

closes on a lower pressure; or a low-pressure control, which opens on low pressure and closes on a higher pressure. Refer to applicable technical manuals for details of operation and set points.

516-3.3.3 THERMAL EXPANSION VALVE. This valve controls the quantity of refrigerant admitted to the cooling coil and reduces the pressure of the refrigerant from that existing in the condenser and liquid line to that required in the cooling coil. The thermal expansion valve is designed to feed enough refrigerant liquid into the coil to keep it working at its maximum effectiveness, in accordance with heat load variations, and to prevent flooding of liquid refrigerant back to the compressor.

516-3.3.4 DESIGN AND CONSTRUCTION. The design and construction of expansion valves vary greatly. [Figure 516-3-123](#) shows a cross-sectional assembly view of a single outlet valve in general use aboard naval ships. This expansion valve consists of three parts: the body, which is brazed in the piping; a cage assembly, which contains the orifice; and a power assembly with capillary tubing and bulb, which is bolted to the body. Other valve designs may have different arrangements for piping connections, adjustment, sealing, and control, but the valve shown will serve to illustrate basic principles upon which all such valves operate. The control bulb of the valve is clamped to the suction line near the cooling coil outlet or inserted in a bulb well in the cooling coil outlet. Temperature changes in the suction line are reflected in corresponding pressure changes within the control bulb. These changes in pressure are transmitted through the control tubing to the power element diaphragm of the valve, which transmits motion to the valve stem and needle assembly. Good thermal contact between the bulb and the bare suction pipe is essential (See paragraph [516-8.2.36.2](#)). Previously, power assemblies were provided with various types of thermostatic bulb charges, such as liquid, gas, cross ambient, and low temperature. Currently, only one type, an all-purpose power assembly charge, is used. The all-purpose power assembly charge may be used to replace all other power assemblies for applications between the -50° F and +50° F (-45.6° C and 10° C) evaporator temperatures found in Naval shipboard thermostatic expansion valve applications, and where the same refrigerant is used.

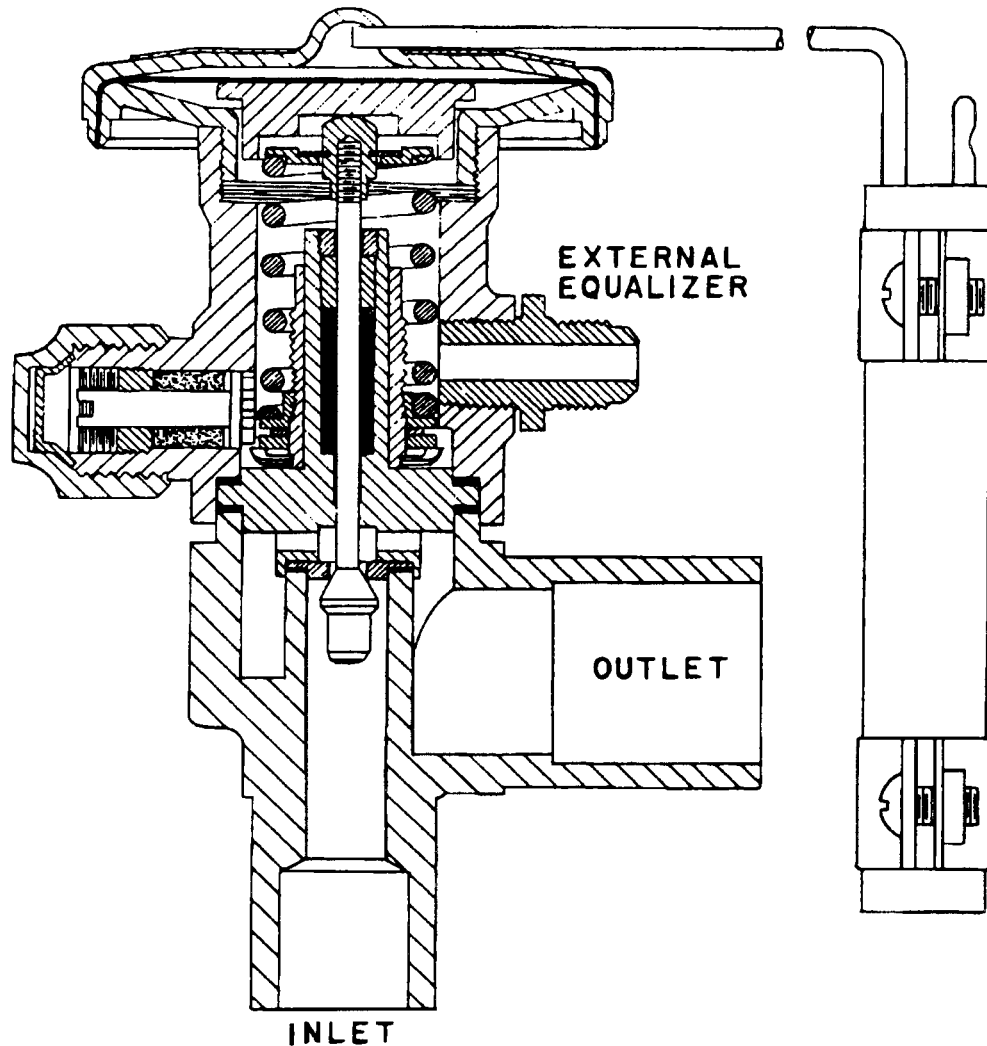


Figure 516-3-123. Thermostatic Expansion Valve

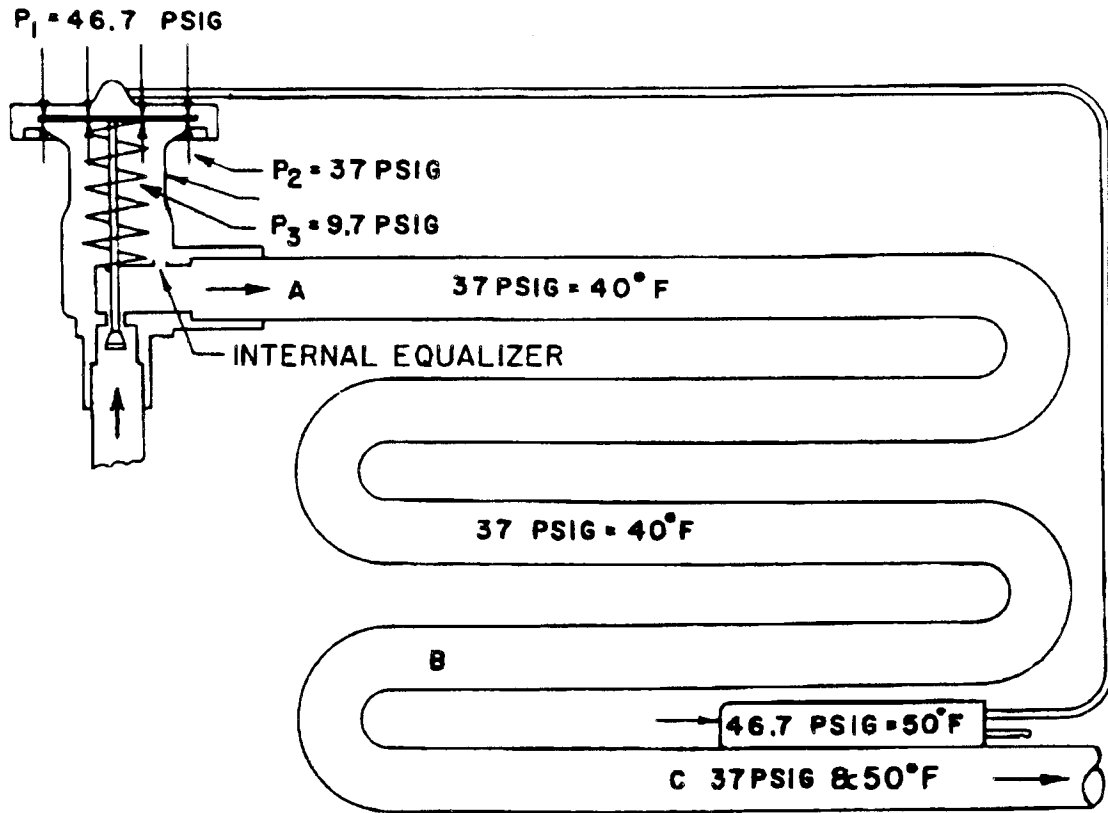
516-3.3.5 EXPANSION VALVE DISTRIBUTOR. The warm, high-pressure liquid refrigerant entering an expansion valve and going through the valve orifice to the cool low-pressure coil, will have to undergo a reduction in pressure and temperature. To accomplish this some of the liquid evaporates, and in so doing cools the remaining liquid. Therefore, the refrigerant at the outlet of an expansion valve includes liquid and a gas called flash gas. It would be normal if this combination gas and liquid were to enter a single circuit coil. However, in a multicircuit cooling coil, chances are that some circuits would get all liquid and some all gas. This would seriously affect coil capacity. To prevent this the outlet of the expansion valve is connected to a distributor. The distributor has an outlet for each circuit and distributes the liquid and gas refrigerant equally to each of the coil circuits. Distributors are usually installed by the coil manufacturers.

516-3.3.6 EXPANSION VALVE OPERATION. Three forces govern the operation of thermostatic expansion valves:

- a. The pressure created in the power assembly by the remote bulb
- b. The refrigerant pressure in the cooling coil (evaporator)

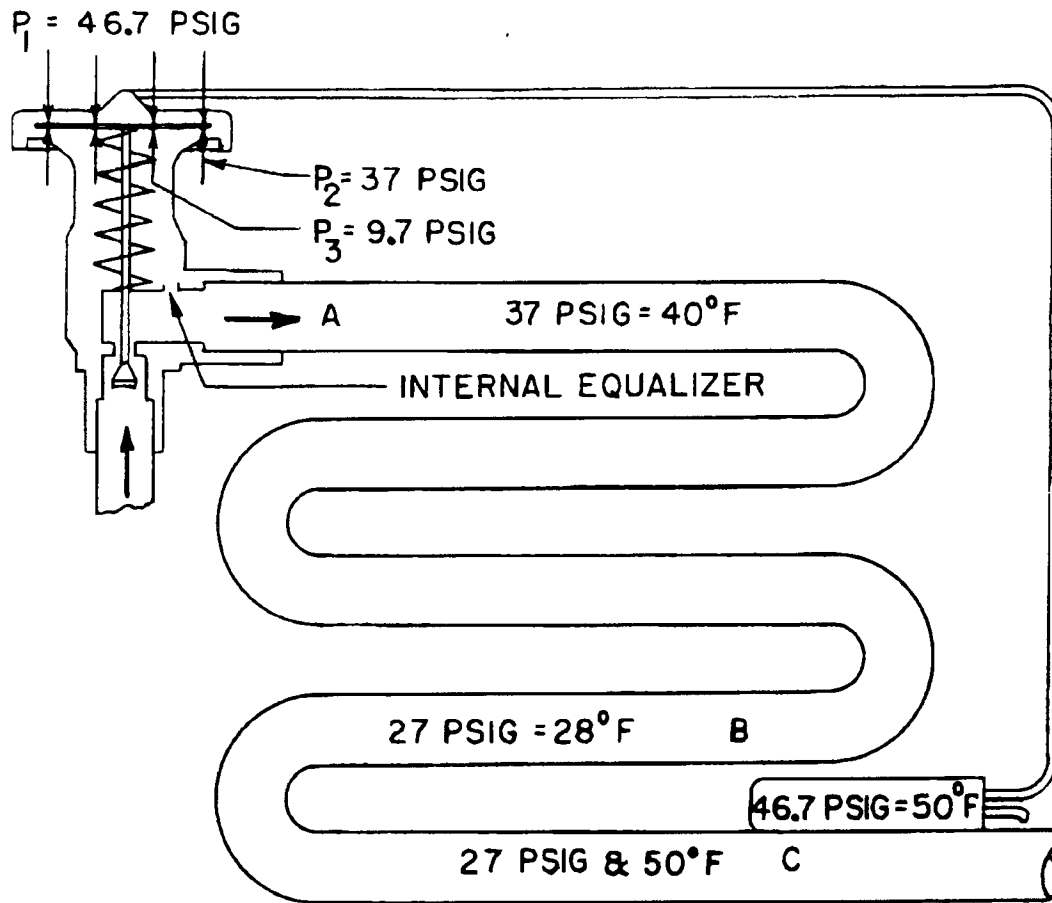
c. The pressure exerted by the superheat spring.

516-3.3.6.1 The force created by the charge in the remote bulb pushes on the diaphragm, moves the valve stem, and opens the valve. On the opposite side of the diaphragm, the pressure of the refrigerant in the cooling coil and the pressure exerted by the superheat spring, tend to move the valve stem in the opposite direction to shut the valve. As noted in [Figure 516-3-124](#) and [Figure 516-3-125](#), a small opening or orifice is provided in the valve so that the actual refrigerant pressure in the cooling coil will be transmitted to the valve-operating diaphragm. A thermostatic expansion valve having this opening or orifice is an internally equalized valve; that is, the pressure equalization is accomplished internally. The opening or orifice is the internal equalizer. When there is a significant pressure drop in the cooling coil (evaporator), the refrigerant pressure at the cooling coil inlet (where the expansion valve is installed) will not be the same as the refrigerant pressure at the cooling coil outlet (where the thermal bulb is installed). Therefore, when a significant pressure drop exists in the cooling coil, the true evaporating pressure in the coil would not be transmitted through the internal equalizer opening to the operating diaphragm. When this condition exists, use an externally equalized valve which has an opening in the power assembly body, provided with a fitting as shown in [Figure 516-3-123](#) and [Figure 516-3-126](#). An external equalizing line is installed between the external equalizer fitting on the power assembly body and the suction piping at the coil outlet. This equalizing line transmits the refrigerant pressure that exists at the cooling coil outlet to the valve operating diaphragm, thus making the valve externally equalized. Operation of the thermostatic expansion valve, with both internal and external equalizers, is explained and illustrated in greater detail in the paragraphs that follow.



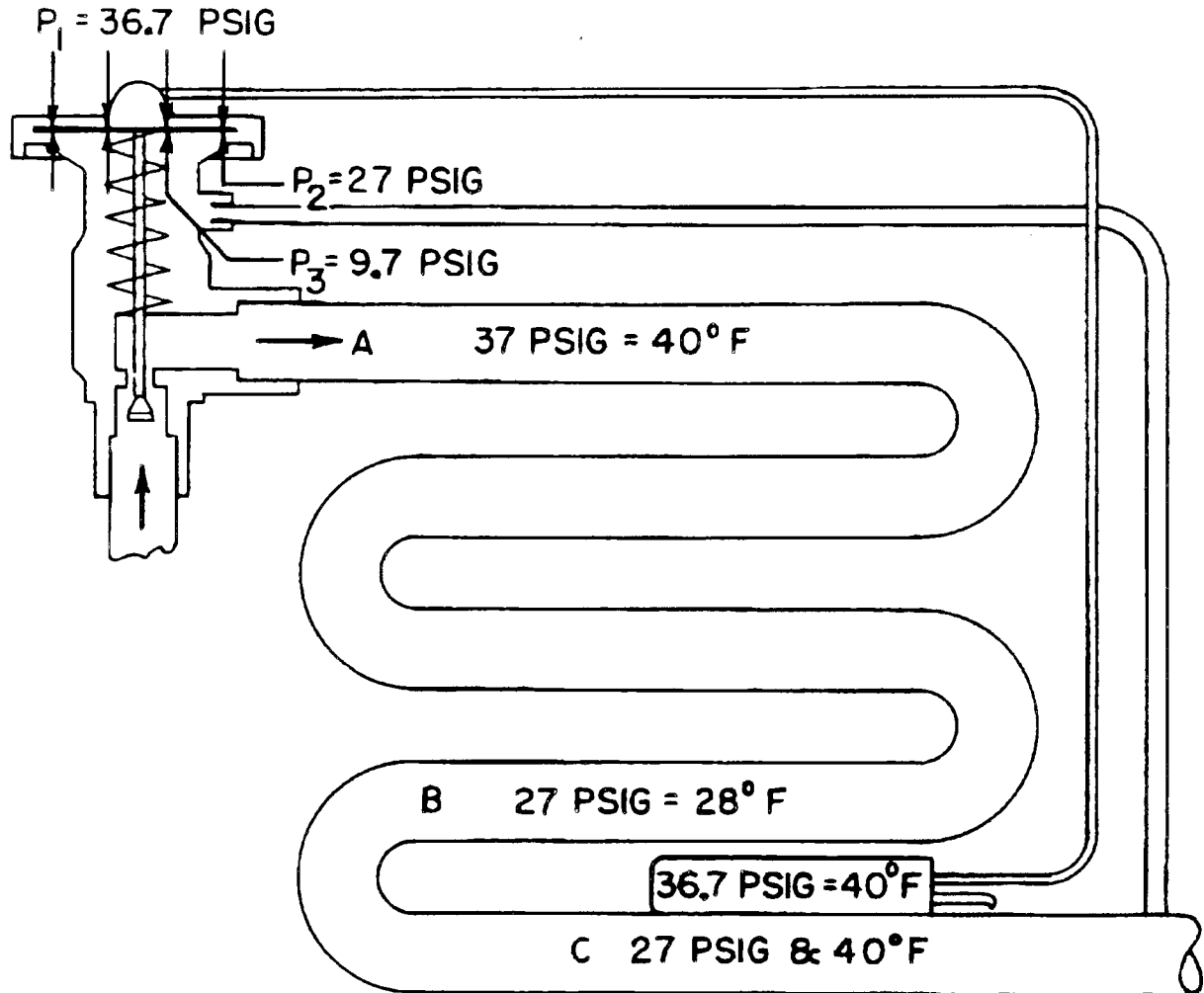
THERMO EXPANSION VALVE WITH INTERNAL EQUALIZER ON EVAPORATOR WITH NO PRESSURE DROP

Figure 516-3-124. Thermostatic Expansion Valve with Internal Equalizer (No Pressure Drop)



**THERMO EXPANSION VALVE WITH INTERNAL EQUALIZER
ON EVAPORATOR WITH 10 PSI DROP**

Figure 516-3-125. Thermostatic Expansion Valve with Internal Equalizer (with Pressure Drop)



THERMO EXPANSION VALVE WITH EXTERNAL EQUALIZER ON EVAPORATOR WITH 10 PSI PRESSURE DROP

Figure 516-3-126. Thermostatic Expansion Valve with External Equalizer (with Pressure Drop)

516-3.3.7 REFRIGERANT SUPER-HEAT. Figure 516-3-124 is a sketch of a thermostatic expansion valve and a cooling coil operating under assumed conditions of 40° F evaporating temperature, with a valve adjusted to operate with a 10° F superheat and with negligible pressure loss in the cooling coil. The 40° F has a corresponding pressure of approximately 37 psig for R-12 (36.98 psig as shown in column 3 of Table 516-1-1). As long as any liquid exists in the coil at this pressure, the refrigerant temperature will remain at 40° F. As the liquid approaches point B on the cooling coil, it evaporates due to the absorption of heat from the surrounding atmosphere equal to the latent heat of vaporization of the refrigerant. The refrigerant, as a gas, continues along the coil at a pressure of 37 psig until at point C. Its temperature has increased to 50° F due to the continued absorption of heat from outside the coil. This then represents the 10° F superheat (50° F minus 40° F). The amount of superheat picked up by the refrigerant in the coil depends on the amount of refrigerant fed by the expansion valve and the load to which the cooling coil is exposed. Since the cooling coil temperature at C is 50° F, the temperature of the thermal bulb strapped to the coil at this point will also be 50° F. The temperature of the thermal bulb affects the pressure of the refrigerant within the bulb so that it has an internal pressure of 46.7 psig (Table 516-1-1). This pressure, shown as P_1 , is the pressure exerted on top of the diaphragm. The pressure P_2 , exerted

on the underside of the diaphragm, is a result of the refrigerant pressure of 37 psig at point A (the expansion valve has an internal equalizer), and P_3 is the force exerted by the spring under compression.

516-3.3.7.1 The movement of the diaphragm, in response to diaphragm pressure, operates the valve stem to regulate the valve opening and to modulate flow. When the cooling load decreases, the extent of liquid refrigerant flow would extend beyond point B, resulting in a temperature lower than 50° F at point C, with a smaller superheat condition. The thermal bulb, in turn, would have a lower temperature with a correspondingly lower pressure. The reduced pressure exerted on top of the diaphragm would start shutting the valve until an equilibrium point is reached. If the cooling load increased, liquid refrigerant would be vaporized before it reached point B, resulting in more superheat by the time the gas passed point C. This in turn would raise the temperature of the thermal bulb, increasing the pressure on top of the diaphragm, and causing the valve to open to admit more refrigerant. It will be noted in the examples that the valve attempted to maintain a predetermined superheat temperature. This amount of superheat is counteracted by the spring pressure, P_3 . The spring pressure is adjustable to increase or decrease the superheat setting and is usually maintained at 5° F to 15° F, depending on the application.

516-3.3.7.2 The external equalizing connection, shown in [Figure 516-3-123](#) and [Figure 516-3-126](#), is required where the refrigerant pressure loss through the cooling coil is above 2-1/2 psig for middle range refrigeration, and 1/2 psig for frozen food applications. The need for an external equalizing port can be explained by using [Figure 516-3-125](#), which shows a thermostatic expansion valve equipped with an internal equalizer. For this example, assume that the pressure loss through the coil is 10 psig. The pressure at point B is 27 psig (37 psig minus 10-psig pressure loss), which is equivalent to an evaporating temperature of approximately 28° F. Pressure within the valve would be 46.7 pounds (37-psig internal pressure plus 9.7-pounds spring pressure). The required pressure above the diaphragm to open the valve would therefore be 46.7 psig, which requires receiving a pressure signal that is equivalent to a thermal bulb temperature of 50° F at point C. However, the difference between the required superheat temperature of 50° F at point C and 28° F saturated condition evaporating temperature at point B, represents a 22° F superheated condition. This increase in superheat (from 10°F to 22 degrees F) could only be provided by using more of the cooling coil surface for superheating the vapor rather than for evaporation of the liquid. This is done by closing the valve to restrict the flow of liquid refrigerant to the cooling coil. The cooling coil is not fully utilized. This condition is known as a starved coil (not enough refrigerant in the coil), and results in the inability of the coil to maintain the desired space temperature. Therefore, use a thermostatic expansion valve with an external equalizer when a substantial pressure drop occurs in the evaporator coil. [Figure 516-3-126](#) shows the valve with an external equalizer. The pressure of 27 psig at C is applied directly to the underside of the diaphragm to get the true response of the valve to the actual superheat temperature for which the system is set.

516-3.3.8 EXPANSION VALVE RATING. Thermostatic expansion valves are rated by the manufacturer in tons of refrigeration for various refrigerant evaporating temperatures and pressure differentials across the valve. Ratings are based on vapor free liquid at 100° F entering the valve. This requires that each valve be selected not only for the tonnage needed for the cooling coil it serves but also for the refrigerant conditions of pressure and temperature at the inlet and downstream of the valve, and for its specific location in the refrigerating piping system. Thus, it becomes necessary to determine pressure losses, including vertical rise in liquid lines, and to anticipate realistic operating conditions to properly select an adequate size valve. The rating is a guide number. The final selection involves some experience and judgment. Expansion valves used in Navy equipment have interchangeable cages so that a cage with a higher or lower rating can be installed if the valve selected is under- or oversized.

516-3.3.9 PILOT-OPERATED EXPANSION VALVES. Pilot-operated (PO) expansion valves, as shown in [Figure 516-3-127](#), are used in many large air-conditioning water chiller applications. The PO valve is piloted by

a conventional thermostatic expansion valve and regulates flow in response to the change in the suction gas superheat. The pilot thermostatic valve supplies the operating pressure to the top of the PO valve piston. This operating pressure is bled off through an orifice in the top of the piston, creating a pressure difference across the piston that moves the PO valve in the open direction. The opening force is balanced by the PO valve spring, which tends to move the PO valve in the shut direction.

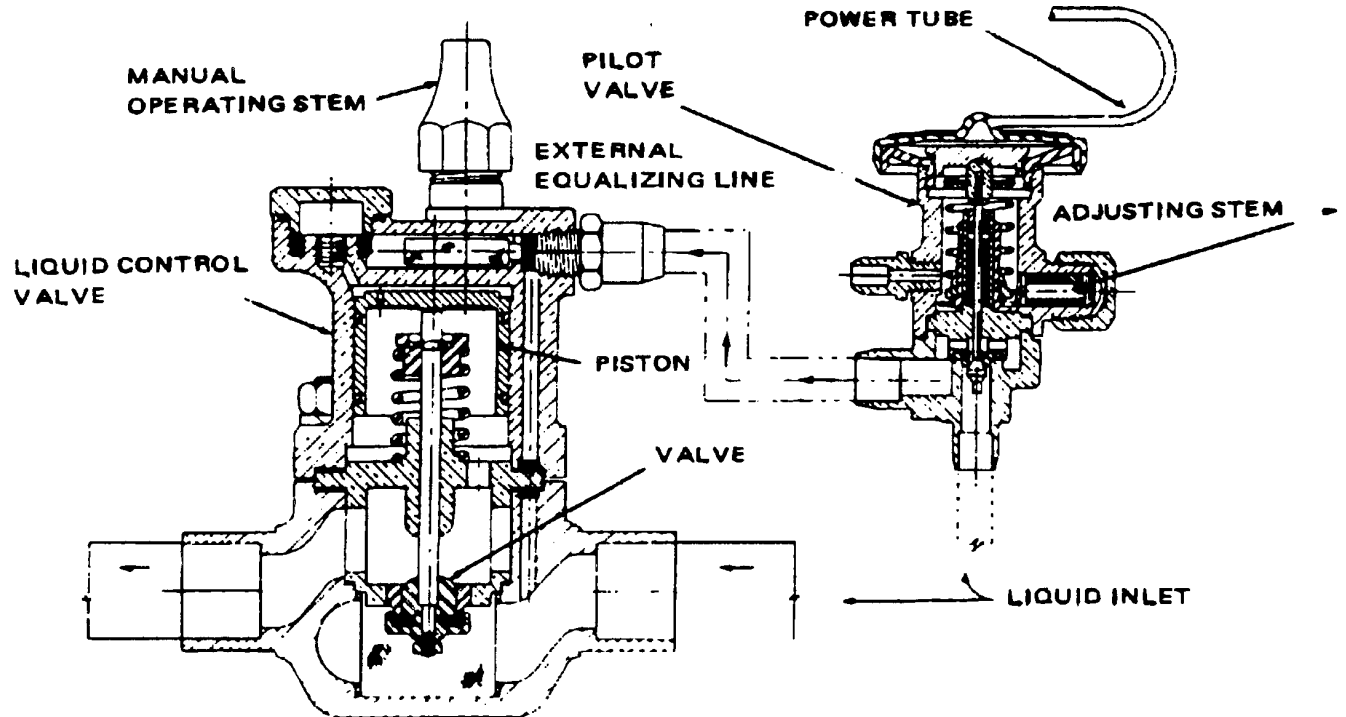


Figure 516-3-127. Pilot-Operated Expansion Valve

516-3.3.9.1 In operation, the pilot thermostatic valve and PO valve assume intermediate or throttling positions, depending on the load. By using an external equalizer for the pilot thermostatic valve, the operating pressure is supplied on top of the PO valve piston without affecting the ability of the pilot thermostatic valve to respond accurately to changes in the superheat of the suction gas. When the suction gas superheat increases (indicating the need for a greater refrigerant flow to the evaporator), the pilot thermostatic valve opens more and increases the pressure on top of the PO piston, thereby moving the PO valve in the open direction and providing greater flow. Conversely, when the suction gas superheat decreases (indicating the need to reduce the refrigerant flow to the evaporator), the pilot thermostatic valve repositions itself, decreases the pressure on top of the PO piston, permits the PO valve to move in the shut direction, and reduces the refrigerant flow.

516-3.3.9.2 PO valves permit the use of a characterized port for smooth regulation over the widest possible load range. It is possible to maintain positive control with loads reduced as low as 15 percent of nominal valve capacity. PO valves are designed for wide load applications and are particularly useful for refrigerating systems that use compressor cylinder unloading. When manual operation of the PO valve is considered, extreme caution should be exercised to carefully control the amount of metering, thus preventing possible compressor damage due to liquid floodback.

516-3.3.10 CAPILLARY TUBES. Capillary tubes are used in place of expansion valves on small, self-contained refrigeration equipment, such as drinking water coolers and refrigerators. The capillary tube is a small

copper or steel tube with an inside diameter of about 1/16 inch and a variable length depending on the application. The capillary acts as a restrictor, reducing the condenser to evaporator pressure. The successful operation of a capillary tube depends on an exact amount of refrigerant and is generally used with hermetic-type systems.

516-3.3.11 HAND EXPANSION VALVE. A bypass line equipped with a manually operated expansion valve is installed around the cooling coil liquid control valve assembly in refrigeration food storage plants and direct expansion air-conditioning plant applications. The hand expansion valve can be operated manually to control refrigerant flow to the cooling coil if any of the liquid control assembly components fail. The hand expansion valve is generally similar in design to other packless-type refrigerant stop valves installed in refrigeration systems except that the valve disc and stem are specially shaped to permit accurate flow adjustment. When a hand expansion valve is used, carefully control the amount of metering to prevent possible compressor damage due to liquid flood-back.

516-3.3.12 REFRIGERANT STOP VALVES. Manually operated shutoff valves are used in refrigerant piping systems to isolate piping segments and various components, when required, and to separate piping systems where condensing units are cross-connected. Manual valves are globe and angle types and have either a packed stem or are packless. Packed valves prevent leakage of refrigerant around the stem by special stem packing compressed in a stuffing box. The special stem packing is impervious to the solvent action of the refrigerant. In addition to the packing, a seal cap is provided. The seal capscrews on the valve body with a gasket between the cap and the body, providing a secondary seal against refrigerant leakage. Whenever it is necessary to turn the disc stem, loosen the packing gland nut approximately 1/2 turn; then retighten after the disc stem has been adjusted. The seal cap, with gasket, shall always be tightly in place on the valve body except when adjusting, opening, or closing the valve. Packless refrigerant shutoff valves are the diaphragm type; they have a set of diaphragms installed between the valve body and bonnet. The valve stem is divided and does not penetrate the diaphragms. The upper stem is in the valve bonnet and the lower stem is in the valve body. The motion of the valve stem is transmitted by the flexing of the diaphragms. [Figure 516-3-128](#) shows a cross-section of a typical diaphragm valve and [Figure 516-3-129](#) shows a packed valve. (For maintenance of shutoff valves refer to paragraphs [516-8.2.32](#) and [516-8.2.34](#)).

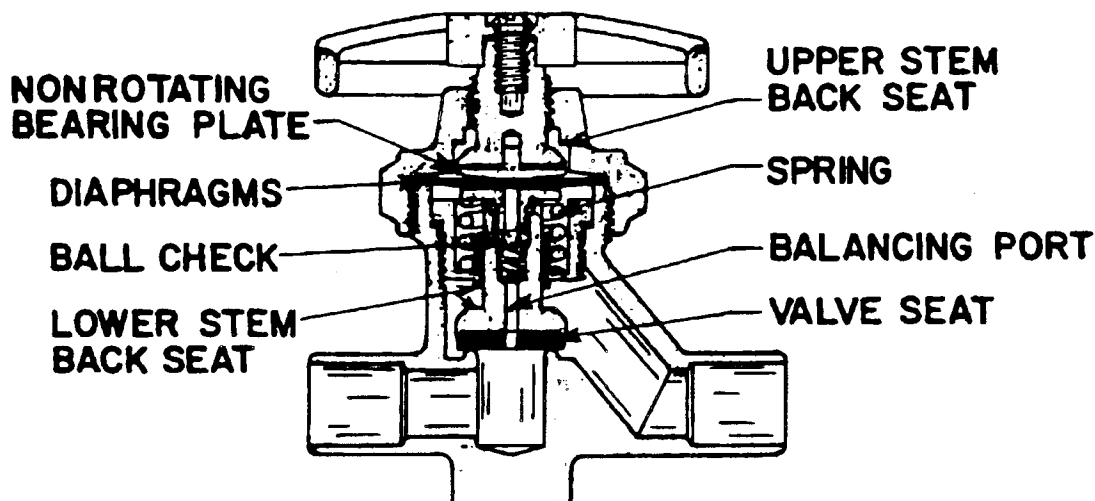


Figure 516-3-128. Packless Shutoff Valve

NO.	DESCRIPTION	Q U A N
1	BODY	1
2	BONNET	1
3	BONNET GASKET	1
4	STEM	1
5	SEAT DISC	1
6	DISC SPRING	1
7	DISC PIN	4
8	RETAINER RING	1
10	WING CAP	1
11	CAP GASKET	1
12	PACKING WASHER	1
13	PACKING	1 SET
14	PACKING GLAND	1
15	BOLT	4

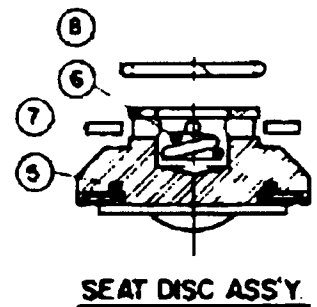
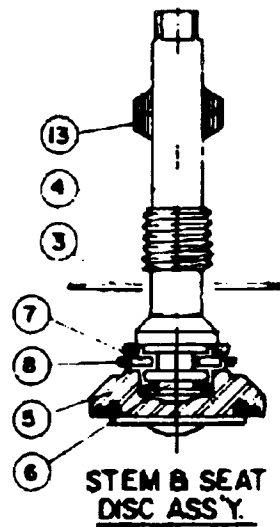
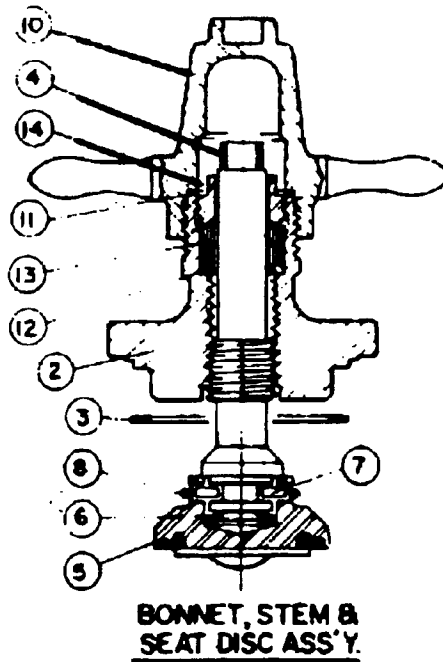
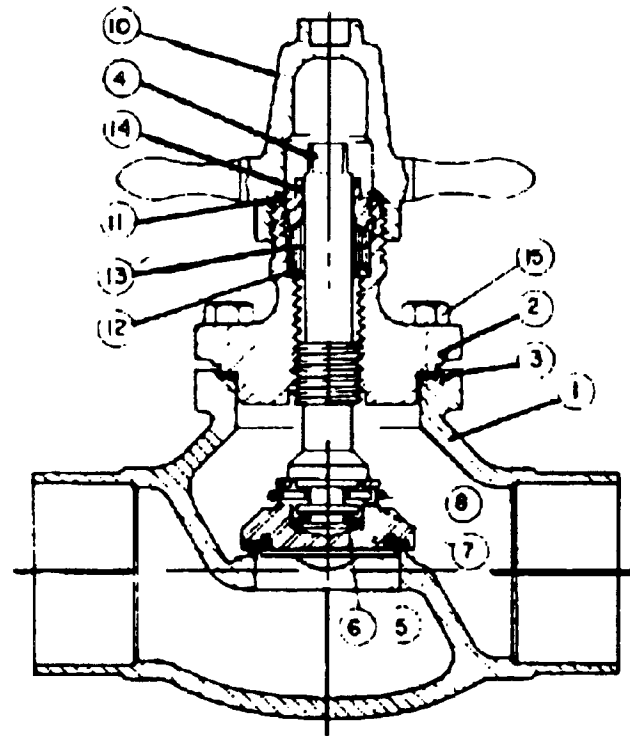


Figure 516-3-129. Packed Shutoff Valve

516-3.3.13 EVAPORATOR (COOLING COILS). The refrigerant flows through the liquid control valve into the evaporator or cooling coil, where it absorbs heat at a saturation temperature corresponding to the pressure within the coil. The surface of the coil acts as a heat-transfer agent between the medium being cooled and the heat-absorbing refrigerant. The cooling coil surface area required depends on the heat load to be transferred. The temperature difference between the refrigerant within the coil and the media to be cooled determines the rate of heat transmission between the media and the refrigerant. The capacity of an air-cooling coil, for instance, depends upon the quantity of air passing through the coil, the temperature and humidity condition of the air, and the temperature of the refrigerant within the coil. The capacity of the coil will increase if the air velocity is increased or if the temperature difference between the air and the refrigerant is increased. This increased capacity results in the coil being able to evaporate a greater quantity of refrigerant in a given time.

516-3.3.13.1 In ship stores, the evaporator in older ships may be wall-type, bare, serpentine cooling coils. On older and converted ships, cooling coils are also wall-type serpentine but are made of finned pipe, as shown in [Figure 516-3-130](#). This type of coil is known as a gravity cooling coil because the airflow across the coil is by gravity flow. Future installations will use unit coolers that are multicircuit, forced circulation cooling coils with attached fans, as shown in [Figure 516-3-131](#). In refrigerated cargo spaces, multicircuit, forced circulation finned cooling coils are used. They are installed in a plenum chamber with a fan mounted directly over the cooling coil to discharge into a ventilation duct to distribute cooled air into the refrigerated compartment. For air-conditioning, the evaporator may be either a unit cooler similar to the ship stores unit cooler or a water chiller that consists of a shell and tube heat exchanger with refrigerant in the tubes, and fresh water in the shell (similar to [Figure 516-3-132](#)). Tubes in the chiller have some type of internal fins to increase heat transfer. The chilled water is then pumped to multicircuit cooling coils that cool living spaces.

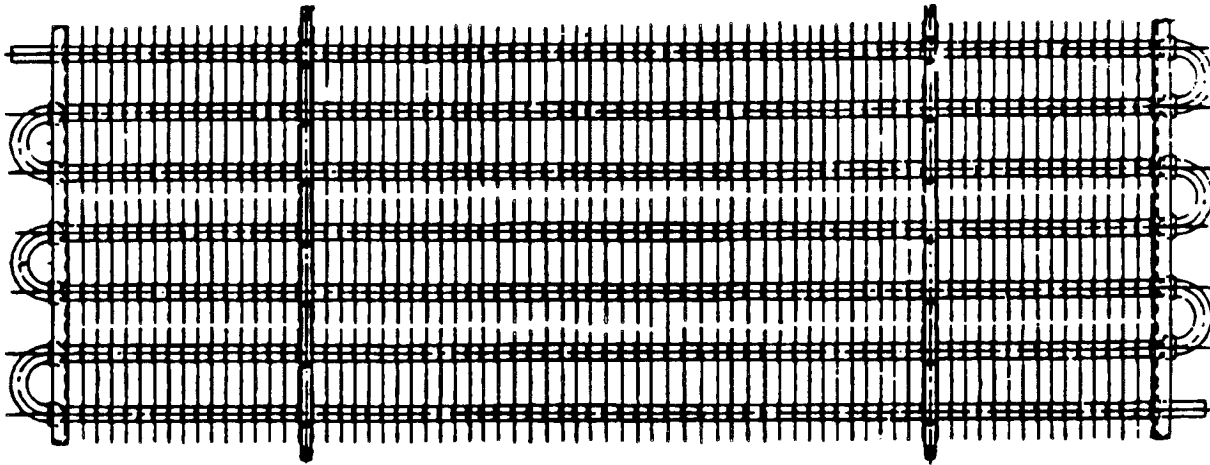


Figure 516-3-130. Finned Serpentine Cooling Coil

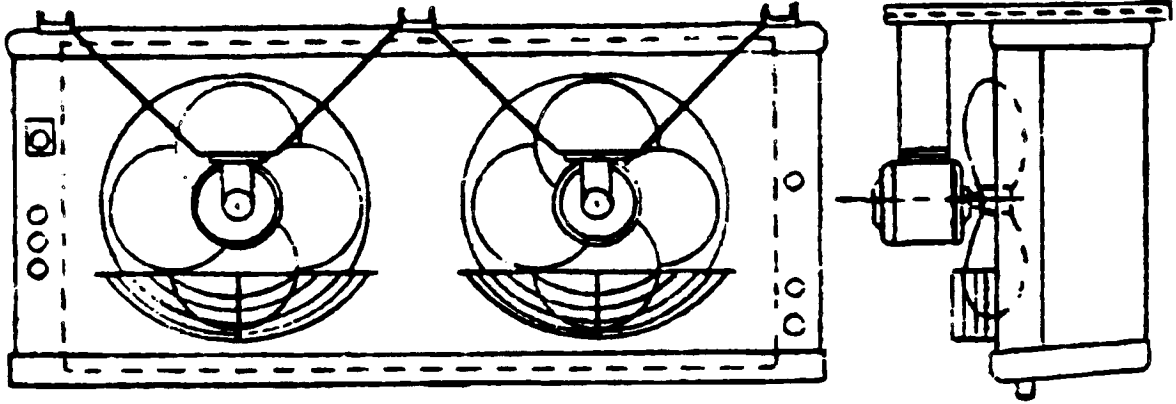


Figure 516-3-131. Forced Circulation Cooling Coil (Ceiling Type)

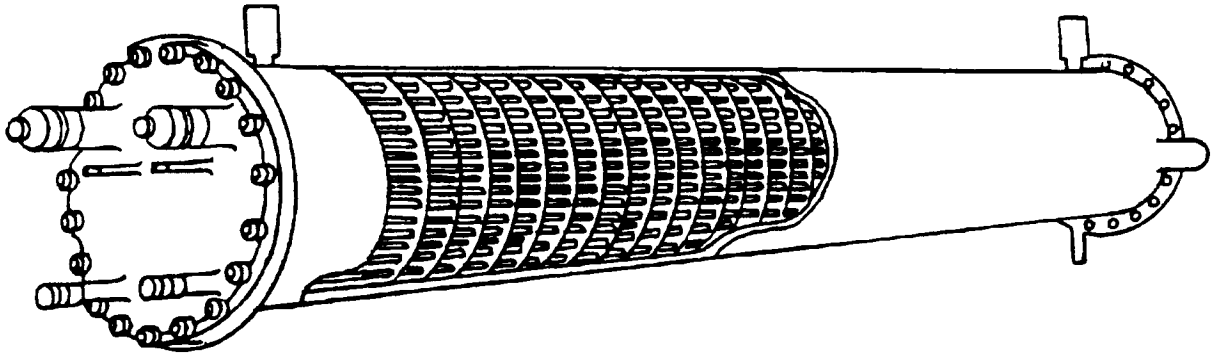


Figure 516-3-132. Liquid Water Chiller

516-3.3.14 EVAPORATOR PRESSURE-REGULATING VALVE. An evaporator pressure-regulating valve is installed in the suction line at the outlet of an evaporator where a temperature higher than a minimum shall be maintained, as in water cooler applications, when high humidities are desired in fruit and vegetable rooms, or where two or more spaces are maintained at different temperature levels with a single compressor unit. Pressure-regulating valves maintain a constant pressure within the cooling coil, higher than the suction pressure downstream and independent of suction pressure fluctuations. [Figure 516-3-133](#) shows an evaporator pressure-regulating valve.

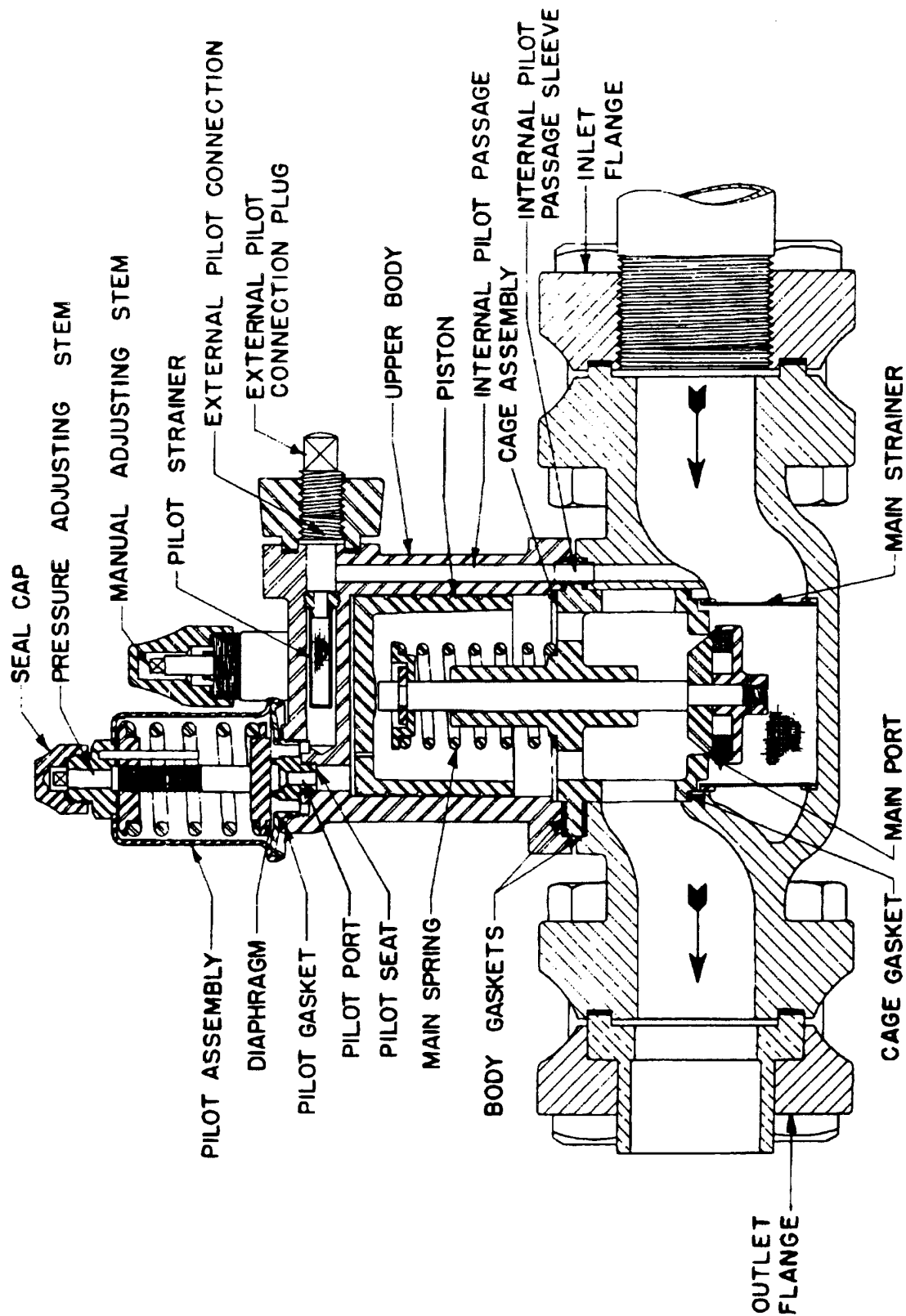


Figure 516-3-133. Evaporator Pressure-Regulating Valve

516-3.3.14.1 Valves are adjusted by compressing the adjusting spring. Automatic operation is maintained by diaphragm balance resulting from small fluctuations in coil pressure, which permit positioning of the valve seat to adjust the refrigerant flow. Evaporator pressure-regulating valves decrease the temperature difference that would otherwise exist between the compartment temperature and the cooling coil surface temperature. The smaller the temperature difference between the compartment and cooling coil surface, the higher the relative humidity in the compartment. Humidity is an important factor in the storage of fruits and vegetables. The higher the humidity, the less dehydration of fruits and vegetables occurs. Operating personnel shall maintain the coil temperature as high as possible by adjusting the evaporator pressure regulator, while maintaining the required compartment temperature, thus taking advantage of the larger coil installed in these compartments because of pulldown requirements. The rate of heat that can be transferred into the evaporating refrigerant is directly proportional to the temperature difference. The use of evaporator pressure-regulating valves requires that more coil surface be provided in a given compartment than would be otherwise necessary. It is therefore not generally practical to install an evaporator pressure-regulating valve in the suction line from an existing cooling coil installation, unless additional coil surface is provided. A valved bypass is provided around the pressure-regulating valve for use in case of derangement. Also, in refrigerated space applications where the space is convertible from 33°F to 0 degrees F, the bypass is required to permit the change to 0° F space temperature.

516-3.3.15 REFRIGERANT LIQUID SUCTION HEAT INTERCHANGERS. A suction/liquid line heat interchanger is generally provided in refrigeration and air-conditioning plants that use R-12, R-134a, and R-22. The heat interchanger, in most applications, improves the plant efficiency. It subcools the liquid refrigerant, preventing the formation of flash gas in the liquid piping because of pressure drops and high ambient temperature. At the same time, it increases the superheat of the suction gas, evaporating droplets of liquid refrigerant which may have carried over from the cooling coil. In ship stores and cargo refrigeration plants, a valved bypass line is provided around the heat interchanger so that liquid refrigerant may bypass the heat interchanger when use of the heat interchanger is not necessary or when the compressor suction gas superheat increases to the point where compressor discharge gas temperatures begin to approach the 250° F to 275 degrees F tolerable limits. This situation may occur during periods of low capacity where the small amount of refrigerant gas pumped is not sufficient to cool the compressor. Figure 516-3-134 shows a typical heat interchanger.

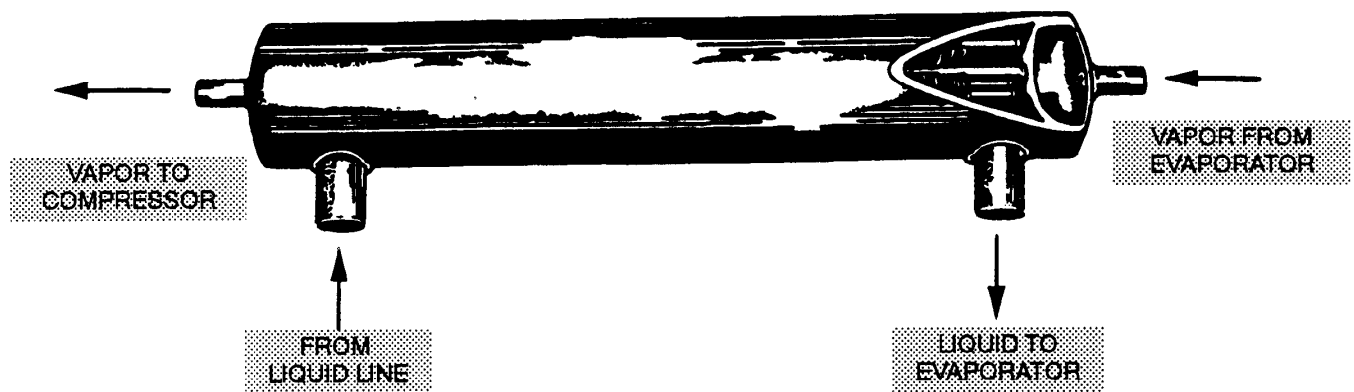


Figure 516-3-134. Liquid-Suction Heat Interchanger

516-3.3.16 SUCTION LINE RETURN. The refrigerant gas from the cooling coil(s) is returned to the compressor suction connection by way of the refrigerant suction line. When multiple cooling coils or coil circuits are installed, branch suction lines connect into a section main. A loop is provided in each branch suction line as it enters the suction main, preventing any oil that may be in the suction main from backing into the cooling coil or collecting in the coil during an off-cycle or shutdown period. Controls and accessories normally installed in

the suction piping are evaporator pressure-regulating valves, the heat interchanger, manual shutoff valves for shutting off branch lines, and cross-connections to other condensing units.

516-3.3.17 HOT GAS BYPASS. Occasionally, in air-conditioning plant applications a load condition exists where the lowest continuing load is below the lowest unloading step of the air-conditioning plant compressor. When this condition occurs, the air-conditioning compressor will stop and start at short intervals (short cycle) and effective cooling and dehumidification cannot be maintained. Short cycling is also detrimental to the air-conditioning equipment as well as the ship electrical system. To provide a nominal steady load on the air-conditioning plant compressor, a hot gas bypass is included in the refrigerant piping, as shown in [Figure 516-3-135](#). Hot gas from the compressor discharge piping is injected into the evaporator (cooling coil) between the thermostatic expansion valve and the evaporator inlet, through a solenoid valve, and through a hot gas bypass regulating valve. The solenoid valve in the hot gas bypass line is connected to the electrical control circuit so that it provides positive pumpdown and shutoff during cycling or shutdown of the equipment. The hot gas regulating valve ([Figure 516-3-136](#)) controls the amount of hot gas bypassed into the evaporator depending on load conditions. All hot gas bypass valves operate on a similar principle. They open in response to a decrease in downstream pressure and modulate from fully open to fully closed over a given range. Introduction of the hot, high-pressure gas into the low-pressure side of the system at the metered rate prevents the compressor from reducing the suction below the low-pressure switch cutout point. The control setting of the valve can be varied over a wide range by means of an adjusting screw.

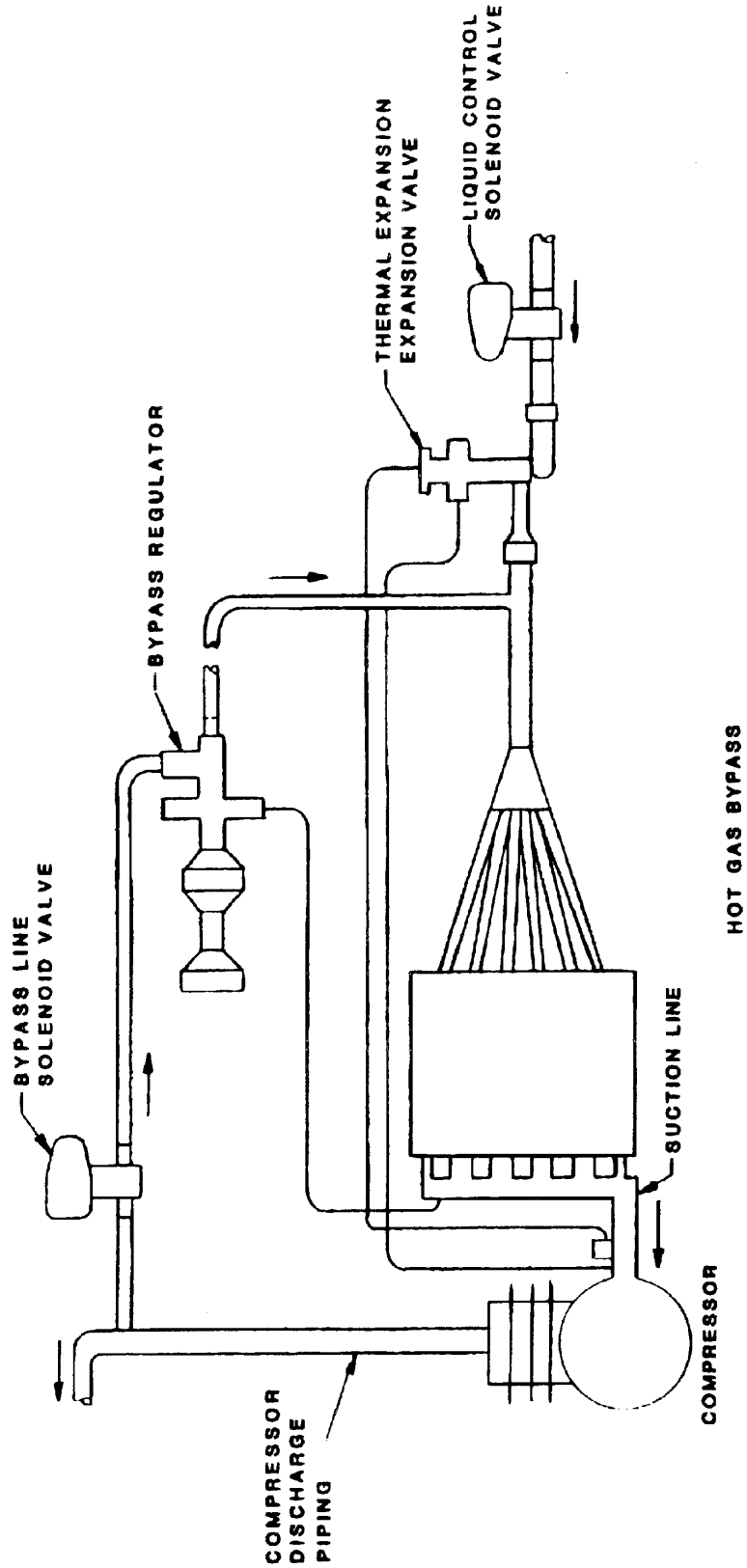


Figure 516-3-135. Hot Gas Bypass Arrangement

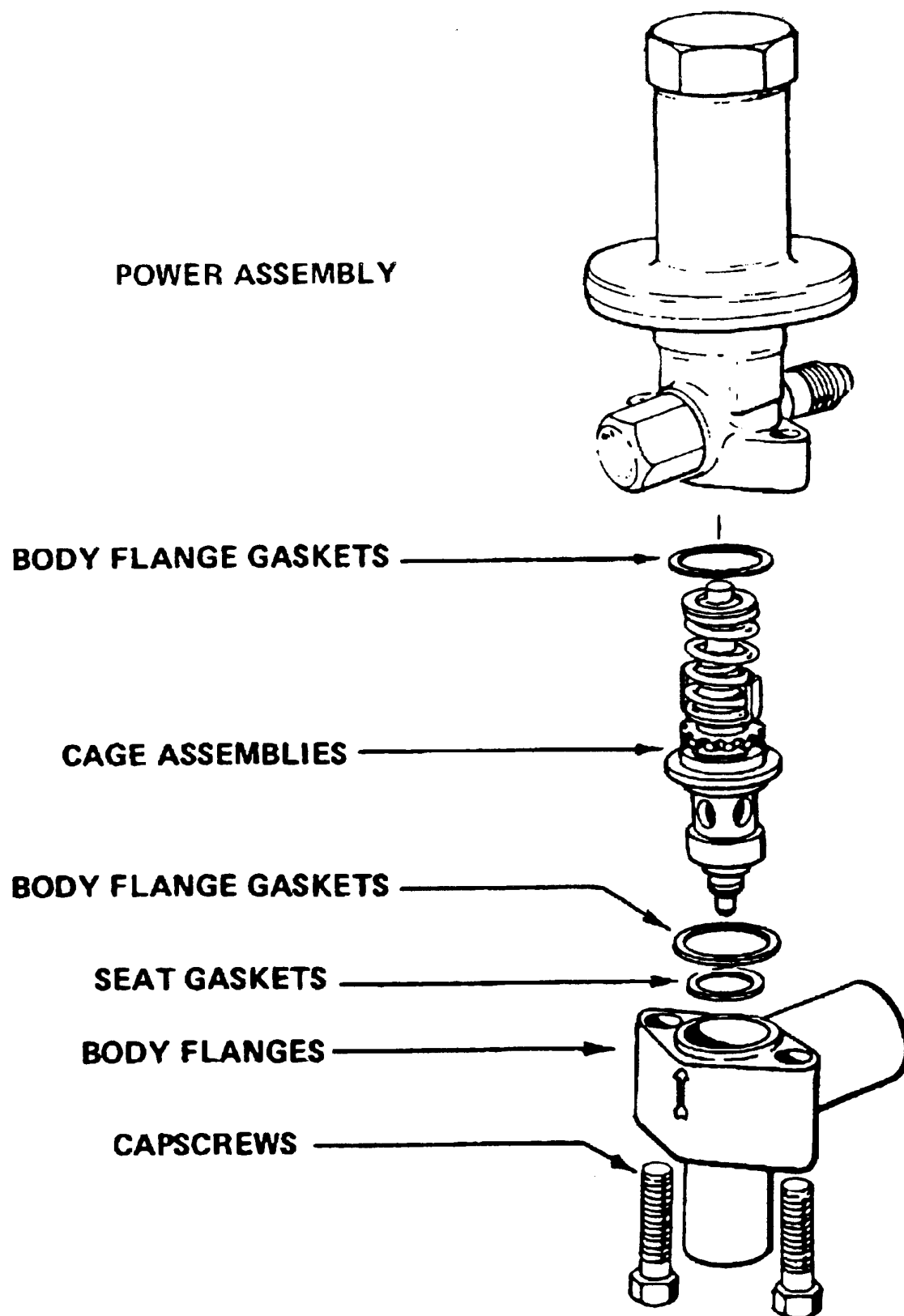


Figure 516-3-136. Hot Gas Bypass Valve

516-3.3.18 SUCTION LINE FILTER. Compressors are designed with strainers as part of the assembly. However, strainers do not filter out the fine particles that are very often found in refrigeration systems. In a number of cases a fine sandy grit, which had passed through installed compressor strainers, was found in compressor crankcases. Some of this fine abrasive matter was attributed to the powdering of the adsorption material in the dehydrators. New refrigeration plant installations may include a suction line filter at the compressor. These filters, which contain a replaceable filter core, will trap contaminants as small as 5 microns (a micron is a unit of length equal to one millionth of a meter or micrometer). The filter core is fluted to maintain a high flow capacity even after prolonged use (Figure 516-3-137). The flow is nondirectional and may be installed in either a horizontal or vertical position as long as the flange is accessible for filter core replacement. However, it is preferable that the flow enter through the inside of the core so that contaminants are trapped inside rather than outside the core.

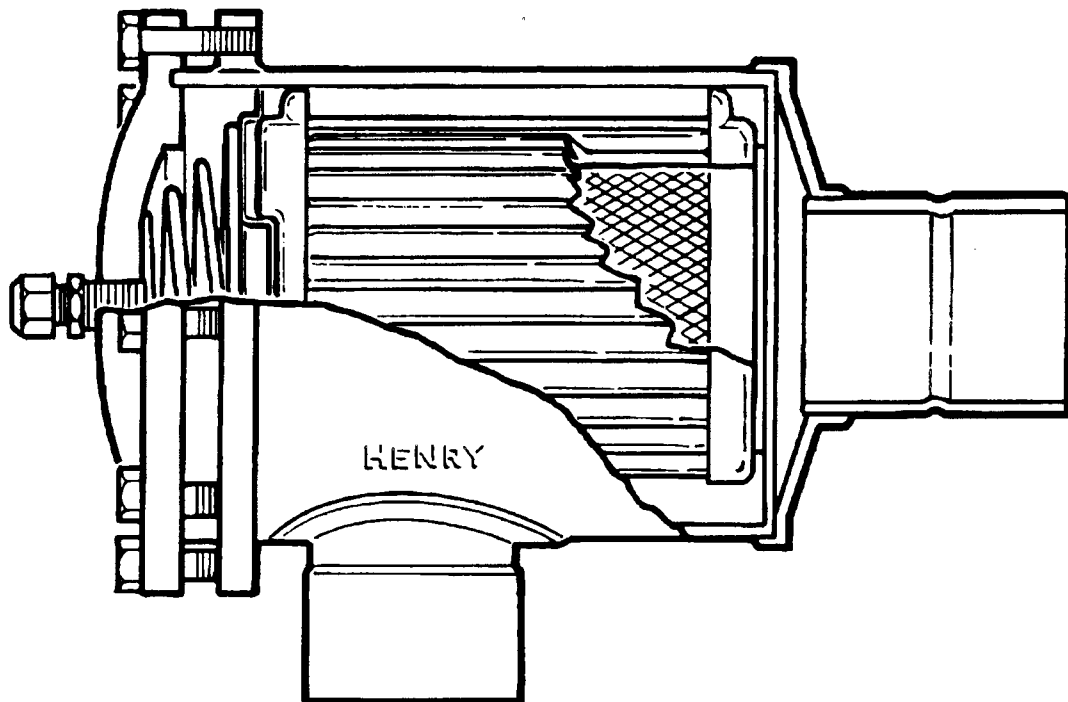


Figure 516-3-137. Suction Line Filter

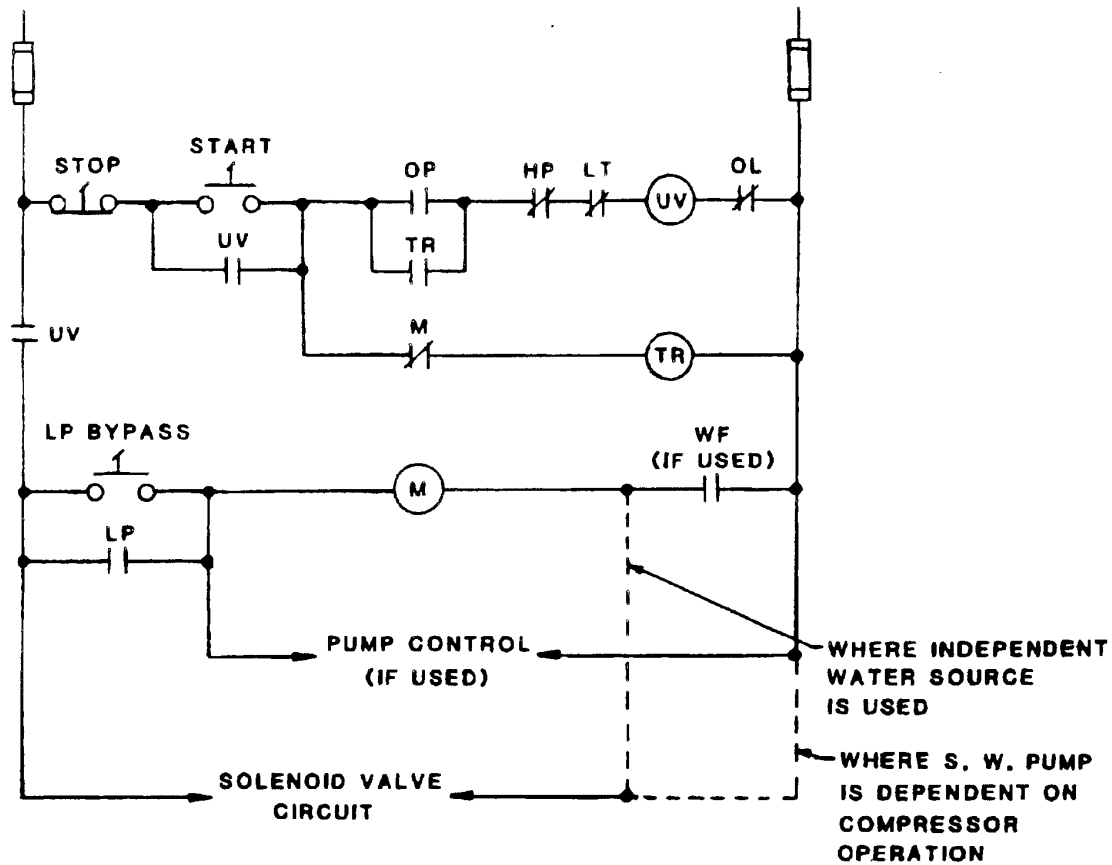
516-3.3.19 DEFROSTING. Refrigerated freeze spaces that operate at temperatures below 32° F require a means to melt the frost on cooling coils. Excessive accumulation of frost on coils interferes with proper heat transfer and obtaining of the required freeze compartment temperatures. This results in low compressor suction pressure and a tendency for the compressor to short-cycle. The defrosting method may be by hot refrigerant gas, electric heating elements, or hot seawater, depending on the design. Virtually all ship stores refrigeration plant cooling coils are defrosted by the hot gas method. New ship stores plants using forced circulation cooling coils (unit coolers) will have automatic electric defrosting. The frequency of the defrost cycle for unit coolers can be changed by means of a timer. Cargo refrigeration cooling coils generally use hot seawater for defrosting. Future cargo refrigeration plant cooling coils may use electric defrosting.

516-3.3.20 ELECTRICAL CIRCUIT. A motor controller, usually of the across-the-line type, is provided with a pilot control circuit, that when energized through operation of the various controls, will automatically close line contacts to start the motor. Accessories provided with small fractional horsepower motors for single-phase alternating current and two-wire direct current generally do not have automatic motor controllers but are started and

stopped by direct action of automatic controls. Controllers include automatic-manual selectors, low voltage and overload protection, and start and stop switches. The automatic-manual switch permits selection of:

- a. Automatic operation, by electrically connecting the suction pressure control switch relay for starting and stopping the compressor motor.
- b. Manual operation of start and stop switches, by electrically bypassing the suction pressure control relay.

516-3.3.20.1 The automatic-manual switch in either position provides connection to all safety controls. Start and stop switches provide manual opening and closing of the pilot circuit. The start switch for the compressor motor controller pilot circuit is usually a momentary contact providing initial electrical input on manual starting and reverting to a normally open position afterwards. High-speed compressors have oil failure protection switches, connected in conjunction with a time delay mechanism. This mechanism allows the compressor to continue to operate on startup until adequate oil pressure has built up. If oil pressure does not build up within a set time or if there is a loss of oil pressure, the compressor will stop. Solenoid valves, other than the main liquid line solenoid valve, are controlled by a thermostat or switch, and may receive their power supply from various sources. When a main liquid line solenoid valve (King valve) is used for refrigeration and air-conditioning service with direct expansion cooling coils, solenoids for an individual cooling coil control may be electrically connected to the ship lighting circuit or other power circuit without interconnection with the compressor motor control. The main liquid line solenoid is usually interconnected with the compressor motor control. When a main liquid line solenoid valve is not provided, individual solenoid valves are usually electrically connected to the compressor motor control circuit for operation at that voltage or through a transformer for reduced voltage. When a main liquid line solenoid valve is used for refrigeration and air-conditioning service with forced air cooling coils, solenoids for the individual cooling coil control are electrically connected to the fan motor controller of the associated cooler. This permits power to be supplied to the solenoid only when the fan motor is operating. [Figure 516-3-138](#) shows a typical electrical control circuit schematic for a chilled water plant.



SYMBOL	LEGEND
UV	UNDervOLTAGE RELAY
M	MAIN CONTACTOR
OL	OVERLOAD RELAY
TR	TIMING RELAY
	AGASTAT DE26N CLOSES INSTANTANEOUSLY, TIMES OPEN AFTER DEENERGIZING
OP	OIL PRESSURE SWITCH
LT	LOW TEMPERATURE CUTOUT
HP	HIGH-PRESSURE CUTOUT
WF	WATER FAILURE SWITCH
LP	LOW-PRESSURE CONTROL

WF IS NOT USED WITH SEAWATER
CONDENSERS WITH SUBMARINE
APPLICATIONS

LT IS USED FOR CHILLED WATER
OR BRINE SYSTEMS

TYPICAL MOTOR CONTROLLER CONTROL CIRCUIT

Figure 516-3-138. R-12 Compressor Schematic Wiring Diagram

SECTION 4.

OPERATION OF RECIPROCATING COMPRESSOR PLANTS

516-4.1 OPERATION

516-4.1.1 PRECAUTIONS IN STARTING. Thoroughness and care are of utmost importance in starting up the compressor. Bent crankshafts, broken or distorted valves, blown gaskets, and other problems result from improper attention to the precautions necessary for starting a refrigeration plant. In preparing for startup of the refrigeration or air-conditioning plant, the general safety precautions concerning halocarbon refrigerating plants in [Section 1](#) apply. Observe the following additional precautions, as applicable to a particular installation:

- a. Make sure there is compressor oil in the crankcase before starting. Inspect the oil level in the crankcase periodically. The proper time to do this is immediately after the compressor has been shut down following a long period of operation. The ideal oil level is from 1/2 to 3/4 up on the bull's eye sight glass. The minimum oil level is 1/4 up on the glass. If necessary, add FED Spec VV-L-825 (Lubricating Oil, Refrigerant, Compressor, Uninhibited), Type II oil to R-12 plants. For R-134a plants, add a commercial-grade polyolester oil in accordance with the compressor manufacturer's recommendation and NAVSEA CID A-A-XXX87. Check compressor motor lubrication.
- b. Do not attempt to add oil to the compressor crankcase while the compressor is operating. Pump down and isolate the compressor to slightly above atmospheric pressure in the crankcase before removing the filler plug or opening the oil-charging valve.
- c. Never start a compressor without making sure that the shutoff valve between the compressor and the condenser is open. Check for proper open or closed position of other line valves.
- d. If possible, before starting, turn over the compressor several times by hand to clear cylinders of any oil that may have collected. Do not jack or turn the compressor by hand when power is on.
- e. Make sure safety controls are not bypassed or closed off. Never bridge an overload, control, or protective device because it kicks out during operation. Find the trouble and make proper repairs.
- f. Do not wipe down in the vicinity of moving parts.
- g. In case of electrical fire, open the circuit switch and extinguish with CO₂. Never use water.
- h. Be sure power is turned off before working on motors, controllers, solenoid valves, and electrical control switches. Tag the circuit breaker to prevent accidental energizing of the circuit.
- i. Stop the compressor immediately for any of the following reasons:
 - 1 Low oil pressure
 - 2 Unusual vibration or noises in the compressor or motor
 - 3 Abnormal heat from the compressor, motor, or motor controller
 - 4 Leakage of refrigerant or oil.
- j. When the compressor motor is first started, the operator should stand by the switch and start the motor in short intermittent spurts until the compressor is operating properly. Avoid rapid pumping down of the low-side pressure. Rapid evacuation may pull the oil from the compressor crankcase. Since a certain amount of refrigerant is always found mixed with the oil in the crankcase, the refrigerant is subject to rapid evaporation as the crankcase pressure is lowered. This will cause the crankcase oil to foam. The crankcase oil will then leave with the evaporating refrigerant and circulate through the system, with perhaps considerable delay in

returning to the crankcase. If the oil is pulled from the crankcase as described, do not run the compressor without the lubricant. Stop the compressor and add oil. The added oil may be removed later if there is evidence of excess oil in the crankcase.

- k. The operator should also be certain that liquid refrigerant is not being returned to the compressor. The return of the liquid refrigerant will be indicated by one or more of the following symptoms, which shall be carefully investigated:
 - 1 Sudden drop in suction temperature and rapid fluctuation in suction pressure.
 - 2 Drop in discharge temperature.
 - 3 The crankcase and cylinders are relatively cold, sweating, or frosted.
 - 4 Compressor knocking.
- l. To avoid rapid pumping down of the compressor low side, the compressor suction valve may be opened one turn and gradually opened as the system pressure is reduced.
- m. Before restarting the compressor, if it was secured because of liquid floodback, secure the refrigerant supply and operate the compressor in short spurts until the compressor has been cleared of liquid refrigerant. Closely watch the compressor oil level during this period to ensure against related hazards due to loss of compressor lubrication.
- n. Operating personnel should be aware of dangers from liquid floodback and recognize symptoms to protect the compressor against damage. See paragraph [516-4.1.30](#).
- o. When isolating any part of the system in which there is liquid refrigerant, close the cutout valve on the inlet side of the part to be isolated and allow the compressor to remove all liquid refrigerant. This will be indicated by a sudden chilling of the part being isolated. When all the liquid refrigerant has been evacuated from the component or piping section, the temperature of the component or piping section will begin to rise to room temperature. When this occurs, close the valve on the outlet (downstream) side of the component or piping section that will be isolated for maintenance or repairs. If bypass valves and piping are provided around the isolated part or piping section, open the bypass valve(s) to permit normal plant operation. Where bypass valves and piping are not provided, a ship stores or cargo refrigerant plant generally may be shut down for 2 or 3 hours without any detrimental effect on the refrigerated product. The air temperature in the refrigerated space may rise several degrees, but the product temperature will not change significantly. If possible, transfer the refrigeration load to another condensing unit. Transfer air-conditioning loads to another plant.
- p. Never open any part of the system that is under a vacuum. If this is done, air and moisture will be drawn into the system and is almost certain to cause trouble at some later date. The pressure should be drawn down to 0 psig before a system is opened for inspection or repair. If any section of the system is to remain void of refrigerant for any length of time, maintain a blanket of nitrogen with a positive pressure of 1 or 2 psig to prevent corrosion.
- q. During the shutdown period of any condenser, if freezing temperatures in the condenser compartment are possible, thoroughly drain the condenser and the connecting piping to prevent a freeze-up that might damage condenser tubes.
- r. Never use a torch or attempt a repair on a line containing halocarbon refrigerant until it is certain that all gas has been pumped out of the pipe section to be repaired, the area is well ventilated, and the line has been valved off. Halocarbon refrigerants, in conjunction with any open flame, breaks down to produce highly toxic gases.
- s. After an investigation or repairs are made, always admit a small amount of refrigerant gas into that part of the system to expel any air that has entered.

- t. If the plant is to be started after a prolonged shutdown period, check that the plant has a proper refrigerant charge.
- u. Ensure that the condenser has the proper seawater flow. If a centrifugal seawater pump supplies water to the condenser, open the seawater pump suction valve, start the pump, and open the discharge valve. Refer to the applicable pump technical manual.
- v. If the seawater supply to the condenser is from the fire main through a reducing valve, be sure that the seawater pressure to the condenser is approximately 25 to 35 psig. Excessive seawater pressure causes serious condenser and valve problems.
- w. Check operation of the condenser water-regulating valve and adjust as necessary to obtain 120- to 125-psig R-12 or 130- to 135-psig R-134a condensing pressure. For systems with an air-cooled condenser, the refrigerant condensing pressure is higher than 130 psig. Generally, condensing pressures for air-cooled units run from 145 to 210 psig, depending on the equipment design and ambient temperature. Consult the applicable equipment technical manual for design condensing pressure.
- x. Make a complete check every 2 hours of all temperatures, pressures, and the oil level in the compressor crankcase.

516-4.1.2 OPERATION OF CONTROLS. The following is a summary of the operation of the various controls:

- a. Manual Operation - Some refrigeration and air-conditioning plants have selector switches that permit either manual or automatic operation. With the selector switch in a manual position, the low-pressure switch is bypassed, thus providing continued operation. During manual operation, safety switches (high pressure, oil failure, and water failure) will stop the compressor if a malfunction occurs. On many refrigeration and air-conditioning plants, a low-pressure (LP) bypass button is provided in place of a selector switch. To operate the plant manually it is necessary to depress and hold in the LP bypass button. Generally, manual operation is used only during plant startup and for pumping down the refrigerant piping when shutting down a condensing unit or the complete plant.
- b. Automatic Operation - If all automatic control valves and switches are adjusted and functioning properly, operation of the plant once it is started will be completely automatic. The refrigerant flow to various space-cooling coils or water chillers is controlled by solenoid valves operated by thermostatic switches. When the refrigerant flow is stopped by cooling coil or water chiller solenoid valves, the compressor will pump the refrigerant from the low side of the system until the cutout setting of the low-pressure switch is reached. At this point the low-pressure switch opens, stopping the compressor. When cooling is again required, the thermostatic switches will close, causing cooling coil or water chiller solenoid valves to open, thus permitting refrigerant to enter the low side of the system. When the low-side refrigerant pressure increases to the cut-in setting of the low-pressure switch, the switch closes and the compressor starts. The plant will continue to operate in this manner unless something occurs to activate one of the safety devices. The functioning of these devices is described in the following paragraphs. See [Table 516-4-1](#) and [Table 516-4-2](#) for recommended refrigeration system control settings.

TABLE 516-4-1. RECOMMENDED REFRIGERATION SYSTEM CONTROL SETTING - R-12

Design Temp., °F	Equipment	Oper. Thermo. Cutout, °F	Oper. Thermo. Cutin, °F	Refr. HP Switch Cutout, lb	Refr. HP Switch Cutin, lb	Refr. LP Switch Cutout, lb	Refr. LP Switch Cutin, lb	Water* Fail. Switch Cutout, lb	Water* Fail. Switch Cutin, lb	Low Chilled Water Temp. Cutout, °F	Low Chilled Water Temp. Cutin, °F
49-50 CW	CW Air-Cond. Plant	38 + 2/-0	49 + 0/-2	150 + 2	125 + 2	20 + 0/2	40 + 2/-0	5 + 2	15 + 2	35 + 2.0	49 + 0.2
44-45 CW	CW Air-Cond. Plant	38 + 2/-0	44 + 0/-2	150 + 2	125 + 2	20 + 2/0	40 + 2/-0	5 + 2	15 + 2	35 + 2.0	44 + 0/-2
45	DX Air-Cond. Plant	75 + 2/-0	78 + 0/-2	150 + 2	125 + 2	35 + 1/-1	55 + 0/-2	5 + 2	15 + 2	--	--
0	Ship Stores Refrig. Plant	-3 + 1	0 + 1	150 + 2	125 + 2	5 + 1	8 + 1	5 + 2	15 + 2	--	--
33	Ship Stores Refrig. Plant	33 + 1/-0	35 + 1	150 + 2	125 + 2	5 + 1	8 + 1	5 + 2	15 + 2	--	--
15	Ship Stores Refrig. Plant	13 + 1	15 + 1	150 + 2	125 + 2	2 + 1	18 + 1	5 + 2	15 + 2	--	--
40	Ship Stores Refrig. Plant	38 + 1	40 + 1	150 + 2	125 + 2	2 + 1	18 + 1	5 + 2	15 + 2	--	--
-10	Ship Stores Refrig. Plant	-13 + 1	-10 + 1	150 + 2	125 + 2	5-in. hg Vac	8 + 1	5 + 2	15 + 2	--	--
If the condenser discharge is located more than 5 feet below the waterline, the water failure switch settings will have to be increased accordingly to compensate for the water head in the discharge piping. NOTE: For air-cooled condensing units, the HP switch settings should be 270 lb± 2.210 lb ± 2.											

Figure 516-4-1. TABLE 516-4-1 RECOMMENDED REFRIGERATION SYSTEM CONTROL SETTING - R-12

TABLE 516-4-2. RECOMMENDED REFRIGERATION SYSTEM CONTROL SETTING - R-134A

Design Temp., °F	Equipment	Oper. Thermo. Cutout, °F	Oper. Thermo. Cutin, °F	Refr. HP Switch Cutout, lb	Refr. HP Switch Cutin, lb	Refr. LP Switch Cutout, lb	Refr. LP Switch Cutin, lb	Water* Fail. Switch Cutout, lb	Water* Fail. Switch Cutin, lb	Low Chilled Water Temp. Cutout, °F	Low Chilled Water Temp. Cutin, °F
49-50 CW	CW Air-Cond. Plant	38 + 2/-0	49 + 0/-2	TBD	TBD	TBD	TBD	5 + 2	15 + 2	35 + 2.0	49 + 0.2
44-45 CW	CW Air-Cond. Plant	38 + 2/-0	44 + 0/-2	TBD	TBD	TBD	TBD	5 + 2	15 + 2	35 + 2/-0	44 + 0/-2
45	DX Air-Cond. Plant	75 + 2/-0	78 + 0/-2	TBD	TBD	TBD	TBD	5 + 2	15 + 2	--	--
0	Ship Stores Refrig. Plant	-3 + 1	0 + 1	TBD	TBD	TBD	TBD	5 + 2	15 + 2	--	--
33	Ship Stores Refrig. Plant	33 + 1/-0	35 + 1	TBD	TBD	TBD	TBD	5 + 2	15 + 2	--	--
15	Ship Stores Refrig. Plant	13 + 1	15 + 1	TBD	TBD	TBD	TBD	5 + 2	15 + 2	--	--
40	Ship Stores Refrig. Plant	38 + 1	40 + 1	TBD	TBD	TBD	TBD	TBD	5 + 2	15 + 2	--
-10	Ship Stores Refrig. Plant	-13 + 1	-10 + 1	TBD	TBD	TBD	TBD	5 + 2	15 + 2	--	--
If the condenser discharge is located more than 5 feet below the waterline, the water failure switch settings will have to be increased accordingly to compensate for the water head in the discharge piping. NOTE: For air-cooled condensing units, the HP switch settings should be 270 lb ± 2.											

Figure 516-4-2. TABLE 516-4-2 RECOMMENDED REFRIGERATION SYSTEM CONTROL SETTING - R-134A

- c. Excessive Refrigerant Condensing Pressure - If the compressor discharge pressure becomes abnormally high, the high-pressure cutout switch opens, deenergizing line contactor coils and stopping motors in the same manner as the opening of the water failure switch. When the discharge pressure returns to normal, the high-pressure switch will close. It may be necessary to restart the plant manually after it has been stopped by opening the high-pressure switch.
- d. Overload Relays - If compressor or pump motors become overloaded while the plant is operating, overload devices in the power line to each motor will open the overload relay switches. When either overload relay switch opens, the control coil is deenergized and control relay switches open, deenergizing line contactor coils and stopping motors. If the overload relays trip, determine the cause and fix it before attempting to restart the motor. Overload relays need to be reset before motors can be operated automatically again.
- e. Oil Failure - If the required oil pressure is not attained within prescribed limits, usually 10 to 30 seconds after starting, or is not constantly maintained during operation, the compressor will stop upon the opening of the time delay relay contacts, in the first case, and upon the opening of pressure differential switch contacts, in the second case. To restart in either case, press momentarily and then release the reset button on the motor controller. The oil pressure differential switch is set to close when the pump oil pressure exceeds the crankcase pressure by a predetermined pressure difference, depending on the make and type of compressor. The switch is set to open at a pressure approximately 5 psi lower than this pressure. When the compressor stops through the action of the oil safety switch, do not bypass or manually control the differential pressure switch to operate the compressor.
- f. Water Chiller Low-Temperature Switches - The water chiller low temperature switch is a safety device that stops the compressor if the chilled water temperature drops to the minimum permissible level. Thus this switch prevents a freeze-up in the chiller. The thermal bulb for the low temperature switch is located in the water chiller shell. If the compressor is stopped by this switch, restart the compressor by pressing the motor controller start button when the chilled water temperature rises above the cut in setting.

516-4.1.3 STARTING THE COMPRESSOR. Use the following procedure to start the compressor:

1. Line up cooling water to the condenser and, if applicable, chill water to the chiller.
2. Check the oil level in the compressor crankcase. The oil level will depend on the amount of refrigerant absorbed in the oil. If the level is low, but within limits, no oil should be added until the reduced oil level has been accounted for. If the level is too low to run the compressor, add enough oil to start the compressor. If necessary, remove the added oil when the oil from the system has returned to the crankcase.
3. Open the compressor discharge stop valve. Open all refrigerant valves required for plant operation except the receiver outlet/main liquid line shutoff valve and the compressor suction stop valve. Open all actuating stop valves.

NOTE

While a unit is secured, the TXV thermal bulb is at the same temperature as the space in which it is located. This causes the TXV to open wide. With the TXV open wide, the evaporator/chiller will be flooded if the main liquid line shutoff valve is opened wide at startup. Once the liquid refrigerant reaches the thermal bulb, the TXV will close, but the evaporator will still be flooded with refrigerant; some liquid refrigerant could, therefore, return to the compressor.

4. Jog the compressor several times and run it for 1 to 2 seconds when first starting up the compressor to remove refrigerant from the oil (some refrigerating plants have an antirecycle timer that prevents restart of the compressor within a minimum time. The antirecycle bypass may be used to bypass the time delay during startup).

If refrigerant has been absorbed by the oil, a rapid reduction in crankcase pressure will cause the oil to foam violently as refrigerant flashes to a vapor. Continuously monitor the crankcase oil level. Take every precaution to avoid running the compressor without lubrication.

5. Place the selector switch in AUTOMATIC and start the compressor. After the compressor stops on the low-pressure switch, crack open the compressor suction stop valve. Slowly open the suction stop valve wide at a rate that will prevent liquid refrigerant, which may be in the suction piping, from entering the compressor. The compressor will lower the suction pressure and stop on the low-pressure switch.
6. Crack open the main liquid line shutoff valve. When the suction pressure increases to the cutin point of the low-pressure switch, the compressor will start and lower the suction pressure. Slowly open the main liquid line shutoff valve wide, at a rate that will prevent liquid refrigerant from entering the compressor. During start-up, closely observe the compressor suction temperature and the saturation temperature corresponding to the suction pressure. Maintain 10°F to 12°F of superheat at the outlet of the evaporator/chiller.

516-4.1.4 STOPPING THE COMPRESSOR. If the compressor shall be stopped for any reason, depress the stop button at the compressor motor controllers. To secure the compressor or system for a prolonged shutdown or to open any part of the system for maintenance, close the receiver liquid outlet valve and allow the compressor to run on a manual setting until a pressure of 1 to 2 psig exists in the system. Then depress the stop button at the compressor motor controller. This pumping-down procedure will result in the liquid refrigerant being pumped back into the receiver. If the pressure starts to rise again, repeat the pumping-down operation. After pump-down is completed, close the compressor shutoff valves and secure seawater and chilled water where applicable. Some compressors are equipped with a crankcase heater that keeps an excessive amount of refrigerant from going into solution with the compressor oil. Most naval shipboard refrigerating plants do not have a crankcase heater since these plants operate on a pump-down cycle, where the refrigerant is pumped from the low side of the system before being stopped by the low-pressure switch. However, new installations will include crankcase heaters. Where crankcase heaters are installed, they shall be electrically interconnected so that the heater is energized only during compressor off-cycle and deenergized during the running cycle.

NOTE

Make sure that crankcase heaters are not energized during the running cycle, as this could cause compressor seal problems.

516-4.1.5 ALTERNATING COMPRESSOR OPERATION. It is not good practice to permit any refrigerating compressor to remain idle for an extended period of time. When two or more compressors are installed for a given plant, operate each of the compressors at least once a week and keep the total time that each compressor operates approximately the same during the service life of the equipment. Newer equipment has elapsed (running) time meters that provide an accurate account of the operating time of each unit. Use the elapsed (running) time meters to determine maintenance requirements.

516-4.1.6 RECORD OF OPERATING CONDITIONS. Always use good judgment in the analysis of operational and maintenance troubles. Where troubles are clearly defined, take specific corrective actions. Where the exact nature of the trouble is not clearly defined, further analysis and evaluation is required to determine the proper corrective action. One of the best methods for determining when and what corrective measures are necessary for a plant is to compare existing pressures and temperatures at various parts of the system with corresponding readings taken in the past when the plant was operating properly under similar heat load and circulating water temperature conditions.

516-4.1.6.1 Use the daily operating log for refrigerating equipment shown in [Figure 516-4-1](#) to maintain a record of operating conditions and as a guide for continuing analysis of operating conditions and results in a refrigeration or air-conditioning plant. Columns containing information on machinery space ambient temperature (° F) and water supply are significant; a record of these conditions is desirable for comparative purposes.

REFRIGERATION/AIR-CONDITIONING EQUIPMENT OPERATING RECORD

INSTRUCTIONS

1. Take readings every two hours. Take compressor and condenser readings: ONLY WHEN COMPRESSOR IS OPERATING.
2. Code for Bull's-Eye level: H = High, L = Low, M = Neutral.
3. Code for condition of liquid line sight flow indicator: C = Clear, B = Bubbles.
4. Code for condition of liquid line moisture: W = Wet, D = Dry.
5. For compartment normal range, enter the normal temperature range (NTR) of the refrigerated space (do not include comfort air-conditioned compartments).

MAKE		SIZE/MODEL		REFRIGERANT		APPLICATION		PLANT NO.		LOCATION				
TIME	MACH. SPACE AMB. TEMP. °F	COMPRESSOR				CONDENSER (Water cooled)				LIQUID LINE		OPERATING TIME METER READING	INITIALS	
		SUCTION		DISCHARGE		LUBRICATING OIL		WATER SUPPLY		TEMP. °F	CONDITION AT SIGHT FLOW INDICATOR			CONDITION AT MOISTURE INDICATOR
		PRESS. PSIG	TEMP. °F	PRESS. PSIG	TEMP. °F	PRESS. PSIG	TEMP. °F	PRESS. PSIG	TEMP. °F					
0200														
0400														
0600														
0800														
1000														
1200														
1400														
1600														
1800														
2000														
2200														
2400														

Figure 516-4-1. Refrigeration/Air-Conditioning Equipment Operating Log (Sheet 1 of 2)

REFRIGERATION/AIR-CONDITIONING EQUIPMENT OPERATING RECORD

TIME	WATER CHILLER					REFRIGERATED COMPARTMENT								REMARKS
	SUPPLY		RETURN				NO.	NO.	NO.	NO.	NO.	NO.	NO.	
	PRESS. PSIG	TEMP. °F	PRESS. PSIG	TEMP. °F										
0200														
0400														
0600														
0800														
1000														
1200														
1400														
1600														
1800														
2000														
2200														
2400														
GENERAL REMARKS														

Figure 516-4-1. Refrigeration/Air-Conditioning Equipment Operating Log (Sheet 2 of 2)

516-4.1.6.2 Other columns represent operating results. Where improper results are in evidence, make an immediate check to determine the cause and remedy. Such precaution may avert serious derangement. For example, if the actual compressor suction line temperature drops to the saturation temperature corresponding to the actual measured suction line pressure (as indicated by temperature and pressure scales on the suction pressure gauge), the possible return of liquid refrigerant to the compressor is definitely indicated. Further evidence of such liquid carry-over will be provided by an accompanying drop in the compressor discharge temperature. If liquid does return to the compressor, correct the trouble at once to prevent possible compressor damage.

516-4.1.7 **MOISTURE PRECAUTIONS.** Take every reasonable precaution to prevent entrance of air into the refrigerant system, partly to avoid the troublesome necessity of purging the condenser but more importantly to prevent the entrance of moisture. Atmospheric air always contains some moisture. Refrigerants, as supplied by the manufacturer, are extremely dry and moisture-free. Always keep existing systems as moisture-free as possible to eliminate not only the freezing of water at expansion valves but also formation of acids, corrosion of parts, emulsification and sludging of lubricating oils, copper-plating, and many other difficulties. If the system has a moisture indicator in the liquid line or on the dehydrator, the presence of excess moisture will be indicated by a pink (Henry) or yellow (Sporlan) element, as previously described. When moisture is indicated, replace the dehydrator cartridge. If the moisture indicator element is any color other than shades of pink or blue (Henry Valve Co.) or yellow or green (Sporlan Valve Co.), the element is washed out due to water or oil saturation. When a moisture indicator element is washed out the refrigerant system should be analyzed to determine the cause of contamination and corrected and the element should be replaced. If the system does not have a moisture indicator, the presence of moisture will usually be evidenced in the operation of the thermal expansion valves. Gums and other substances formed by moisture in the system will cause expansion valves to stick and operate erratically. Also, a small quantity of moisture can condense and freeze in the valve orifice, blocking the flow of refrigerant. Intermittent freezing and thawing of ice in the expansion valve also causes the valve to operate erratically.

516-4.1.7.1 If the crankcase oil turns dark brown or black this is another sign of excessive moisture in the system. In older systems, the dehydrator was installed in a bypass line parallel to the main liquid line. When there is any indication of moisture in these systems, put the dehydrator into service by opening valves in the dehydrator bypass piping and closing the valve in the main liquid line so that the refrigerant flows through the dehydrator. In newer systems, the dehydrator is installed directly in the main liquid line. In these systems, any symptoms of moisture mean that the dehydrator cartridge is saturated with moisture and should be replaced. It is best to have the refrigerant flow through the dehydrator at all times, providing a continuous pickup of moisture, rather than try to dry out a system that has become heavily loaded with moisture.

NOTE

If the plant has no moisture indicator and contains a Henry dehydrator, requisition a dehydrator cover plate containing a moisture indicator. Cover plates are interchangeable. Update ship's COSAL.

516-4.1.8 **PUMPING DOWN THE SYSTEM.** Pump-down a plant or system whenever it is to be secured. Return all refrigerant to the receiver, permitting a positive pressure of approximately 2 psig to remain in the suction piping. Trapped refrigerant within the compressor discharge piping, condenser, and receiver to the main liquid line shutoff valve will be at higher pressure. To pump down the system, close the main liquid line shutoff valve. Allow the compressor to operate on manual control until the suction pressure reaches approximately 1/2 to 2 psig; then stop the compressor. In a chilled water air-conditioning plant, keep the water flowing through the chiller to prevent freezing. Repeat the compressor manual operation in periodic cycles until all of the liquid refrigerant in the evaporator/chiller has evaporated and the suction pressure remains relatively constant at 1/2 to

2 psig. During the pump-down period, the evaporation of liquid refrigerant can be traced on the liquid line back to the main liquid line shutoff valve by formation of frost and subsequent melting as liquid refrigerant is evaporated.

516-4.1.9 LAYING UP THE SYSTEM. Lay up the system when the plant or system is to be shut down for an indefinite period of time. To lay up the system, remove all refrigerant in accordance with local guidance, drain the oil from the compressor and replace it with new oil, evacuate the refrigerant system to ensure a tight system, and charge the system to 5 psig of dry nitrogen.

516-4.1.9.1 Open the power-supply switch to the compressor and pump motors and solenoid switches, and close the compressor suction and discharge shutoff valves. Shut off the water supply to the condenser and drain the condenser water. Where the liquid refrigerant contained in the system is in excess of the receiver capacity, draw off the surplus liquid refrigerant into separate refrigerant cylinders.

516-4.1.10 COMPRESSOR MOTOR OVERLOAD ON START. When the refrigerating compressor of a new plant, or the compressor of an old plant, is first started after prolonged, complete shutdown, compartments to be cooled are warm and the refrigerant evaporating pressure will be much higher than normal. Under these conditions the compressor motor may be overloaded. Carefully observe the unit for the first few hours of operation. If the motor is overloaded, an overload trip in the motor controller should stop the motor. After the motor temperature has been reduced to a safe value, the overload trip may be reset and the plant put back into operation. If the overload trip fails to function, it will be necessary to stop the compressor motor manually, to avoid damage if the motor overheats.

516-4.1.11 COMPRESSOR SHORT CYCLING. Compressor short cycling, that is, stopping and starting every few minutes, is not normal and generally indicates a shortage of refrigerant; a partial blockage of refrigerant flow; or malfunctioning of a switch, the capacity control, or a control valve. Since the compressor in any system is designed to handle the maximum load, occasionally very light load conditions may cause short cycling. Where two or more compressors are used during pull-down operation of a ship store or cargo refrigeration plant, short cycling may occur as the refrigerated spaces reach design temperatures. If this occurs, shut down one or more of the condensing units and place the entire holding load on one or two condensing units.

516-4.1.11.1 Most refrigeration and air-conditioning plant compressors are designed to unload one or more cylinders as the system load drops off. When the system load becomes less than the capacity of the compressor, one or more cylinders will unload to match the smaller system load. Eventually, when the system load drops below the smallest capacity of the compressor, the refrigerant pressure in the low (suction) side of the system will be reduced to the cutout point of the low-pressure switch, stopping the compressor. Unless there is an unusual increase in the system load, the compressor should remain off for a reasonable length of time. Continuous short cycling will cause the motor to overheat and eventually burn out. Also, there will be excessive wear of the electrical controls. When short cycling occurs, investigate the cause and take appropriate corrective action.

516-4.1.12 MISCIBILITY OF REFRIGERANTS WITH OILS. Halocarbon refrigerants and lubricating oil are highly miscible. Oil will absorb appreciable quantities of refrigerant, with the amount absorbed depending on oil characteristics, temperature, and pressure at which the refrigerant and oil are in contact. High refrigerant pressures and low oil temperatures will permit absorption of more refrigerant than will low refrigerant pressures and high oil temperatures. When the compressor stops, the lubricating oil temperature decreases and the refrigerant backpressure in the low side of the system (including compressor crankcase) gradually increases. These pressure and temperature changes permit the refrigerant vapor to become absorbed by the lubricating oil in the compressor crankcase. When the compressor is restarted, the compressor pressure in the crankcase is rapidly decreased

and the temperature of the lubricating oil rises because of friction. Thus, the absorbed refrigerant in solution has a tendency to boil or separate out of the crankcase lubricating oil, causing the oil to foam. Some oil foaming will occur each time the compressor starts. This is normal and will not harm the compressor. Where foaming is excessive and prolonged, the compressor can be damaged. Investigate and correct the cause of the excessive oil foaming, possible refrigerant floodback, refrigerant overcharge, or leaky valves.

516-4.1.13 CHECKING COMPRESSOR LUBRICATING OIL LEVEL. The actual effective lubricating oil level in the compressor crankcase is difficult to observe because of the indeterminate amount of refrigerant that may be mixed with the oil. The greater the amount of refrigerant in the mixture, the higher the apparent oil level will be. The amount of refrigerant in the mixture will be greater after a prolonged shutdown period. A check of the oil level after a prolonged shutdown is therefore worthless as far as determining the actual working oil level. Such a check will generally indicate a level higher than the normal oil level. If the oil level is within the range of the sight glass, it will be indicated by a distinct line on the inside surface of the glass. If no line is visible on the glass, the level may be above or below it.

516-4.1.13.1 An ideal time for checking the oil level is after a period of operation with the refrigerant suction pressure at or near the regulated cutout point of the low-pressure control switch; at this time, the least amount of refrigerant will be mixed with the oil. During operation, the refrigerant will be pumped out of the oil until only the normal quantity remains in solution. If fresh oil has been introduced into the compressor crankcase, the oil absorbs a small quantity of the refrigerant, and the oil level tends to rise in the crankcase. Follow specific instructions regarding the desired oil level for every design of compressor when these instructions are available in technical manuals furnished with the plant. Where no specific instructions are available, it is generally safe to consider that the proper oil level is from 1/4 to 3/4 up the sight glass when checked as outlined above.

516-4.1.13.2 Do not remove oil from the crankcase because of an apparent high level unless it is known that too much oil had been previously added or unless it is apparent that oil from the crankcase of one plant compressor has been inadvertently deposited in the crankcase of another. If the oil level as checked above is lower than its recommended height on the glass, add additional lubricating oil. Do not add more oil than is necessary to obtain the desired level. If oil needs to be added frequently in an attempt to maintain an oil level in the sight glass, something is wrong.

516-4.1.14 RECIPROCATING COMPRESSOR OIL QUALITY. To ensure the quality of the compressor oil, both a visual inspection and a spectrographic analysis should be performed. The visual inspection, which consists of carefully noting the color of the oil, should be performed whenever the oil level is checked. New oil is clear; when it begins to turn muddy brown or black, renew it. Discolored oil indicates adverse conditions inside the system piping and is generally caused by dirt or moisture. This foreign material might have been in the system at the time of installation and might never have been properly removed when the system was first started, or it might have entered the system during a service operation. If the condition is not corrected, some part of the system (usually compressor parts) may eventually fail. If the compressor discharge valve plate, valves, or other parts show a decided discoloration or dark sludge (commonly known as copper-plating), excessive moisture is indicated. Copper-plating appears as a copper-colored surface, normally on surfaces subject to high temperatures (discharge valves and valve parts, bearings, etc). Sludge may result, also, but it will be in the crankcase or oil passages, not necessarily where the copper-plating occurs.

516-4.1.14.1 If the results of the spectrographic oil analysis reveal high levels of copper, aluminum, or iron, the cause should be determined, as this is unusual in refrigerating compressor oil. The high metal levels can result from high acid levels. High acid levels are normally associated with moisture contamination of the refrigeration system. They can also result from inadequate refrigerant circuit cleaning or evacuation (dehydration) after fabri-

cation or after repairs or piping modifications. Also, wear in the piston or connecting rod area can contribute to high levels of aluminum or babbitt; high iron and copper levels are usually indicative of an acid attack. An accelerated increase in acid number may be attributed to high operating temperatures. Navy experience with similar equipment has established a threshold limit for metal content in oil at 26 parts per million (ppm) for copper, 30 ppm for aluminum, and 32 ppm for iron. The acid neutralization number, also known as Total Acid Number (TAN), should be around 0.05 for mineral oil and 0.20 for polyolester (POE) oil. At 0.10 for mineral oil and 0.30 for POE oil, corrective action should be taken.

516-4.1.14.2 Whenever the acid neutralization number reaches 0.10 for mineral oil and 0.30 for POE oil, or metal contamination of the oil reaches the threshold values indicated above, the refrigerant circuit should be thoroughly leak-tested, and all refrigerant leaks repaired. The compressor oil and all dehydrator cartridges should then be replaced. After 50 to 75 hours of operation, the oil should be resampled and the oil and dehydrator cartridges should be replaced again. If all the repairs cannot be accomplished at once, and the system has to be operated, oil and dehydrator cartridges should be changed on a weekly basis. Anytime an oil sample indicates a high aluminum or babbitt content, the compressor should be opened and inspected.

516-4.1.14.3 Check the condenser, water chiller, and oil cooler, if installed, for leakage of moisture into the refrigerant system. If leakage of moisture is from one of these heat exchangers, the best solution is to repair the leak; remove and discard the refrigerant, oil, filters, and dehydrators; evacuate and dehydrate the system; add new oil and refrigerant; and install new filters and dehydrators. Correct other moisture conditions by continued use of the liquid line dehydrator, renewing cartridges as often as necessary. Also renew the crankcase oil at frequent intervals until the moisture condition is cleared. When adding new oil to a compressor, use only oil made for refrigeration compressors. Never add automotive oil for diesel engines. Check the oil and container before adding, as rusty containers and oil containing water have occasionally been obtained from the supply system.

516-4.1.15 CONDENSER SEAWATER SUPPLY. In condenser operation, seawater leaks are one of the most serious problems operating personnel experience. The condenser may obtain its seawater supply either from a dedicated pump sized for the condenser, or from the fire main through a reducing valve. When using the fire main, operators do not consider that the fire-main pressure varies, that the reducing valve may not be properly adjusted or perhaps not functioning, or that the water regulating valve by-pass is open, and therein lies the problem. When the normal cooling supply fails, the operator will either manually open the cross-connection to the fire main or it will be done automatically if the design has this feature. In newer ships, pressure in the fire main may be substantially above the fire pump rated pressure because the fire pump may be operating at or near shut-off. The pressure-reducing valve should reduce the pressure to that required for the condenser.

516-4.1.15.1 Unfortunately, reducing valves in seawater service tend to malfunction or fail. A malfunction or failure results in higher pressures and, thus, greater than required seawater flow rates and attendant higher velocities. The condenser can withstand the higher pressure but not higher seawater flow rates and attendant velocity. This higher velocity results in accelerated erosion at the inlet of the condenser tubes. Experience has shown that, with high velocity, tube erosion occurs in the first 3 to 4 inches of tube inlet, and fairly rapid failure (within a matter of 2 to 6 months) allows seawater to enter and contaminate the refrigerant circuit. When water enters a refrigerant circuit, the refrigerant and water react to form hydrochloric acids. When a refrigerant system becomes contaminated with seawater, do not just secure the plant and leave it to be repaired some other time. At a minimum, secure the plant, flush with fresh water as soon as possible to remove the seawater, dehydrate with a vacuum pump to remove the residual moisture, and secure with a blanket of nitrogen. If the water and refrigerant are left in the plant for more than a day or two and the plant is not immediately flushed, cleaned, and dehydrated, the interior surfaces rust badly. Acid cleaning will most likely be required and, in severe cases, component removal to a shop is required for disassembly, cleaning, and repair.

516-4.1.15.2 Another problem associated with seawater supply to refrigeration air-conditioning condensers is debris, seaweed, shells, barnacles, and other trash entrained in seawater. Recognize that air-conditioning and refrigerated ship stores plants operate continuously for long periods of time at dockside, whereas other seawater heat exchangers are secured. At dockside all kinds of debris and trash are entrained in seawater not normally found when a ship is at sea. Additionally, many seawater circuits to air-conditioning condensers are not provided with strainers or, if a strainer is included, the mesh may be so large that practically all trash and debris enter the condenser. The foreign material then winds up collecting in heads and plugging condenser tubes. Condenser inspection reports have noted many cases of all kinds of debris found in condenser heads with plugged tubes and, in some cases, as many as 40 to 60 percent of tubes plugged with debris. The problem reveals that either maintenance is being neglected or that there is a shortage of personnel to perform proper maintenance. Eventually plugged tubes will cause tube leaks as operators, noting higher seawater outlet temperature and higher refrigerant pressure and temperature (indicating that the condenser is not functioning correctly), will most likely increase the seawater flow.

516-4.1.15.3 Increasing the water flow through the condenser will temporarily cure the symptoms of the problem, and the plant will continue to operate. However, the increased flow passes through tubes that are not blocked. The velocity and erosion in tubes that are not blocked or partially blocked increases rapidly and the tubes fail. Invariably, a partially blocked or severely restricted tube will be the first to fail. Operators should be aware that when a condenser is not functioning properly, but the water regulating valve is operating correctly and purging air from the condenser does not relieve the problem, condenser fouling should be suspected. Inspect and clean the condenser. Refer to the Planned Maintenance System (PMS). The PMS should require condenser seawater tube cleaning at least once a year.

516-4.1.16 CONDENSER OPERATING PRECAUTIONS (RECIPROCATING AND CENTRIFUGAL). For convenience, operating personnel sometimes line up the emergency cross-connection to the fire main as the normal water supply without realizing the end result. Since the equipment operates effectively, the operator tends to assume that no problem could occur. For the same reason, an operator does not feel any necessity to pursue repair of a malfunctioning pressure-reducing valve in a timely manner. Operating personnel are advised it is essential that the normal low-pressure seawater supply be maintained in operating order and used. Turn on the fire-main supply only in an emergency. Maintain air-conditioning seawater pumps, pressure-reducing valves, and water regulating valves and operate correctly. Install orifice plates when required by design of the seawater system. In some applications the pumps are not readily accessible to the air-conditioning plant they serve. However, maintain or repair the dedicated low-pressure seawater source to avoid erosion problems, as many more hours of maintenance time are required to repair a plant that has experienced tube failure because of erosion.

516-4.1.16.1 Proper Seawater Flow. The problem of unregulated excessive seawater flow can be illustrated by the experience of a ship supplying seawater from the fire main to an air-conditioning condenser. The fire-main pressure-reducing valve and air-conditioning water-regulating valve were both inoperative for over nine months because of lack of repair parts. The condenser had tube failures during this time and had been retubed. The newly retubed condenser, on inspection, showed pronounced erosion and was well on the way to a repeat of the tube leaks. Neither of the valves that controlled the water flow had been repaired. This type of experience can be avoided only by controlling seawater flow rate with a properly operating, reducing and regulating valve. In operating any refrigeration plant, either air-conditioning or ship stores, operating personnel should be aware of the following precautions in paragraphs [516-4.1.16.2](#) through [516-4.1.16.8](#) concerning condenser operation.

516-4.1.16.2 Emergency Seawater Cooling. In an emergency where it is necessary to provide seawater cooling from the fire main, carefully monitor the flow to prevent excessive velocity through the tubes and avoid the erosion noted above. If reducing or regulating valves are not operating properly, carefully control seawater flow

manually. This can be done using a globe stop valve to throttle seawater flow in the water circuit. Since no flow-measuring devices are included, it is impossible to determine how much to throttle the valve, particularly with varying fire-main pressure. In such a situation, however, ensure that the condenser is purged of noncondensable gases, and manually throttle a supply seawater globe valve to obtain approximately 25- to 35-psi seawater pressure to the condenser. Maintain proper condensing pressures and temperatures until normal cooling water supply is restored.

516-4.1.16.3 Condenser Tube Blockage. It is common knowledge that most of the debris that plugs the condenser tubes is picked up dock side. Since refrigeration equipment is usually on the line continuously, these units experience plugged tubes. If the ship spends extended time dockside, frequently inspect the strainer and condenser and clean if necessary. Do not operate with a damaged or missing strainer basket. Do not operate a partially plugged condenser. This will lead to big problems later as noted previously. Clean a condenser if more than 10 percent of the tubes in any one pass are plugged. For condenser maintenance see paragraph [516-8.2.20](#) and **NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors** .

516-4.1.16.4 Condenser Tube Inserts. Tube velocity causes erosion in the first 3 to 4 inches of the tube inlet in a scattered tube pattern. Monitored tests after the installation of nylon tube inserts have indicated that the inserts will extend tube life. Although operating personnel shall be vigilant in preventing excessive seawater velocity through the condenser tubes, nylon tube inserts will protect the inlet area from erosion. Some shipyards have installed short tube inserts, 2-3/8 inch long. These are unsatisfactory. Remove these short tube inserts and install the correct ones. The installation of nylon inserts is discussed in paragraph [516-8.2.25](#).

516-4.1.16.5 Condenser Zincs and Tube Material. Two other factors considered in resolving the corrosion or erosion problem in refrigeration condensers are tube material and condenser zincs. Present tubes are made from 90:10 or 70:30 copper-nickel alloy, depending on the application. While 90:10 copper-nickel provides satisfactory service in seawater, experience indicates that 70:30 copper-nickel resists erosion better. It is anticipated that all new future air-conditioning condensers will have 70:30 copper-nickel condenser tubes. Zincs were removed and eliminated from condensers many years ago because they were considered unnecessary when condensers were fabricated from specified materials. It appears, however, that the corrosion or erosion problem may be less severe where zincs are installed. Reinstall zincs in refrigeration condenser heads where heads include provisions for them. Where provisions for zincs are not included in heads, request a ship alteration to add the zincs. The requirement for zincs is discussed in **NSTM Chapter 254** . Although surface ship air-conditioning plant condensers are experiencing condenser tube erosion or corrosion and leakage, rarely does it occur in submarines. Submarine condensers have dedicated seawater pumps, no fire-main connection, use 70:30 copper-nickel tubes, and have zincs installed in condenser heads.

516-4.1.16.6 Pump Impeller Replacement. On some ships that have installed a replacement impeller in an existing seawater pump to supply seawater cooling to a refrigerant condenser, the pump produced a higher flow than the original flow. Operating and maintenance personnel shall be made aware that where an impeller is applicable to a pump with a series of flow rates, only the largest impeller diameter is usually stocked with the intent that for lower flow rates, the impeller diameter would be machined down. Repair personnel, however, are not aware of this and install the oversized impeller they receive. There is usually no indication on the impeller part that it is to be machined for a desired flow rate that is lower than the maximum. On operation, the oversized impeller will produce higher than design flow rates. When replacement impellers are requisitioned, personnel shall carefully check the replacement impeller part with the actual pump requirement in the technical manual to ensure that design flow rates will be maintained.

516-4.1.16.7 Condenser Tube Leak. When a tube leak is found, drain the condenser of water and immediately isolate it from the rest of the refrigeration system. Since the refrigerant pressure is higher than the water pressure under normal conditions, if a tube leak is found early enough, it is possible that no water has entered the refrigerant system (except R-11 and R-114 plants). In that case, for R-12 or R-134a plants, the tube may be plugged and the system placed in operation if no indication of moisture is present (see paragraphs [516-4.1.7](#) and [516-4.1.14](#)). These condensers are adequately sized so that approximately 10 percent of the total number of tubes can be plugged without any deterioration of capacity. For velocity considerations, however, the number of tubes plugged in any pass shall not exceed 10 percent of the number of tubes in that pass.

516-4.1.16.8 System Cleaning After Tube Leak. Where a tube leak has occurred and the refrigerant system has been contaminated with seawater, drain the complete refrigerant circuit immediately. If compressor oil indicates water is present, discard oil and replace with new oil. If repairs are delayed, charge and maintain with a blanket of nitrogen to prevent corrosion until repairs are started. To restore a refrigerant plant contaminated with seawater, proceed as follows:

1. Repair or plug the seawater tube leak or seawater leak source; ensure that all leak sources have been found through a refrigerant pressure test.
2. After draining and blowing out any residual seawater, remove all filters, dehydrators, and strainers, and flush the refrigerant circuit with fresh water from compressor suction connection, through the system, to compressor discharge connection. Continue flushing until all evidence of chloride has been removed. If a pump cannot be used, fill and drain the system with fresh water at least three times and blow out residual moisture with nitrogen.
3. Disassemble and clean compressor parts, automatic controls, and strainers. Replace dehydrator cartridges and oil filters.
4. Completely test the system for leaks (refer to paragraphs [516-1.10.7](#) through [516-1.10.7.11](#)).
5. Evacuate and dehydrate the system (paragraph [516-8.2.17](#)).
6. When all leaks have been repaired and the system is dehydrated, charge the system with clean, dry refrigerant, and charge the compressor with new oil. Renew all filters, dehydrators, and moisture indicators.

516-4.1.17 NONCONDENSABLE GASES. In operating refrigeration condensers, operating personnel should be able to recognize and correct the following problems described in paragraphs [516-4.1.17.1](#) through [516-4.1.17.4](#).

516-4.1.17.1 Noncondensable Gases in System. Air and noncondensable gases, if present in the system, are pumped throughout the system and discharged by the compressor into the condenser. These gases are trapped in the condenser by the liquid seal maintained over the receiver outlet. They are usually lighter than the relatively dense refrigerant vapor and tend to collect in the upper part of the condenser when the compressor is stopped. The purge valve for discharging these gases to the atmosphere is located in the upper part of the condenser shell or in the compressor discharge line above the condenser. While the machine is operating, these noncondensable gases are intimately mixed with the refrigerant vapor because of the turbulence produced by the rapid and pulsating discharge of the refrigerant into the condenser. It is therefore inadvisable to try to purge noncondensable gases from the system while the compressor is operating. Noncondensable gases in a condenser cause excessive condensing pressures with resulting inefficiency and should never be allowed to remain in the system. It can be seen from [Table 516-1-1](#), [Table 516-1-4](#), [Table 516-1-5](#), and [Table 516-1-6](#) that the condensing pressure of refrigerants vary directly with the temperature. As the proportion of noncondensable gases in the condenser

increases, the difference between the condensing temperature of the contaminated refrigerant and the condensing temperature of pure refrigerant increases, because of the partial pressure exerted by the air and noncondensable gases.

516-4.1.17.2 Checking for Noncondensable Gases. To check the condenser for the presence of air or noncondensable gases, it is essential that gauges and thermometers be accurate and that the system have sufficient refrigerant charge for the liquid refrigerant present in the receiver to seal the liquid line connection. To check for noncondensable gases proceed as follows:

1. Close the liquid line valve down stream of the receiver.
2. When the compressor shuts off on the L.P. switch, stop the compressor by pressing and releasing the STOP pushbutton. Close the condenser-receiver equalizing line valve, and the compressor suction and discharge service valves.
3. Determine the actual condensing temperature. Install a service gauge in the compressor discharge connection where a discharge pressure gauge is not already provided. An approximation of the actual condensing temperature will be reached when no further decrease is noted in the discharge pressure. The reduction in pressure can be accelerated in water-cooled condensers by permitting circulation of condenser water. Open the water-regulating valve bypass valve or operate the manual stem to ensure constant water flow through the condenser. Observe the readings on the condenser cooling water inlet and outlet thermometers. When there is no longer any difference in inlet and outlet temperatures, observe the reading on the discharge pressure gauge. If the pressure in the condenser is 10 psi or more above the refrigerant saturation pressure corresponding to the condenser water temperature (refer to [Table 516-1-1](#), [Table 516-1-4](#), [Table 516-1-5](#), or [Table 516-1-6](#)), purge the condenser by performing paragraphs 516-4.1.17.3 steps 1 through 6. If the saturation pressure is less than 10 psi above the refrigerant saturation pressure, return the system to normal operation by performing paragraphs 516-4.1.17.3 steps 4, 5, and 6. The thermometer in the liquid line at the receiver provided on most vessels will then indicate the actual condensing temperature. If a thermometer is not installed place one near the condenser to record the ambient temperature at that location. When the pressure and temperature of the air-cooled condenser have lowered to the ambient temperature, the thermometer will read the approximate actual condensing temperature. Read the condensing temperature that corresponds to the condensing pressure registered by the high-pressure gauge. It is the condensing temperature of pure refrigerant at this pressure. Subtract the existing condensing temperature from the condensing temperature of pure refrigerant at the existing condenser pressure. If the difference between these two temperatures is more than 5° F, it is necessary to purge.

516-4.1.17.3 Purging Criteria and Procedures for Reciprocating Plants. Purging is the process of removing air and other noncondensable gases from the refrigerant system. Noncondensable gases can inhibit system performance by artificially raising vapor pressures of the condenser refrigerant. High discharge pressure can be a sign that purging is necessary. However, high head pressures can also be caused by insufficient condenser water flow, clogged condenser tubes, or a clogged water strainer. Additionally, the effects of noncondensables can be masked by too much condenser water (seawater) flow or a too low condenser water temperature. Air or other noncondensable gases can enter the refrigeration plant only if a leak is present and the machine has been run in a vacuum or if the system was not properly evacuated after service. Purging may be necessary if the discharge pressure rises above the specified range and adjusting the water-regulating valve does not reduce pressure to normal. Check for the presence of air or other noncondensable gases as follows:

WARNING

Check space ventilation. Do not breathe refrigerant: it can cause asphyxiation.

1. Slowly open purge valve connected to top of condenser 1/4 to 1/2 turn and allow gas to blow for a few seconds. Purge slowly to keep refrigerant loss to a minimum. The necessity for further purging shall be determined on the basis of compressor discharge pressures. Purging noncondensable gases such as air causes compressor discharge pressure to drop.
2. Observe the discharge gauge after each opening of the purge valve. Repeat purging until there is no further pressure drop or until the pressure comparison test no longer indicates the presence of noncondensable gases.
3. Avoid unnecessary waste of refrigerant. If the pressure comparison test does indicate that no purging is necessary, but running discharge pressure is still high, make sure the seawater lineup is correct, clean seawater strainers, inspect tubes for blockage through zinc holes; or remove heads, drain condenser, remove water heads, and clean tubes as required.

Table 516-4-3. BOILING POINT OF WATER AT VARIOUS PRESSURES

System Pressures Above Atmospheric				
	Absolute			
Psig	Psia	Millimeters of Mercury (Hg)	Microns (Hg)	Boiling Temperature of Water (° F)
250	264.7			
200	314.7			
100	114.7			
0	14.696	760	760,000	212
System Pressures Below Atmospheric				
	Absolute			
Inches of Mercury (Hg)	Psia	Millimeters of Mercury (Hg)	Microns (Hg)	Boiling Temperature of Water ° F
10.14	9.629	500	500,000	192
22.05	3.865	200	200,000	151
25.98	1.935	100	100,000	124
27.95	0.968	50	50,000	101
28.94	0.481	25	25,000	78
29.53	0.192	10	10,000	52
29.72	0.099	5	5,000	35*
29.842	0.039	2	2,000	15
29.882	0.019	1.0	1,000	+1
29.901	0.010	0.5	500	-11

Table 516-4-3. BOILING POINT OF WATER AT VARIOUS PRESSURES -

Continued

29.917	0.002	0.1	100	-38
29.919	0.001	0.05	50	-50
29.9206	0.0002	0.01	10	-70
29.921	0	0	0	
*Recommended field evaluation conditions (water freezes @ 32° F). Standard atmosphere = 14,696 psia = atmospheric pressure at sea level = 760-mm Hg absolute pressure at 32° F = 29.921-inches Hg. Notes: psig = lb per sq in. gauge = pressure above atmosphere psia = lb per sq in. absolute = sum of gauge plus atmospheric pressure Hg = Mercury				

4. Close the water-regulating bypass valve and, if installed, return the manual override stem so the valve functions automatically.
5. Open the condenser-receiver equalizing valve and the compressor discharge service valve.
6. Restart the compressor and slowly open the compressor suction service valve.

516-4.1.17.4 Checking Water-Cooled Condenser Performance. An overall check of water-cooled condenser performance may be used to check the condition of the condensing surface after, and only after, the condenser has been properly purged. To check overall condenser performance, proceed as follows:

1. Make preliminary preparations of the system as explained in paragraph [516-4.1.17.2](#).
2. Read the condensing temperature that corresponds to the pressure in the condenser, while the compressor is operating.
3. Read the temperature of the water leaving the condenser.
4. Subtract the temperature of the water leaving the condenser from the condensing temperature obtained in step 2. The temperature of the water leaving the condenser will be several degrees below the condensing temperature of pure refrigerant. This temperature difference is affected by the amount of condensing surface per ton of refrigeration, the condition of the condensing surface, and the presence of noncondensable gases. Therefore, record the condenser performance under varying heat load and circulating water temperature conditions when the condenser is known to be clean and free of noncondensable gases. Use the recorded results as a measure of comparison for good performance under similar service operating conditions. The suction pressure is a measure of the heat load on the compressor.
5. When the temperature differences between the outlet circulating water and the temperature corresponding to the condensing-pressure increase by 5° to 10° F above the temperature difference obtained when the condenser was in good condition and operating under similar heat load and circulating water conditions, the water side of the condenser should be cleaned (paragraph [516-8.2.21](#)) if the increase was not caused by noncondensable gases or excessive refrigerant charge.

516-4.1.17.5 Operation of Reciprocating Air-Conditioning Plants with 95° F Seawater. Navy R-12 and R-134a reciprocating air-conditioning and refrigeration plants are designed for 85° F seawater. However, the Navy mili-

tary specification requires the condensers and motors to be oversized so that the system will not be overloaded during pull-down operation. The following discussion is for reciprocating air-conditioning plants in general. Refer to the applicable technical manual for specifics.

1. Oversized components will allow these plants to operate in 95° F seawater.
2. When operating at higher temperatures, the condenser water-regulating valve will open to allow more water through the condenser.
3. At full load with maximum design seawater flow [6 feet per second (fps) through the tubes] entering at 95° F, the condensing temperature will probably rise between 5° and 10° F above readings with 85° F seawater.
4. When fully loaded, the compressor discharge pressure, which is normally 125 psig, may rise to 145 psig. This will result in a new system balance point, with an increase in suction and evaporating pressure and temperature. This will increase the leaving chilled water temperature in air-conditioning plants.
5. Higher than expected discharge temperatures can be caused by noncondensable gases and air in the refrigeration system. If noncondensable gases and air are suspected, secure the plant and purge the system in accordance with the plant technical manual.

516-4.1.17.6 Condenser Problems. Degradation of plant performance and an increase in chilled water temperature can be minimized by maintaining the condenser in a clean condition according to the following information:

- a. The volume (gallons per minute) of water flowing through a condenser determines the water velocity in the tubes. Seawater-cooled air-conditioning and refrigeration condensers are designed for velocities of 6 fps. This is a conservative value, selected to protect the condenser tube inlet regions. The flow of water is most turbulent in the tube inlet because of the change in flow pattern. Even though the overall tube velocity is 6 fps, erosion occurs at the tube inlets, where damage is limited to the first 4 to 5 inches. To protect this area, nylon and metallic tube inserts have been installed. Both types of inserts have been effective in this application. Under controlled circumstances, average tube velocities of up to 7.5 fps can be maintained without causing accelerated erosion in the tubes. When operating with seawater flows above design, the main concern is condenser tube fouling. A few partially obstructed tubes will force the remaining clear tubes to pass more water at a higher velocity. Unless corrected, accelerated flow will damage the clear tubes, while partially obstructed tubes will also be damaged because of crevices, localized eddies, and cavitation formed by the obstruction. The condenser flow will appear to be adequate, but because of fouling, the tubes will be eroding.
- b. In warm seawater, increasing the seawater flow rate beyond design helps correct higher than normal compressor discharge pressures. This shall not be done to compensate for condenser fouling. It may be done occasionally, when the condenser is known to be entirely clean, and all other plant parameters discussed above are known to be operating correctly. This is the last technique to try to force the plant to carry a heavy load. Overlooking the requirement that the condenser be entirely clean will result in failed condenser tubes.
- c. A condenser tube leak can put the plant out of commission for 6 weeks to 9 months, depending on the corrective action required.
- d. If a water-regulating valve (WRV) is suspected of malfunctioning and it is equipped with a manual actuator, open the valve for full flow through the condenser in accordance with the WRV drawing in the plant technical manual. Do not open the WRV bypass valve. Clean the pilot control section of the WRV whenever the condenser is secured for cleaning or when the WRV is malfunctioning. If a problem still exists, it is not with the WRV. Look elsewhere for the cause, such as air or other noncondensable gases in the refrigerant circuit or insufficient seawater flow due to a clogged seawater strainer or a fouled condenser. Refer to the equipment

technical manual or paragraph 516-4.1.17 for testing for noncondensable gases. If ever the WRV is by-passed, the plant shall be monitored closely to avoid excessive water flow through the condenser. Repair or replace the WRV as soon as possible.

- e. If condenser fouling from silt is suspected, vent the seawater side of the condenser and flush it by ensuring that seawater inlet and outlet valves are open full. Also, open the WRV bypass full for maximum flow for 5 minutes; this will flush out the silt. Then, close the WRV bypass valve. If the symptoms continue with the silt flushed out, the problem is elsewhere.
- f. Keep the seawater strainer baskets clean to allow unrestricted flow. Also keep the seawater side of the condensers clean. If fouling is still suspected, secure the plant and drain seawater from the condenser. Follow the procedure for the PMS quarterly condenser inspection. Use a fiber optic borescope to look through the zinc anode plug openings. Check the inlet end of each condenser pass for plugged tubes and debris. If tube or tube sheets cannot be inspected without removing the heads, remove the condenser heads. Marine growth and debris shall be removed from the tube sheets and heads so flow is not restricted.
- g. Once the condenser is clean and free of noncondensable gases, verify proper condenser seawater flow. With a high seawater temperature, sufficient flow is mandatory before plant capacity can be maximized. Despite the lack of a flow measuring device, seawater flow can be deduced by carefully reviewing the plant instrumentation and log sheets. The plant shall be fully loaded before the automatic seawater flow-regulating valve will provide full flow. The plant technical manual defines full-load conditions. Full seawater flow is indicated by the seawater differential temperature across the condenser and the refrigerant condensing temperature and pressure. These shall be compared with equivalent temperatures and pressures of the plant or sister plants on the ship operating under equivalent conditions. The seawater differential temperature will be similar to that at operation at design seawater temperature. If the seawater differential temperature is greater, insufficient seawater flow is likely. The refrigerant temperatures and pressure will be higher than normal because of the high seawater temperature. Thus, log sheet data from a plant operating with cooler seawater cannot be used as a basis for comparison.
- h. Most of the heat transfer characteristics of the condenser are fixed by the design. Two factors that change over time are seawater-side fouling and the accumulation of noncondensable gases in the condenser shell. Because the effect of noncondensable gases and fouling on machine operation is very much the same, the machine should always be purged first to eliminate the effect of noncondensable gases when troubleshooting the cause of high pressures and reduced performance.

516-4.1.18 COOLING COILS. Regularly inspect and clean gravity or forced circulation cooling coils as required. Where coils are subject to ice formation, such as in refrigerated ship stores, defrost the cooling coils as often as necessary to maintain the effectiveness of the cooling surface. Inspect the expansion valve bulb attached to the outlet of the cooling coil to ensure that it is properly fastened to the outlet tubing and insulated from the ambient temperature.

516-4.1.19 COOLING COIL DEFROSTING. Regularly inspect coils for frost accumulation. The maximum permissible time interval between defrosting operations depends on many factors such as refrigerant evaporating temperature, free moisture content of supplies placed in the refrigerated space, temperature of refrigerated spaces, frequency of opening of cold storage compartment doors, and atmospheric humidity. It is good practice to defrost gravity cooling coils before the average frost thickness reaches 3/16 inch in the average cold storage refrigerating plant installation. This rule is only approximate, however, and in some cases the frost layer may become appreciably thicker without seriously interfering with plant operation. In other cases it may be necessary to defrost more often to maintain satisfactory operation of the plant and proper compartment temperature, particularly when operating in the tropics.

516-4.1.19.1 Where finned coils are installed that use forced-air circulation, frequently inspect for frost so that defrosting can be started before airflow is restricted by frost and air quantities passing through the coil are reduced or closed off. In refrigeration compartments where the temperature is maintained above 32°F, coils will defrost on the off-cycle. However, to defrost the coils otherwise, shut off the liquid supply stop valve ahead of the expansion valve. The frost will melt off the coils or may be easily brushed off. Take care not to injure the evaporator coil by scraping surfaces when defrosting. When the frost has melted, open the refrigerant liquid supply stop valve to resume operation.

516-4.1.20 HOT GAS DEFROSTING. Many refrigerating plant installations are provided with hot gas defrosting lines to facilitate defrosting where compartment temperatures are below 32°F. A hot gas refrigerant line is arranged between the discharge line of the compressor and the suction line at the cooling coil to be defrosted. The defrosting procedure can best be described using [Figure 516-4-2](#) as an example of a typical installation. While [Figure 516-4-2](#) and the following explanation apply to a typical shipboard installation, always follow the detailed instructions provided for the refrigeration plant in the equipment technical manual or operating chart when using the hot gas defrosting lines.

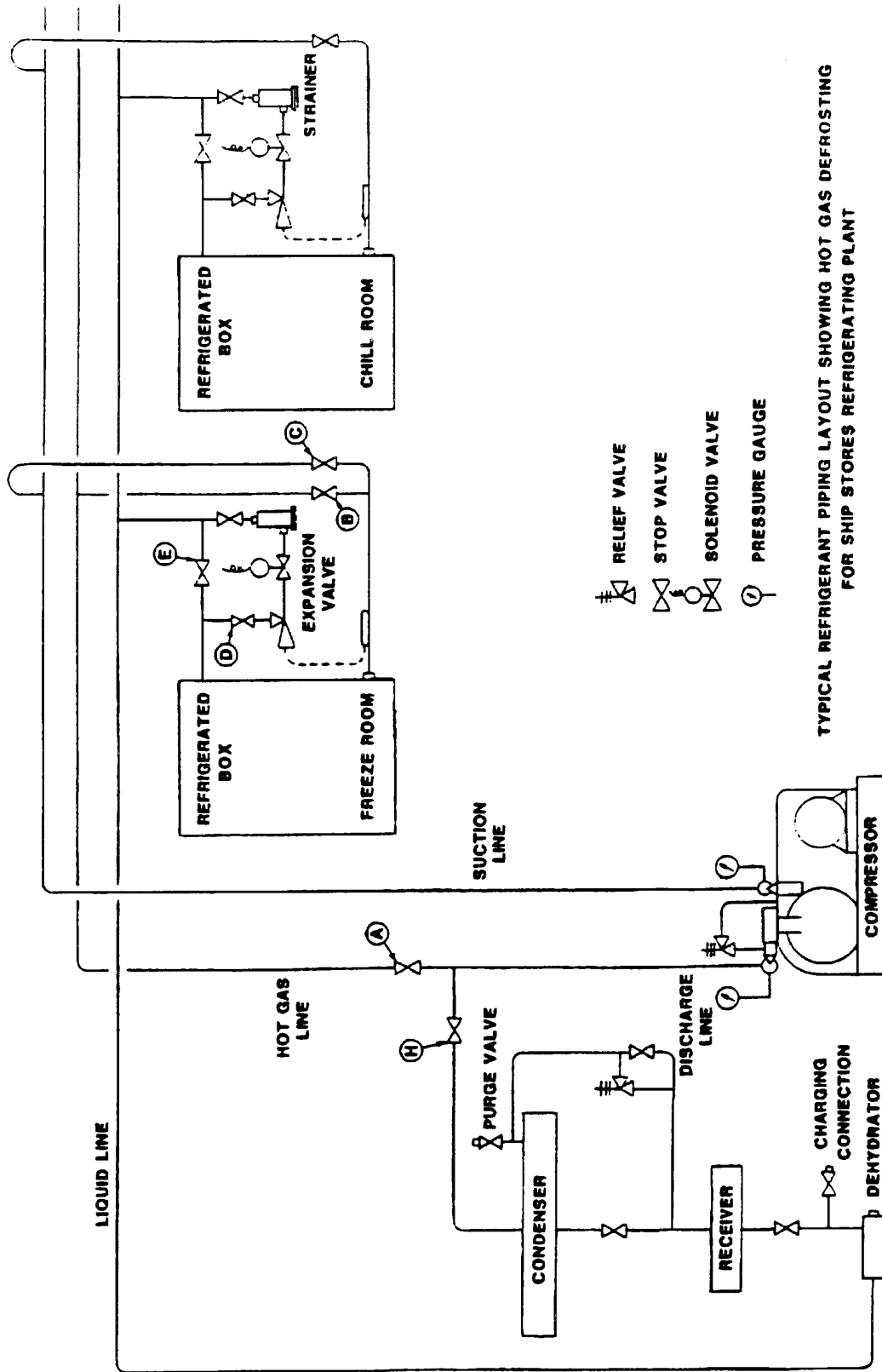


Figure 516-4-2. Hot Gas Defrosting

516-4.1.20.1 When it is desirable to defrost the freeze room coils, the normal refrigerant liquid supply valve (valve D) to the evaporator and the suction return line valve (valve C) from the cooling coil are closed. The valves in the hot gas supply line (valves A and B) are then opened, and compressed refrigerant hot gas is admitted to the coil. This gas is condensed in coils during defrosting. This condensed refrigerant liquid in the freeze compartment coil is subsequently returned to the liquid supply line, after which any or all other cooling coils or compartments may use it through their regular thermal expansion valves. The specific overall procedure is as follows:

1. Close the liquid cutout valve (valve D) at the outlet of the thermal expansion valve.
2. Close the freeze room evaporator coil return valve (valve C) after allowing sufficient time to pump out the coil.
3. Shut off the circulating fans within the freeze compartment.
4. Energize electric heating cable on the defrost water drain piping and in the drain troughs. Drain piping within the compartments should be wrapped for its entire length with enough turns of cable to provide approximately 125 Btu/hr (37 watts) per linear foot of pipe. The maximum temperature of the cable should not exceed 145°F (gradient plus ambient temperature). All cable-wrapped pipe should be insulated as specified in MIL-STD-769. Drip troughs have heating cables installed lengthwise inside the trough on the bottom to provide approximately 95 Btu/hr (28 watts) per linear foot of single drip trough (troughs under single cooling coils) and 135 Btu/hr (40 watts) per linear foot of double troughs.
5. Open the hot gas defrosting valve (valve B) at the freeze room coil.
6. Slowly open the hot gas defrosting valve (valve A) at the compressor, and throttle the condenser refrigerant inlet valve (valve H).
7. Open the hand expansion (bypass) valve (valve E) on the freeze room, liquid control, thermal expansion valve assembly to permit condensed liquid to return to the liquid line for use in an adjacent compartment. If these compartment temperatures are satisfied, then open the doors to induce a refrigeration load.
8. The operator at the compressor shall maintain about 135 psi for R-12 on the compressor discharge gauge. This is done by throttling the condenser refrigerant inlet valve (valve H) mentioned in step 6 above. For other refrigerants, consult the manufacturer's technical manual for the correct pressure.

516-4.1.20.2 The cooling coil will be completely defrosted when the hand expansion valve (valve E) becomes warm and a hissing sound is heard, indicating that gas is passing through the valve. To return the system to normal operation proceed as follows:

1. Close the hand expansion valve (valve E).
2. Close the hot gas valve at the freeze room coil (valve B).
3. Slowly open the suction return valve on the freeze room coil valve (valve C). Slowly open this valve to prevent any liquid trapped in the coil from entering the suction line.
4. Close the hot gas valve at the compressor (valve A).
5. Start air-circulating fans in the freeze room.
6. Open the cutout valve (valve D) at the outlet of the thermal expansion valve for the defrosted coil to return to automatic operation.
7. Open the hot gas valve (valve B) at the coil suction line to the compressor long enough to empty out the hot gas line.

8. Open the throttled condenser refrigerant inlet valve (valve H) to return to normal condensing pressure.
9. Deenergize electric heating cables.

516-4.1.21 **HOT SEAWATER DEFROSTING.** Most cargo refrigeration plants have forced convection evaporators with a hot seawater defrosting system. Where technical manuals are provided for these systems, follow the specific defrosting procedures outlined in those manuals. In the absence of specific instructions, use the following general procedures:

1. Position appropriate valves to provide steam to seawater heater.
2. When defrost seawater temperature is adequate for defrosting, shut off evaporator (cooling coil) fans. This should also shut the solenoid valve in the refrigerant supply.
3. Energize electric heating cables on defrost water drain piping and open any drain piping valves.
4. Open appropriate valves to provide hot defrost water to the cooling coil spray nozzles.
5. When all frost has been removed from coils, shut off hot seawater supply to coils and shut off steam to water heater. Drain piping as appropriate.
6. Blow out the residual defrost water from the cooling coil supply piping.
7. Reenergize evaporator (cooling coil) fans.
8. Deenergize the drain piping heating cable.

516-4.1.22 **ELECTRIC DEFROST.** Forced air unit cooler systems with electric defrost are designed for any low temperature duty. The forced air unit cooler has closely spaced fins on the evaporator to increase heat transfer. As frost accumulates, the heat transfer rate and flow of air across the cooling coil decrease. The cooling coil should be defrosted frequently so the frost does not block the airflow between the fins. The electric heaters defrost the coil quickly if the frost accumulation is not too thick. Excessive frost and ice build up is usually an indication of insufficient defrosting. Either there are not enough defrost cycles per 24 hours, or the defrost cycle is being terminated by the defrost controller timing relay instead of by the defrost termination thermostat. In either case, after resetting the controls, the unit cooler can be manually cycled through additional defrost cycles to remove the excess frost and ice. If this effort fails, the frost and ice build up will have to be manually removed. Use of a heat gun is preferred, but carefully scraping the coil may be necessary. There are other factors that can contribute to unusual frost and ice on the cooling coils, such as insufficient refrigerant charge, incorrectly set or clogged refrigerant controls or incorrectly set compressor controls. Refer to the troubleshooting guide, [Figure 516-4-7](#).

516-4.1.22.1 Defrosting is accomplished automatically. The operator sets the number of cycles on the defrost controller 24 hour timer and the duration of the defrost cycle on the defrost controller timing relay. Pins should be installed in the defrost controller 24 hour timer so that the coil undergoes 6 defrost cycles per day, or more than 6 cycles if experience determines it to be required to control excessive frost build-up.

516-4.1.22.2 The defrost cycle is terminated automatically by a thermostat which senses coil surface temperature. Once the frost is melted, the coil temperature starts to rise. The thermostat stops the defrost cycle when the coil temperature is about 40 degrees F. The unit cooler has controls to stop the fans and the flow of refrigerant to the unit cooler during defrosting periods. As originally configured on some unit coolers, when the defrost cycle is terminated, the fans will not restart until the coil temperature falls below the set point of the termination thermostat. However, the refrigerant control solenoid valve will open if the room thermostat is calling for cooling. Without the fans operating, the refrigerant flowing through the coil may not evaporate and a liquid floodback

situation might develop. Units on which the fans do not start until the defrost termination thermostat falls below its set point should be rewired so that the fans will start immediately. If the thermostatic termination does not occur before a preset time period, the defrost cycle is automatically terminated by a time termination relay that is adjustable from 2 to 120 minutes, in two minute increments. The preset time period is required to terminate the defrost cycle in case the thermostatic termination fails. The length of the time period should be set at 14-16 minutes so that normal thermostatic termination will not be overridden.

516-4.1.22.3 In addition, there is a high temperature safety thermostat that is set at 90°F in case of failure of the temperature and time termination features. The safety thermostat also lights up a "HI Temp" pilot light to indicate that a high temperature condition has occurred. A manual reset pushbutton is provided to reset the defrost circuit after the high temperature condition has cleared (the "HI Temp" thermostat has fallen below the set point).

516-4.1.22.4 On some unit coolers, power to the drain line heaters comes from the defrost timer. This arrangement puts the electrical load of the drain line heater on the control transformer, for which it is not designed. In addition, this arrangement does not allow sufficient time to defrost the drain line, and has created ice back-up problems. Where the drain line heater are energized by the unit cooler control transformer, and/or they do not operator continuously, the drain line heaters should be rewired to be powered from an independent 120 volt power source controlled by a relay that is energized when power is supplied to any of the refrigeration plant motor controllers, which will supply power to the drain line heater any time the plant is in operation.

516-4.1.23 WATER CHILLER OPERATION. For air-conditioning and other processes requiring liquid (water) chilling, in the reciprocating compressor systems the evaporator or cooling coils usually take the form of a shell and tube-type water chiller (see [Figure 516-3-132](#)). The liquid chiller is similar in construction to a refrigerant condenser. However, if a leak is suspected in the chiller, the leak-testing procedures for water chillers are complicated by the fact that water chillers have chilled water on the shell side and refrigerant on the tube side. This is the reverse of the condenser arrangement, where the seawater is on the tube side and the refrigerant is on the shell side. The leak-testing procedure is made more difficult by the fact that the tube or refrigerant side of the chiller has to be opened to observe the tube sheets and tubes. Therefore, refrigerant leak detectors cannot be used to determine the exact location of leaks as can be done with the condenser, where tubes and tube sheets can be observed with the shell or refrigerant side of the system intact and under pressure.

516-4.1.24 WATER CHILLER LEAK TESTING PROCEDURES. Procedures required for determining if water chiller leaks are present, and then determining the locations of these leaks, are described in the following paragraphs. Test the water chiller for leaks on a regular basis (see equipment technical manual) or whenever a chiller leak is suspected because of refrigerant loss or fresh water contamination of the refrigerant system or compressor crankcase. Several methods of chiller leak testing are used; the first of these is preferred because it requires neither the chilled water nor the refrigerant systems to be opened.

516-4.1.24.1 The water chiller can be tested for leaks without opening the chilled water or refrigerant side by securing the plant and valving off the chiller shell. If a pressure gauge is not already provided on the shell, temporarily install one to indicate the shell chilled water pressure. Then allow the refrigerant high-side and low-side pressure to equalize, which will place the refrigerant in the tubes under a higher pressure than the chilled water in the shell. A leak in the chiller will then be evidenced by an increase in the shell chilled water pressure, which can be noted by observing the chiller shell pressure gauge.

516-4.1.24.2 Another method of testing for chiller leaks is to secure the plant and valve off the chiller shell. Drain the chilled water in the shell; the chiller can then be tested for leaks by inserting the exploring tube of a

halide or electronic leak detector into the shell through the drain valve. A refrigerant leak is indicated by the presence of gas in the shell. If the leak is small, allow some time for the refrigerant gas to collect in the shell before inserting the leak detector exploring tube.

516-4.1.25 LOCATION OF LEAKS. Once the presence of a leak has been determined by one of the above methods, the next step is to locate the leak. The exact locations of leaks can be determined by one of the following methods:

- a. Pump down and secure the refrigerant system. Break the refrigerant inlet and outlet connections to the chiller with the ends of the piping connections plugged to prevent the entry of air, dirt, or lint into the refrigerant system. Remove chiller heads and any partition plates and gaskets to expose tube sheets and tube ends. Leave the chilled water side of the system intact and under pressure. Any leaks will be easily located by chilled water seepage or spray in the area of the leak. Mark any leaks found for later identification and repair. After thoroughly checking for leaks, repair all leaks discovered and marked. Leaking tubes can be plugged or replaced, and leaks between tube sheets and the tubes can be repaired by rerolling, or if necessary, by replacing the tube.
- b. For larger leaks, the leak-locating method described above is satisfactory. For smaller leaks, however, it is possible for the leak to pass refrigerant, but not chilled water, so that the leak-locating method described above will not work. For locating smaller leaks, a more complicated procedure is required. Pump down and secure the refrigerant system, and break and remove the refrigerant inlet and outlet connections from the chiller as described above. Remove chiller heads, and any partition plates and gaskets, to expose tube sheets and tube ends. Then valve off the shell side and drain the chilled water from the chiller shell. Connect a refrigerant cylinder to the chiller shell and charge the shell with 10 psig of refrigerant gas. Disconnect the refrigerant cylinder and connect a dry nitrogen cylinder, with a regulator and relief valve, to the chiller shell. Take care to prevent overpressurizing the chiller shell. Pressurize the shell to a pressure no higher than 100 psig. Leaks can then be detected by following the condenser leak-locating procedures described under condenser leak testing (see paragraph [516-8.2.23](#)). Mark any leaks found for later identification and repair. Disconnect the nitrogen cylinder. After thoroughly checking for leaks, repair all leaks discovered and marked. Leaking tubes can be plugged or replaced, and leaks between the tube sheets and the tubes can be repaired by rerolling, or if necessary, by replacing the tube. Chiller tubes usually have special inserts to insignificantly increase the heat transfer rate between the refrigerant and the water. Do not replace chiller tubes having inserts with tubes that do not have them.

516-4.1.26 CHILLED WATER SYSTEM (RECIPROCATING AND CENTRIFUGAL). Although the chilled water system is not in the refrigerant circuit, the system, its function and components, are of importance in providing satisfactory cooling to various compartments. The chilled water system for both reciprocating and centrifugal plants is arranged the same. The system consists of a pump, cooling coils, expansion tank, chiller venturi meters, and piping valves and controls in a closed loop. Where more than one chilled water air-conditioning plant is installed, the chilled water system is cross-connected. Operating personnel should become familiar with the system to ensure that the chilled water is properly distributed to the various branches and coils. To help an operator operate and line up the system, provide and mount a laminated plastic operating chart in the machinery room next to the chiller. With a diagrammatic chart the operator can be sure that all coils have flow and the chilled water returns to the chiller as it should. In some cases, operating personnel are unfamiliar with the function of two components in the chilled water system, the venturi meters and the expansion tank.

516-4.1.26.1 Venturi Meter. The venturi meter is usually permanently installed in the outlet chilled water piping of a chiller in a ship with multiple chilled water systems. The venturi is a flow-measuring device used to determine the flow through a chiller where an approximation of the plant air-conditioning load is desired. It is also used to determine chilled water flow when it is necessary to divert part of the flow to an adjacent plant

because of low air-conditioning load or when an adjacent plant has been deranged. To measure the flow, a differential pressure gauge and the meter calibration curve, showing pressure difference versus water flow in gallons per minute, are required. These should be provided with the meter. The venturi has connections upstream and downstream of it. A differential pressure gauge and meter is installed across these connections. As the chilled water flow increases, the pressure drop across the venturi increases; and as the water flow decreases, so does the pressure differential. Using the differential pressure reading and the curve for the installed venturi, the water flow can be determined. The curve of pressure versus flow shall be for the installed venturi.

516-4.1.26.2 Expansion Tank. The expansion tank is installed in the chilled water system. The expansion tank has a sight glass and a connection for makeup fresh water and air. The tank is operated with an air dome. The unit is approximately 1/2 filled with water and 1/2 with air. One function of the expansion tank is to take care of thermal expansion of the water and make up for any small water losses. A second function is to ensure that a positive water pressure exists at the highest water coil.

516-4.1.26.2.1 Expansion tanks on ships built after 1975 have a capacity equal to 10-seconds pumping capacity at the chilled water pumps for noncombatant ships and 30-seconds pumping capacity at the chilled water pumps for combatant ships. If the water expands because of an increase in temperature and the system is full, a pipe may burst if there is no means for the expansion to take place. This occurs because water is not compressible. To prevent this, the air dome in the tank will take up the expansion. In addition, if some water is lost through a small leak, the water in the tank will make up the loss. Also, the water level can be monitored to determine if there is a system or water leak, provided the air dome is airtight. The second function, to ensure that a positive pressure exists at the highest cooling coil, is important to prevent coils from getting airbound. If a vacuum exists in the water side of the cooling coil, air could leak into the chilled water system, perhaps through a water valve gland packing, and gradually accumulate in top coils, thus causing the coil to be airbound and limiting its cooling function. To prevent this, the upper part of the tank is charged with air and pressurized. The exact pressure is unimportant as long as the chilled water pressure at the highest coil is at a positive pressure, approximately 15 to 25 psi. To determine the pressure at the highest coil, install a gauge at a high point. Determine the pressure when the chilled water pump is stopped and when the pump is operating. From the readings, charge the expansion tank with air as required, so that a positive pressure is obtained at the highest cooling coil whether the chilled water pump is operating or stopped. Do not consider the pressure at the pump down in the machinery room. The pressure at the pump reveals nothing so far as this function is concerned. Operating personnel should maintain an adequate water level at the determined pressure in the tank.

516-4.1.27 THERMOSTATIC EXPANSION VALVE OPERATION. The major difficulty encountered with expansion valve operation is moisture or dirt collecting at the valve seat and orifice. Carefully analyze the symptoms of improper valve operation before concluding that the valve is out of adjustment. Once a valve is properly adjusted, further readjustment should be unnecessary unless changes are made to the cooling coil arrangement or thermal bulb location. Bulb location and where the bulb is installed are critical to operation of the thermostatic expansion valve (see paragraph [516-8.2.35](#)). Adjust the thermal expansion valves in accordance with the detailed instructions in the valve or equipment technical manual. The following general procedure is applicable, for most thermal expansion valves:

1. The valve is adjusted by means of the adjusting stem, which engages the gear on the cage assembly (shown in [Figure 516-4-3](#)), changing the spring tension to maintain the refrigerant superheat at the cooling coil (evaporator) outlet. Increased spring pressure increases the degree of superheat at the coil outlet and decreased spring pressure reduces the superheat. Some expansion valves are nonadjusting, with a setting fixed by the manufacturer, and are not intended for field adjustment. These would be used on self-contained equipment. If these valves get out of adjustment, replace them with a similar valve.

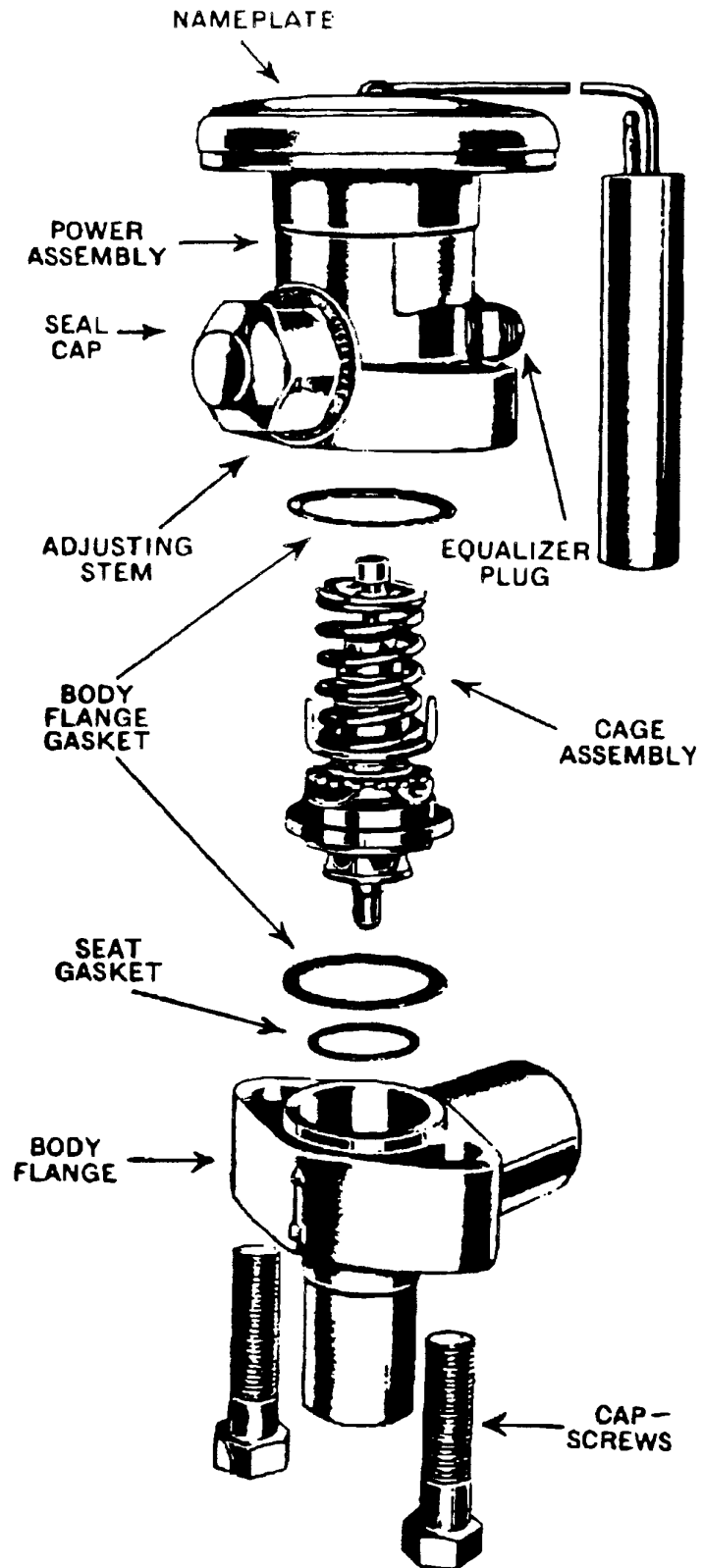


Figure 516-4-3. Thermostatic Expansion Valve Parts

2. If expansion valves are adjusted to give a high degree of superheat at the coil outlet, or if the valve is stuck shut, an insufficient amount of refrigerant will be admitted to the cooling coil and the coil will operate at reduced capacity. The coil will be starved, and the compressor lubricating oil carried with the refrigerant vapor may tend to collect at the bottom of the cooling coils, robbing the compressor crankcase of oil and providing a condition whereby slugs of lubricating oil may be drawn back to the compressor. If the expansion valve is adjusted for too low a degree of superheat or if the valve is stuck open, liquid refrigerant may flood from the cooling coils back to the compressor. If the refrigerant liquid collects at a low point in the suction line or coil and is drawn back to the compressor in slugs, there is a danger of damage to the moving parts of the compressor. Adjustment for 8°F to 10°F superheat at the cooling coil outlet will be generally satisfactory where more specific instructions for a particular superheat in a particular plant are lacking. In general, expansion valves for air-conditioning and water-cooling plants (high-temperature installations) are to be adjusted for higher superheat than expansion valves for cold storage refrigeration and ship stores equipment (low-temperature installations).

516-4.1.28 CHECKING THERMOSTATIC EXPANSION VALVE SUPERHEAT. The thermostatic expansion valve (TXV) is erroneously considered by some to be a mysterious and complex device. As a result, many valves are needlessly replaced when the cause of the system malfunction is not immediately recognized. Actually, the thermostatic expansion valve performs only one very simple function - it keeps the evaporator supplied with enough refrigerant to satisfy all load conditions. It is not a temperature control, a suction pressure control, a control to vary the compressor running time, or a humidity control. How effective the valve performs can be determined by checking the superheat. Measure this function as accurately as possible, or, in the absence of accuracy, be aware of the magnitude and direction of whatever error is present.

516-4.1.28.1 Superheat has been previously defined as the temperature increase of the refrigerant gas above the saturation temperature at the existing pressure. With this definition, the pressure and temperature of the refrigerant suction gas passing the TXV remote bulb are required to accurately determine superheat. When the temperature and pressure at the remote bulb are found, refer to the properties of saturated R-12 ([Table 516-1-1](#)) or R-134a ([Table 516-1-6](#)) and find the saturated temperature of the pressure recorded. Subtracting this temperature from the temperature of the refrigerant at the bulb will give the superheat. The recommended practice when measuring superheat is to install a calibrated pressure gauge in a gauge connection at the evaporator outlet. In the absence of a gauge connection, a tee installed in the TXV external equalizer line may be just as effective. To measure the temperature, a refrigeration-type pocket thermometer with appropriate bulb clamp may be used, but use of a service-type potentiometer (electric thermometer) with thermocouples (leads and probes) is more effective. Tape the temperature element from the thermometer to the suction line at the point where the TXV remote bulb is located, and insulate it against the ambient temperature. The temperature reading will be an average of suction line and ambient temperature if not insulated. This method will provide sufficiently accurate superheat readings for all practical purposes.

516-4.1.28.2 Compressor cycling and thermostatically controlled liquid line solenoid valve operation will have a significant effect on superheat readings. Ensure stable compressor operation and uninterrupted refrigerant supply to the TXV when checking superheat reading. On installations where a gauge connection is unavailable and the TXV is internally equalized, two alternative methods are possible. Both of these methods are approximations only.

516-4.1.28.3 The first of these is the two-temperature method, which uses the difference in temperature of the evaporator inlet and the outlet as the superheat. This method is in error by the temperature equivalent of the pressure drop between the two points of temperature. Evaporator pressure drop is usually an unknown and will vary

with the load. For this reason, the two-temperature method cannot be relied on for accurate superheat readings. The error in the two-temperature method always indicates a superheat lower than the actual figure.

516-4.1.28.4 The other method commonly used to check superheat involves taking the temperature at the evaporator outlet and using the compressor suction pressure as the evaporator saturation pressure. The error here is due to the pressure drop in the suction line between the evaporator outlet and the compressor suction gauge. On packaged equipment and close-coupled installation, the pressure drop and resulting error are usually small. However, on large, built-up systems or systems with long runs of suction line, considerable discrepancies will usually result from the larger pressure drops. Estimates of suction line pressure drop are usually too inaccurate to give a true picture of the superheat. The error in this instance will always be superheat higher than the actual value. The only method of checking superheat that will yield an absolute value involves a pressure and temperature reading at the evaporator outlet. Although symptoms may indicate that a TXV adjustment is needed more frequently, the origin of the trouble usually lies elsewhere. Carefully check other possible causes of incorrect superheat before attempting an adjustment (see paragraphs [516-4.1.28](#) and [516-8.2.37](#) for testing expansion valve).

516-4.1.29 HAND EXPANSION VALVE. The hand expansion valve is intended for emergency use only if the thermostatic expansion valve becomes inoperative. At times, hand expansion valves are opened with the thought that additional capacity can be achieved by feeding more refrigerant. This assumption is wrong. Opening the valves not only causes liquid refrigerant to return to the compressor, it also reduces the refrigeration effect by raising the evaporator pressure and thus evaporator temperature. Take great care when using the hand expansion valve to ensure that it is regulated to discharge no more refrigerant than the evaporator can handle and that liquid refrigerant is not permitted to flood back to the compressor. Maintain a watch at the compressor when a hand expansion valve is being used to prevent damage from liquid refrigerant possibly returning to the compressor or oil leaving and not returning to the compressor.

516-4.1.29.1 Keep hand expansion valves tightly closed when the system is in normal operation. To guard against accidentally opening the valve and to safeguard the compressor, wire the handwheel of the hand expansion valve so that the valve wheel cannot be turned or removed without breaking the wire. This wiring should be done on all hand expansion wheels. Where hand expansion valves are used for hot gas defrosting operation, the wire can be broken and, at the conclusion of the defrosting, reinstalled.

516-4.1.30 REFRIGERANT LIQUID FLOODBACK. A common but serious problem to avoid in operating a refrigerating system is the return of liquid refrigerant to the compressor. This is referred to as liquid floodback. Slugging, floodback, and flooded starts are three ways in which liquid can return to the compressor. These faults may cause serious or catastrophic damage to the refrigerant compressor, since the compressor cannot pump liquid refrigerant. Often, liquid floodback causes oil to leave the compressor crankcase, which in turn causes loss of lubrication. The excess oil in the refrigeration systems can cause oil slugging back to the compressor, with possible additional valve damage. The liquid floodback problem can be attributed to four major causes:

- a. Faulty evaporator design
- b. Faulty design or selection of the TXV
- c. Faulty use of refrigerant controls
- d. Excessive ice buildup on cooling coils.

516-4.1.30.1 In paragraph [516-4.1.30](#) , causes a and b are up to the designer; causes c and d are under the control of operating personnel. Concerning cause c, two possibilities need to be emphasized: misadjustment of TXV superheat and faulty use of hand expansion valves.

516-4.1.30.2 The TXV is a precision device designed to regulate the quantity of liquid refrigerant that passes to the evaporator. As previously stated, it is also designed to maintain a relatively constant degree of superheat of refrigerant gas leaving the evaporator regardless of suction pressure. The TXV controls the flow of refrigerant to the evaporator, subject to demand, and prevents the return of liquid refrigerant back to the compressor. For proper TXV operation, it is necessary for the remote thermal bulb to be highly responsive to changes in superheat. Obviously, the bulb location and application are governing factors. The highest degree of responsiveness of a thermostatic valve is obtained by using an insert-type bulb, but externally applied bulbs are used in most cases. If the remote bulb is not properly applied to the suction line and insulated (refer to the technical manual), liquid floodback may occur. On a refrigerating ship stores plant with long off-cycles, it is particularly important to insulate the bulb. Attaching the bulb to a vertical line may also cause liquid floodback.

516-4.1.30.3 Thermal expansion valves are supposed to be factory set for 8°F to 10°F superheat. If the operating superheat is set unnecessarily high, the evaporator capacity decreases. If set too low or at zero, liquid slugging occurs and compressor breakdown is a good possibility. To determine superheat, see paragraph [516-4.1.28](#). Installed TXVs are very reliable and, once correctly installed and adjusted, require very little attention. However, very often the automatic feature of the TXV is compromised by the use of a hand expansion valve. The hand expansion valve may be a separate valve piped to manually direct the flow of refrigerant around the TXV, or it may be an integral part of the TXV body, which holds the valve open in the event of failure or suspected failure of the TXV.

516-4.1.30.4 At times, hand expansion valves are opened with the belief that additional capacity can be achieved by feeding more refrigerant. This assumption is wrong. Opening the valves not only causes liquid slugs to enter the compressor, but also reduces the refrigeration effect by raising the evaporator pressure and, hence, evaporator temperature. The hand expansion valve is installed for emergency use if the TXV fails. Adjusting a hand expansion valve so a proper superheat is obtained, however, is very difficult, and virtually impossible without continuously monitoring the temperature and pressure. Therefore, avoid using a hand expansion valve to safeguard against the hazard of liquid floodback.

516-4.1.30.5 The return of liquid refrigerant will be indicated by one or several of the following symptoms:

- a. Sudden drop in suction temperature and rapid fluctuation in suction pressure
- b. Drop in discharge temperature
- c. Frost formation on compressor crankcase, cylinders, or compressor suction flange connection, and adjacent pipe
- d. Compressor knocking.

516-4.1.30.6 Carefully check for any of these symptoms, and if compressor knocking is observed, stop the compressor immediately. Before restarting the compressor, secure the refrigerant supply and the compressor suction valve. Operate the compressor in short spurts until the compressor has been cleared of liquid refrigerant. Gradually open the compressor suction valve while monitoring compressor operation; then gradually open the refrigerant supply valve. Closely watch the compressor oil level during this period to ensure against related hazards due to loss of compressor lubrication. Operating personnel should be aware of dangers from liquid floodback and

recognize the symptoms to protect the compressor against damage. One of the safeguards is to wire the hand-wheel of the hand expansion valve so it cannot be opened by mistake or in haste. The wiring should be such that the valve wheel cannot be turned or removed without breaking the wire.

516-4.1.31 STRAINER CLEANING. Clean the suction and liquid strainers and filters after the first few hours of operation in a new installation, or after overhaul, to remove the foreign matter loosened from the system by the solvent action of the refrigerant circulating through the refrigerant lines and depositing the foreign matter in the strainers or filters. Another cleaning is usually necessary after the first few days of operation. Frequently inspect the strainers during the early service life of the plant and clean when necessary.

516-4.1.31.1 During normal operation, strainers generally require cleaning only during overhaul. To clean compressor strainers, refer to the compressor section. If a liquid line strainer becomes clogged to the extent that it needs to be cleaned, this condition will be manifested by a loss-of-refrigeration effect. The body of the strainer and tubing after the strainer will be colder than the tubing ahead of it. To clean the liquid line strainer, shut off the manually-operated stop valve between the receiver and the strainer and continue operation for a few minutes to allow any liquid remaining in the strainer to flow to the evaporator. Then close the valve at the outlet of the strainer, and carefully and slowly loosen the cap that is bolted to the end of the strainer body. Use goggles for eye protection. When assured that no gas pressure exists in the strainer body, remove the cap and lift out the screen. The strainer screen can readily be cleaned with solvent and a small stiff brush.

516-4.1.31.2 When assembling the liquid strainer, be sure that the screen and spring are properly placed and that the strainer cap gasket is drawn up tightly after purging the air from the strainer body by blowing refrigerant through it from the inlet side.

516-4.1.32 VENTILATION OF REFRIGERATED CARGO. Carbon dioxide (CO_2) and other gases will be given off as a by-product of fruit and vegetables during their storage even though they are refrigerated. The rate of release is a function of the type of food, temperature, and condition. Since a refrigerator or refrigerated cargo compartment is a sealed chamber, in time the gases can accumulate to a dangerous concentration. Carbon dioxide is heavier than air and will collect at a low point. Exercise caution when entering or inspecting a refrigerated area that has been closed for some time and where ventilation is not available. The use of a CO_2 indicator is advisable. Refrigerated cargo vessels are normally provided with ventilation systems for such areas. The ventilation system forces fresh outside air into the refrigerated space and exhausts stale compartment air to the outside. The use of warm outside air imposes a considerable refrigeration load on the equipment and thus requires judicious application in both design and operation. The equipment is sized to provide a fan with an hourly capacity equal to the gross cubical content of the compartment and shall be operated under the following limitations:

- a. A maximum of 20 minutes in any one hour
- b. With only one compartment on a refrigeration plant ventilated during a 20-minute period
- c. During normal operation period only (not during pull-down condition). Respiration, or the giving off of CO_2 and ethylene gases, does not occur with frozen products.

516-4.1.33 VENTILATION OF REFRIGERATION MACHINERY SPACE. Always install refrigerating machinery in a space where adequate ventilation is provided. Remove the heat generated by motors and compressors from the machinery space. Fresh air is also required for personnel working in the space. Equipment with air-cooled condensing units, which depend on the condenser capacity and location, may require positive exhaust as well as adequate ventilation to remove the heat discharged from the refrigerant condenser.

516-4.1.33.1 Occasionally, during maintenance and repair operations in machinery spaces, amounts of refrigerant may be released into the atmosphere. Each machinery space shall have not only ventilation (air inlet) but positive exhaust. At least one-third of the exhaust quantity shall be in the vicinity of the refrigeration plant, with the terminal located approximately 9 inches above the deck. In some cases, because of compartment location, available space, or other considerations, air-conditioning machinery is located in an air-conditioned space. Where the refrigeration plant is located in such a space, replenishment air shall be supplied to provide a 15-minute rate of change (four air changes per hour). Locate all the exhaust next to the machinery and approximately 9 inches above the deck.

516-4.1.34 SELF-CONTAINED EQUIPMENT. For small self-contained refrigerating equipment such as ice cream units, refrigerators, or drinking water coolers, maintain a daily inspection to check compartment temperatures, frost conditions, and obvious operating conditions. When operating difficulties occur in the small refrigerating units not equipped with gauges, temporarily connect separate service gauges to the suction and discharge fittings provided to diagnose the trouble. A charging and testing manifold, consisting of combined shutoff valve assembly with suction and discharge gauge, as shown in [Figure 516-4-4](#), may be used to advantage for such service. The manifold is arranged to permit its use for testing, charging, evacuating, and purging, and is provided with flexible hoses for connection to the compressor. Glass-etched stem test thermometers in a metal shield are used for taking temperature readings of the particular media being cooled.

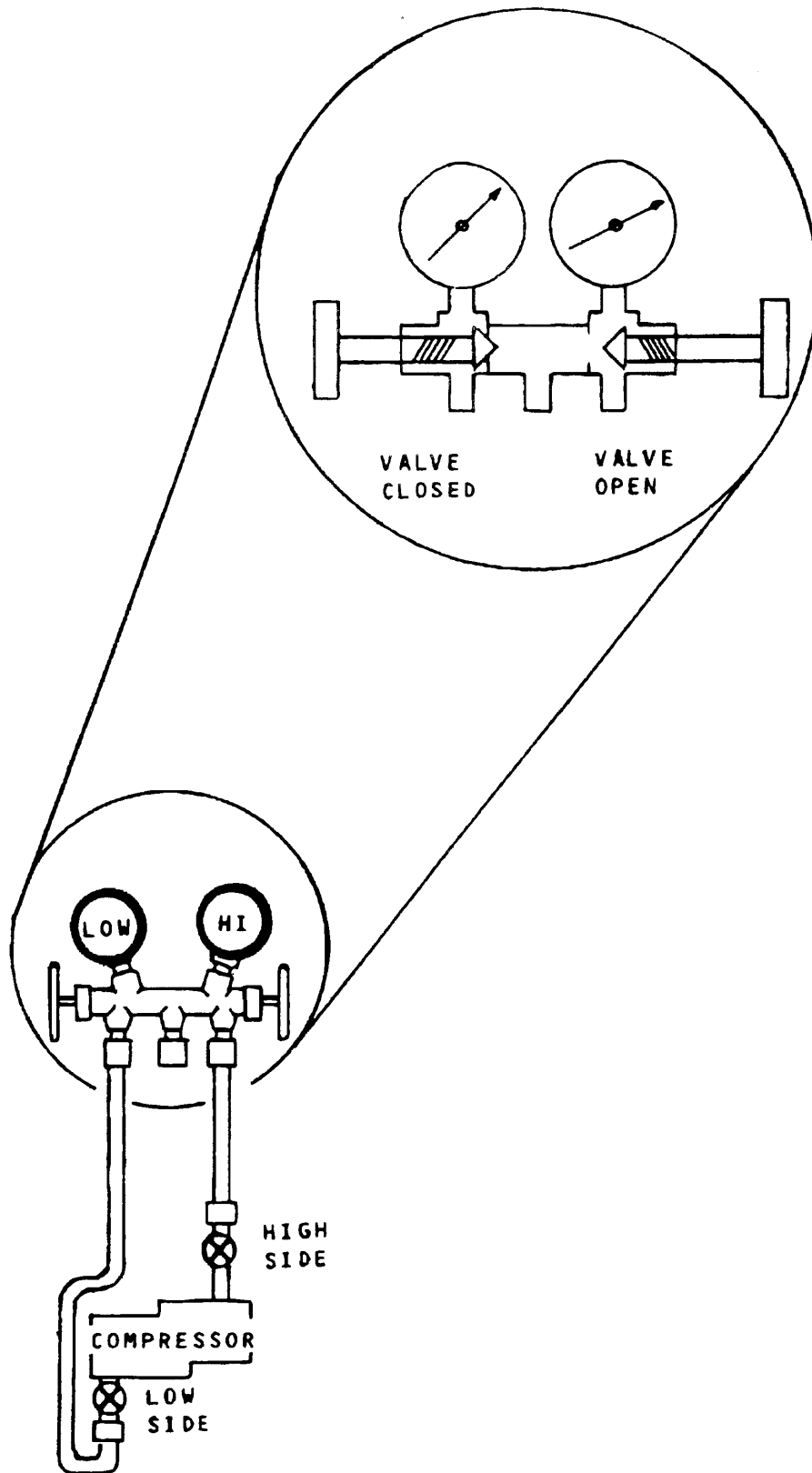


Figure 516-4-4. Charging and Testing Manifold

516-4.1.35 **SHORTAGE OF REFRIGERANT.** When the plant is operating at full capacity, the normal refrigerant level indicated on the receiver liquid level gauge shall be approximately 1/8 full. Insufficient refrigerant will cause the following:

- a. Hot liquid lines
- b. Warm suction lines
- c. Low compressor suction pressure
- d. Low compressor discharge pressure
- e. Partial cooling through part of the coil
- f. Warm crankcase and cylinder
- g. Bubbles in sight flow indicator
- h. Compressor that either short-cycles or runs continuously.

516-4.1.35.1 The above symptoms may be accompanied by an intermittent or constant hissing sound at the expansion valve, which is caused by the passage of refrigerant vapor through the expansion valve orifice with the liquid. This sound, with practice, can be distinguished from the sound caused by the normal flow of liquid through the valve. When all these conditions exist simultaneously, take immediate steps to add or transfer the required amount of refrigerant to the receiver of the unit in use. Refer to [Figure 516-4-7](#) for symptoms of refrigerant shortage.

516-4.1.36 **ADDING REFRIGERANT TO THE OPERATING SYSTEM.** The refrigerant charge in a large R-12 system is not critical. Several pounds of refrigerant above or below the calculated charge will not have an appreciable effect on system operation. However, if the refrigerant charge is short, so that the liquid seal is lost in the receiver, then a loss of capacity will result. Refrigerant can be added to an operating system through the refrigerant charging valve. If a large quantity of refrigerant is to be added to the system, close the receiver liquid outlet valve and pump down the refrigerant system. With the system pumped down, add the refrigerant by weight. When charging, never charge liquid refrigerant in the compressor suction side. If charging is to be on the suction side, always maintain the cylinder in an upright position so that gas is charged. Liquid refrigerant can be charged in the liquid side of the system by inverting the cylinder. Refer to the equipment technical manual for specific details on adding refrigerant. Be careful not to overcharge. Be aware that if some refrigerant is lost, there is a leak. Do not keep on adding refrigerant without first searching carefully for a leak.

516-4.1.37 **ADDING REFRIGERANT TO SELF-CONTAINED EQUIPMENT.** Self-contained refrigerating equipment is generally furnished complete with the correct operating charge of refrigerant. This equipment often lacks a liquid line charging valve. If it is necessary to add some refrigerant, it is best to replace the complete charge. Add the charge as refrigerant gas into the suction side of the system. Compressor shutoff valves may have provisions for attaching test gauges and charging lines. In most cases, shutoff valves have a threaded plug, which is removed, and a male flare adapter fitting is inserted to provide a connection for the gauge or charging line.

516-4.1.37.1 In some instances, a capped male flare fitting is provided, and in some commercial equipments a male flare to a pin-operated check valve in the fitting is provided. These pin-operated check valves are similar to Schrader-type valves used in automobile tire valve stems. [Figure 516-4-5](#) shows a cross-section of the pin-operated check valve. Where fittings have these check valves, it is necessary to have gauge or charging lines with a fixed pin in the female connection to open the fitting check valve. Where the test or charging opening or fitting is located in the compressor shutoff valve, backseat the valve (turn fully open), remove the threaded plug,

and temporarily install an adapter fitting. [Figure 516-4-6](#) illustrates compressor shutoff valves in both the backseated and fully closed position. With the compressor shutoff valve backseated (turned fully open), connect the charging line between the refrigerant cylinder and the adapter fitting, male flare fitting, or Schrader-type valve.

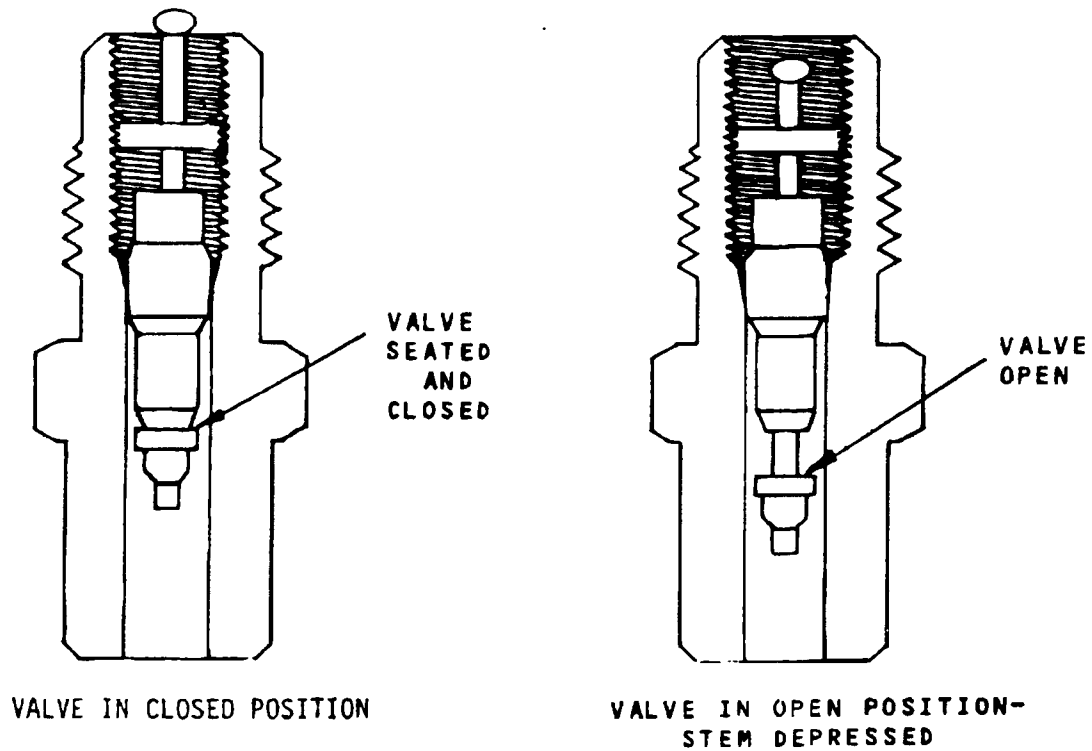


Figure 516-4-5. Pin-Operated Valve

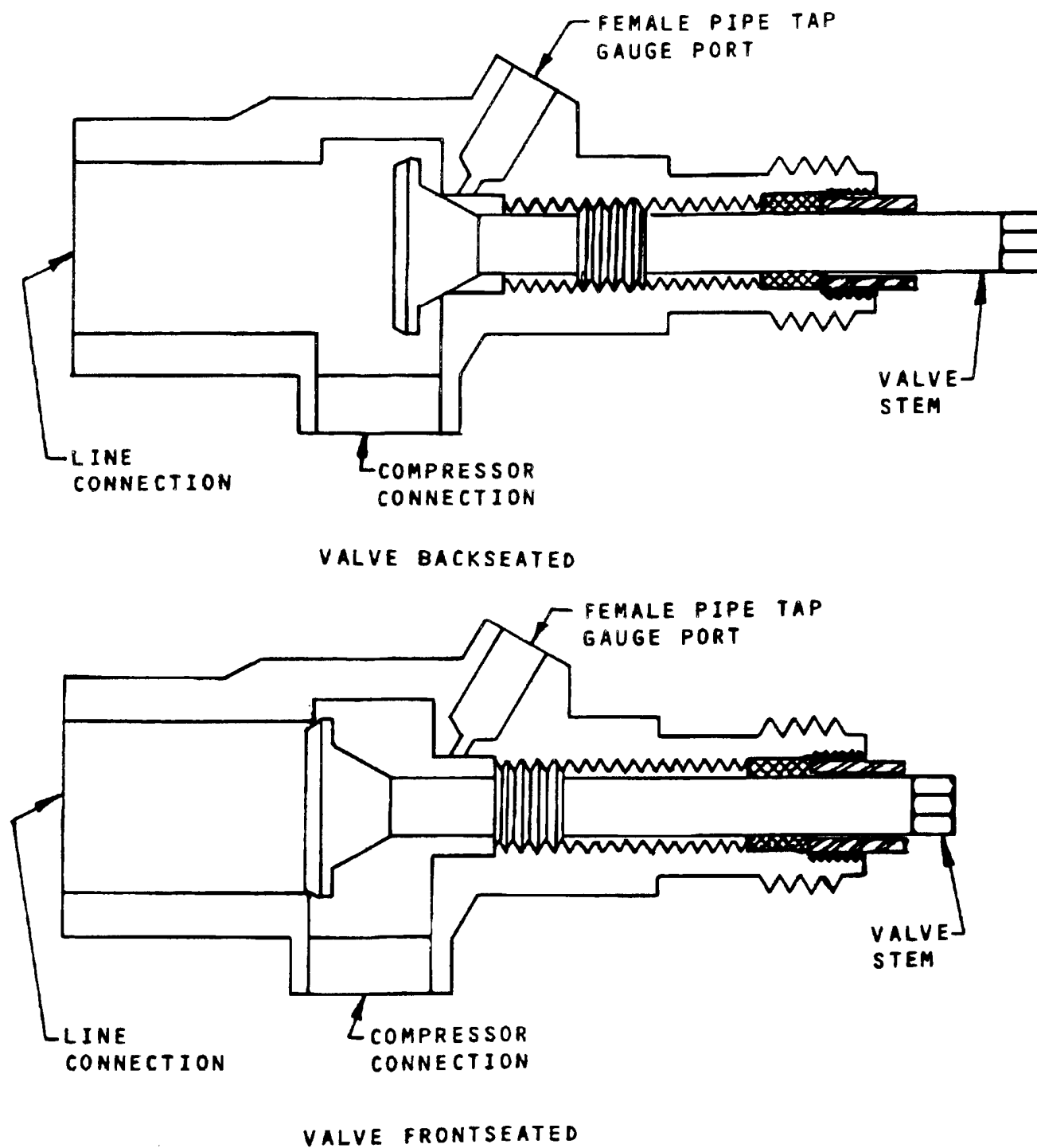


Figure 516-4-6. Compressor Service Valve

516-4.1.37.2 Only refrigerant gas is charged into the system. Purge air in the charging line by slightly opening the refrigerant cylinder valve before completely tightening the charging line connection to the adapter fitting, male flare fitting, or Schrader valve. After the air has been purged, tighten the connection and with the refrigerant cylinder valve still open, start the compressor and close (front seat) the compressor shutoff valve to admit refrigerant gas into the system from the refrigerant cylinder. Once the required weight of refrigerant gas has been admitted to the system, close the refrigerant cylinder valve, stop the compressor, and completely open (backseat) the compressor shutoff valve.

516-4.1.37.3 As previously described, the amount of refrigerant charged into the system can be determined by mounting the charging cylinder on a scale and noting the weight as charging cylinder progresses. The decrease in weight of the charging cylinder represents the weight of refrigerant charged into the system. For unitary or self-contained equipment, the amount of refrigerant charge is critical, so use an extremely accurate set of scales (accurate to the nearest ounce) to determine the weight of refrigerant charged into the system. The reason refrigerant charge is so critical for unitary or self-contained equipment is that most of this equipment has a capillary tube instead of a thermal expansion valve to control refrigerant flow. The capillary tube has a relatively constant feed characteristic compared to the thermal expansion valve, which modulates to vary the refrigerant flow. With a capillary, a slight overcharge of refrigerant may result in liquid floodback and cause damage to the compressor.

516-4.1.37.4 A slight undercharge will result in a starved evaporator and a loss of cooling effect. An overcharge of refrigerant is evidenced by frosting of the suction line due to the carryover of liquid refrigerant past the evaporator. An undercharge of refrigerant is evidenced by incomplete frosting of the evaporator due to the shortage of refrigerant. Unitary or self-contained equipment can also be charged from small, commercially available refrigerant charging cylinders, which usually have a built-in indicator or a means of determining the weight of refrigerant to be charged into the system. When charging is completed with the compressor shutoff valve backseated, the charging line and cylinder may be disconnected; the adapter fitting (if used) removed; and the plug, male flare fitting, or Schrader valve cap replaced. Where the amount of refrigerant charge is unknown, proceed as above, but admit gas from the cylinder to the compressor for 30 seconds; then operate the unit for 1 hour, checking the temperature of the unit and discharge pressure. Repeat this procedure at stated intervals until the temperature of the unit and the discharge pressure are satisfactory or are at design levels. Take care to prevent overcharging the unit. When the system is undercharged, suction pressure will be low, and the evaporator will not be completely frosted as described above. If the system is seriously undercharged, the compressor may run continuously or may not start at all because of insufficient suction pressure to close the low-pressure control switch.

516-4.1.37.5 As additional refrigerant is charged into the system, the system performance will improve, and the suction pressure and superheat will approach their normal or design levels. When the correct quantity of refrigerant has been charged into the system, system performance should be satisfactory, with the system suction and discharge pressure at their normal or design levels and the evaporator completely frosted.

516-4.1.37.6 A clamp-on ammeter can be used to check full-load amps (FLA) as indicated on the nameplate. With no air in the refrigerating system and the correct refrigerating charge, FLA should be achieved when the condenser and evaporator are at design temperature. As the system is overcharged, the discharge pressure will increase above the normal or design level, and frost on the evaporator will extend into the suction line as described above. If the system is seriously overcharged, the compressor will short-cycle on the high-pressure switch because of insufficient condenser capacity because the condenser tubes are submerged in condensed refrigerant. See the technical manual for instructions for removing excess refrigerant.

516-4.1.38 OVERCHARGING THE SYSTEM. Abnormally high condensing pressures will result if a system is accidentally overcharged or, in multiple compressor unit installations, if the refrigerant that is normally divided between all liquid receivers is accidentally overcollected in one of the receivers. If abnormally high condensing pressures are encountered and if none of the other conditions outlined for high discharge pressures in [Figure 516-4-7](#) are obtained, it is likely that such a receiver is overcharged.

516-4.1.39 DRAINING OVERCHARGED REFRIGERANT FROM THE SYSTEM. If the refrigerant system has been overcharged with refrigerant, proceed to correct the condition, as follows:

1. Start the compressor on manual control and pump down the evaporator and suction line pressure to 0 psig, with the liquid line valve at the receiver outlet closed.
2. Stop the compressor and secure.
3. Shut the compressor discharge line valve.
4. Connect an empty refrigerant service cylinder to the refrigerant-charging valve. Be sure the cylinder is large enough to prevent overfilling. Before connecting the cylinder to the system, immerse it in an ice-water bath to cool the cylinder thoroughly to permit rapid draining of the refrigerant into the cylinder. Always use a clean service cylinder containing no air or water, so that the drained refrigerant can be kept in suitable condition for future use. If a vacuum pump is available, drawing a vacuum on the cylinder will accelerate the filling. The use of a certified refrigerant recovery unit could also be used.
5. Purge air out of the line connecting the charging valve and cylinder by leaving the connection at the cylinder valve loose and slowly flushing refrigerant through the line and out at the connection; then tighten the connection. Refrigerant can now be drained into the cooled cylinder by opening the charging, receiver outlet and service cylinder valves. When the desired quantity of refrigerant has been removed, close the charging valve and permit the liquid refrigerant in the drain line to evaporate; then, close the service cylinder valve and disconnect the cylinder from the system.
6. During removal and after disconnecting the cylinder from the system, weigh it to be certain that it has not been overcharged. Do not fill the cylinder to more than 80 percent of its water weight capacity (see paragraph [516-1.10.3](#)). The net and gross weight are stamped on the cylinder. Weights include the cast iron protector cap over the cylinder valve.

NOTE

Do not overcharge a cylinder: thermal expansion could burst the cylinder.

516-4.1.40 TRANSFERRING REFRIGERANT FROM ONE RECEIVER TO ANOTHER. If it is necessary to transfer all or part of the liquid refrigerant contained in one liquid receiver to another liquid receiver of the plant, proceed as follows:

1. Start the compressor serving the receiver to which the refrigerant is to be transferred.
2. Keep the liquid outlet valve of this receiver closed.
3. Open the liquid outlet valve of the receiver from which refrigerant is to be removed.
4. Continue compressor operation until the desired amount of refrigerant has been transferred to the receiver of the compressor unit in operation. Be careful not to overcharge this receiver. Then stop the compressor and return the plant to normal operation.

5. During the above process, keep a careful check on the compressor crankcase lubricating oil level.

516-4.1.41 CORRECTING FAULTY OPERATION. Steps to be taken in detecting and correcting faulty operation of refrigeration systems are outlined in [Figure 516-4-7](#). The proper methods of making these service adjustments, repairs, and corrections are discussed in this and other sections of the manual.

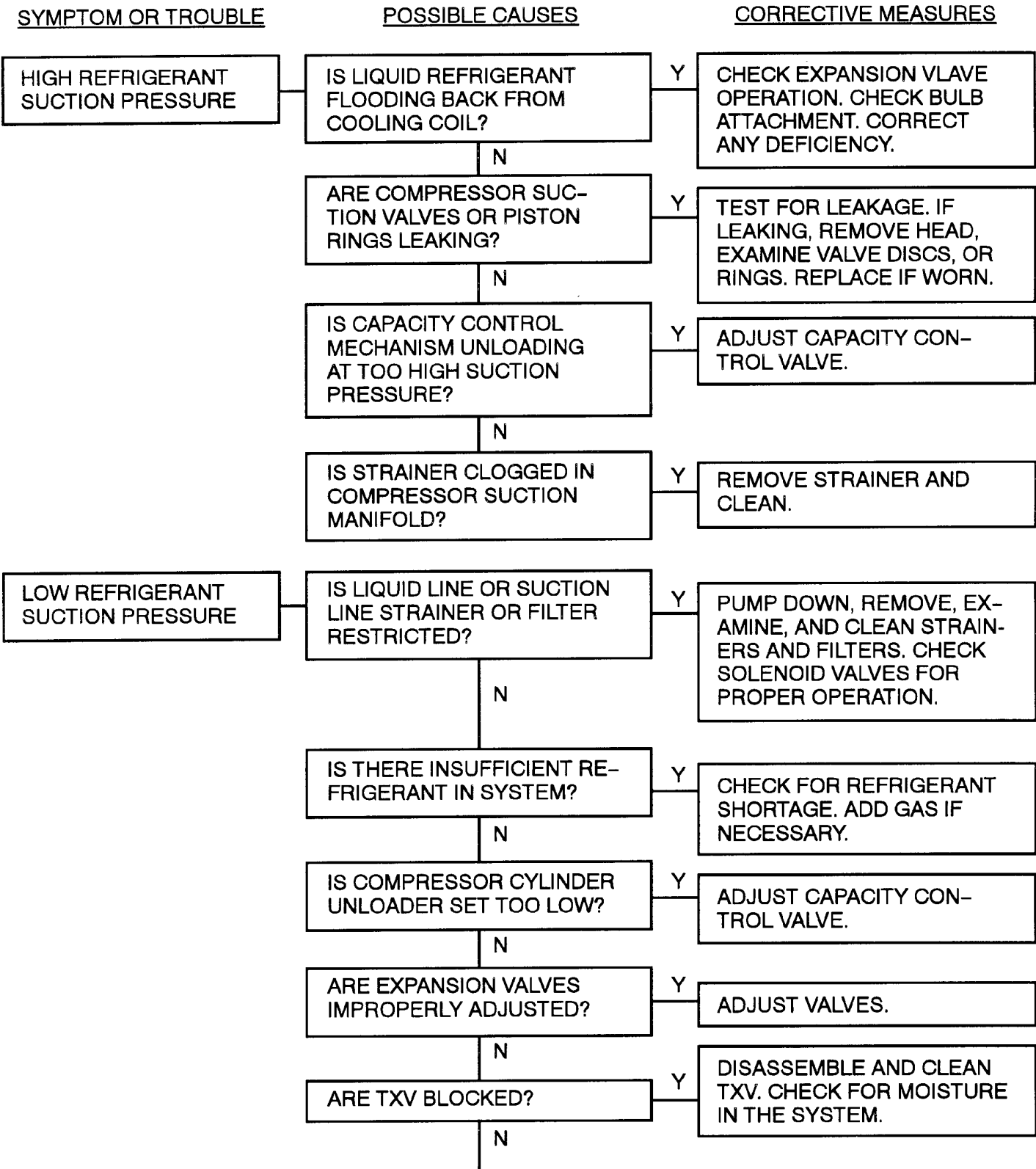


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 1 of 21)

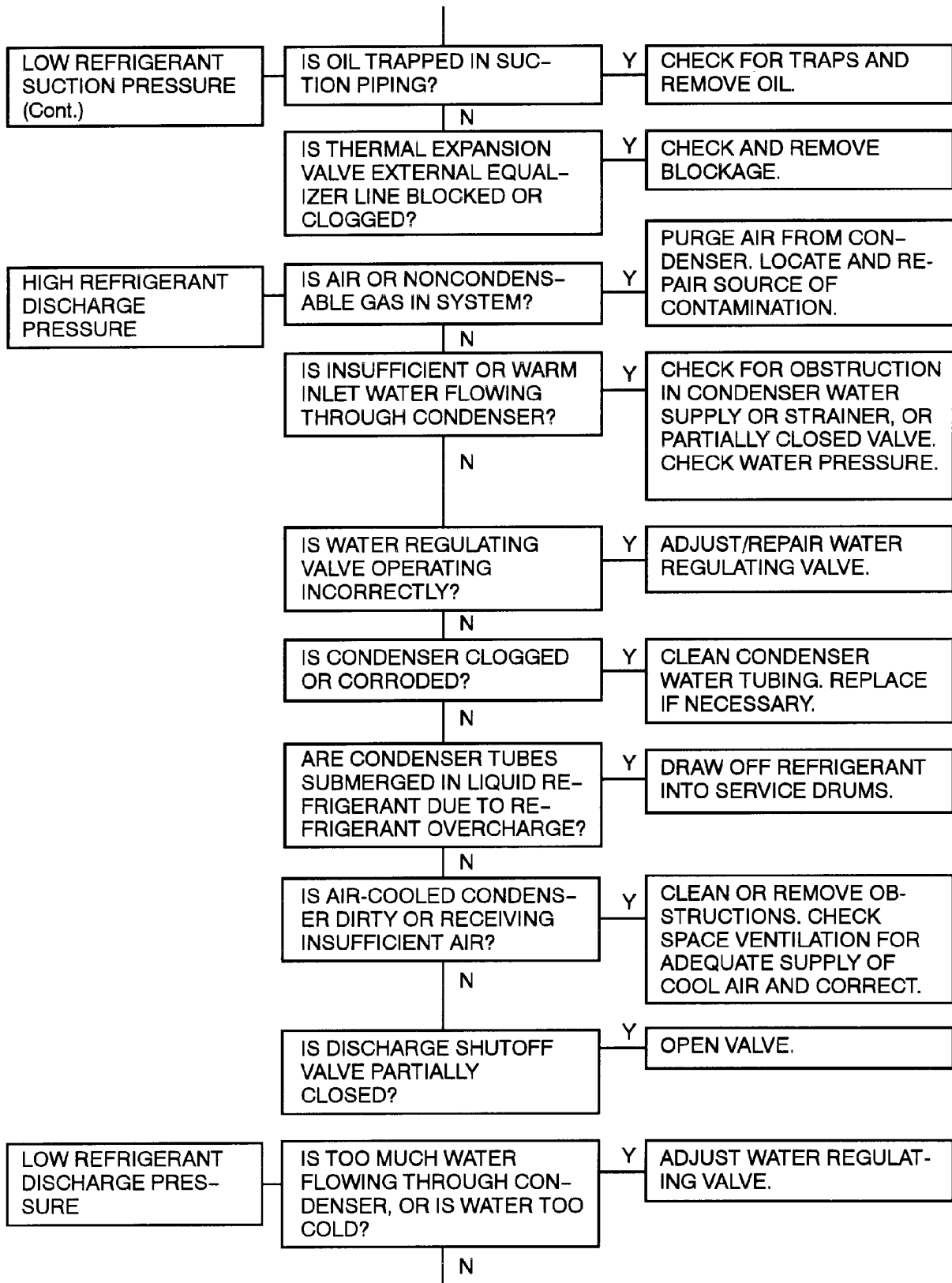


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 2 of 21)

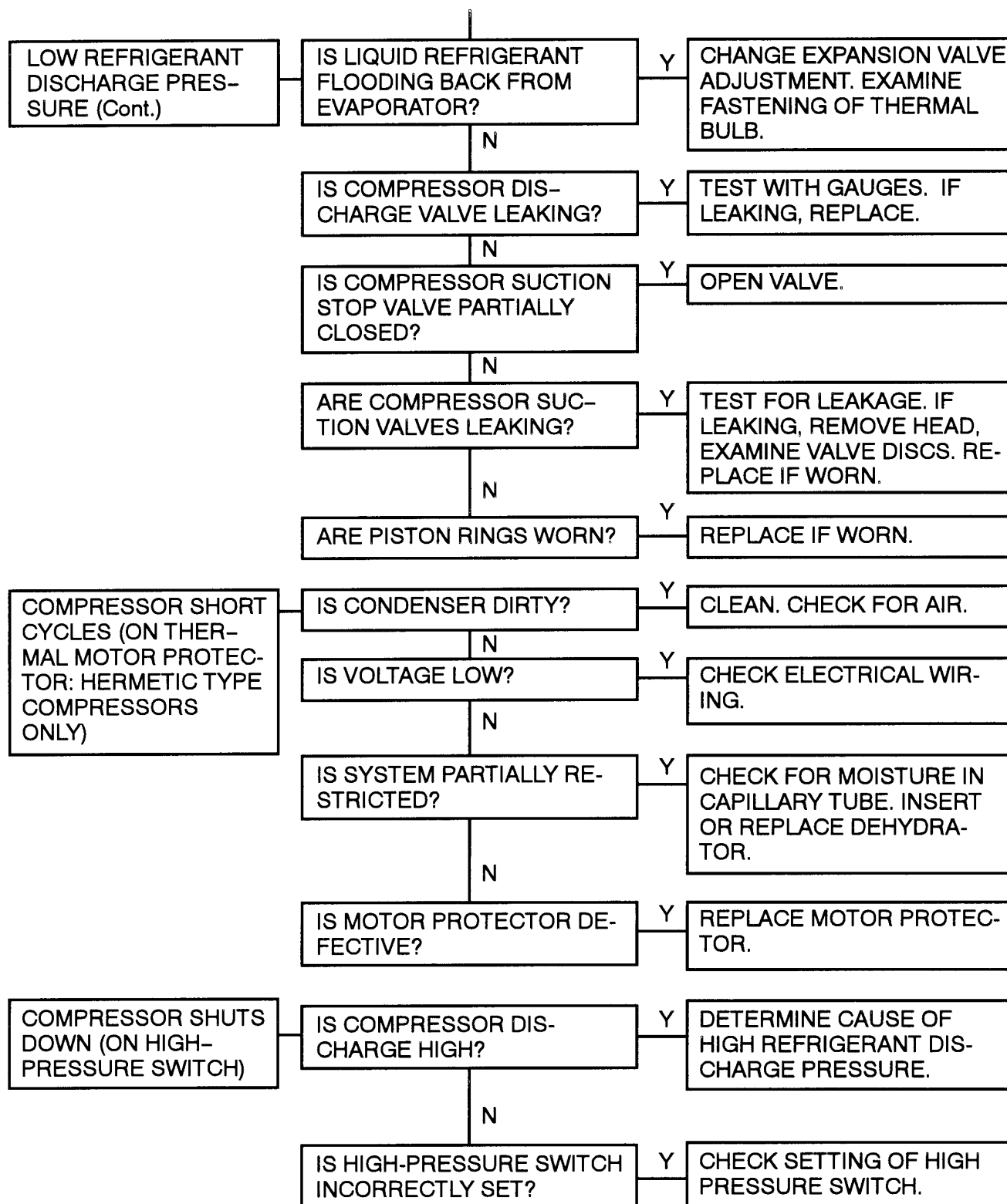


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 3 of 21)

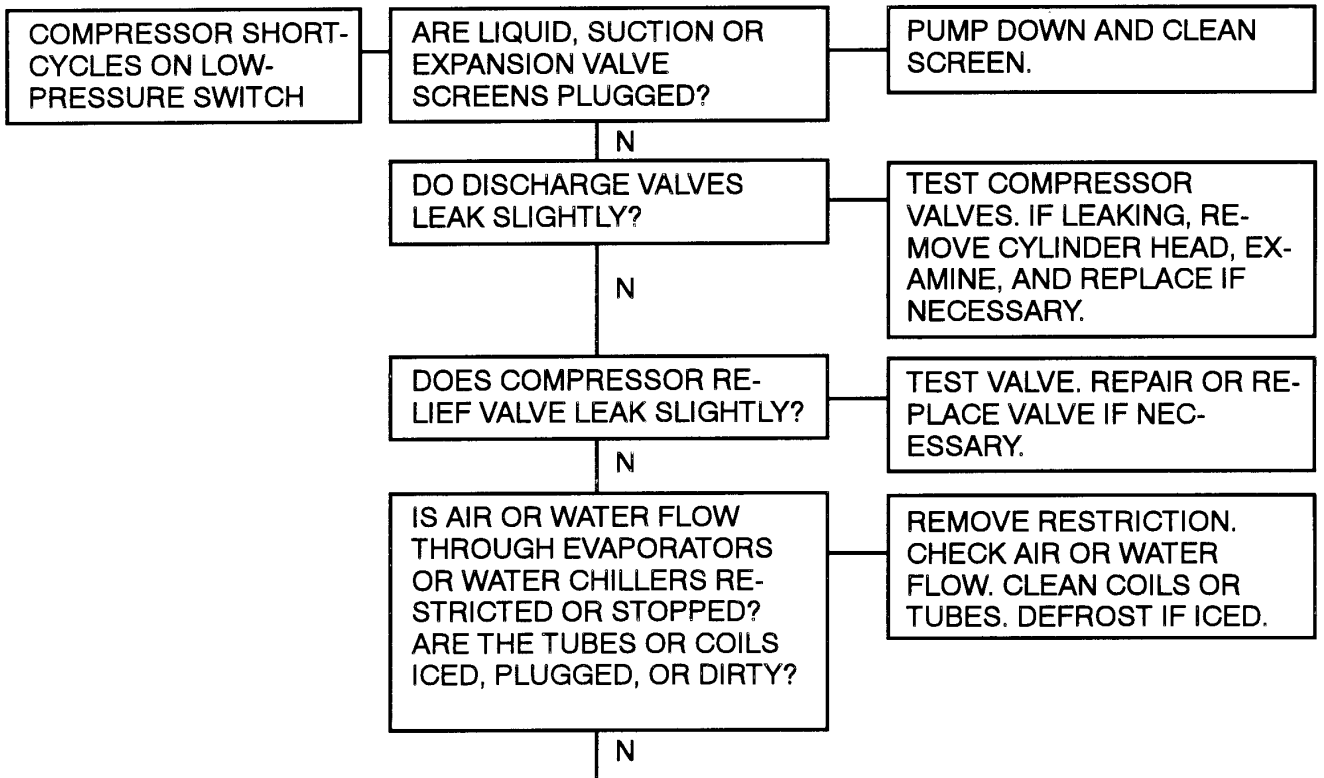
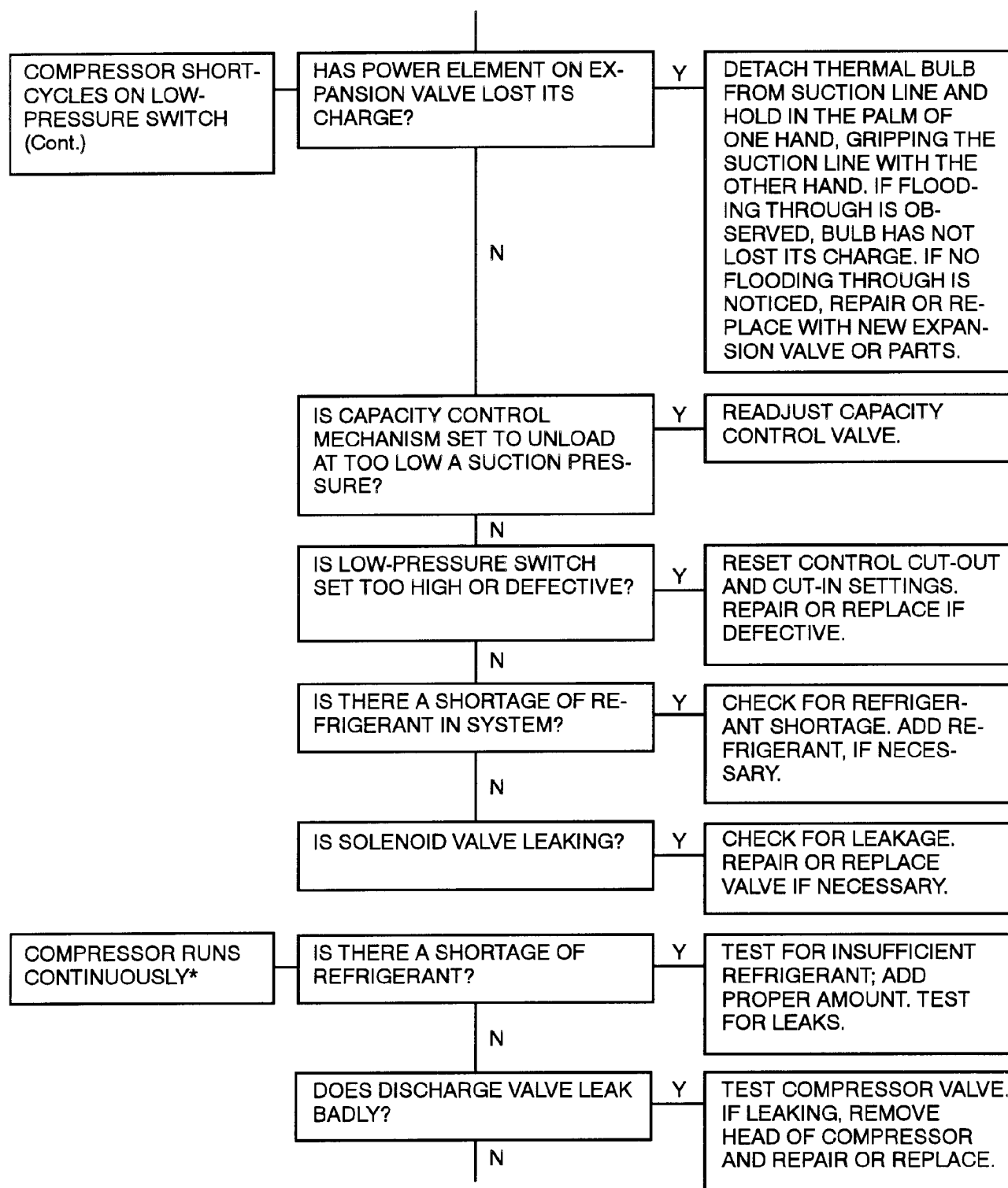


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 4 of 21)



*CONTINUOUS COMPRESSOR OPERATION IS NORMAL IN FULL LOAD AIR-CONDITIONING APPLICATIONS.

Figure 516-4-7. Reciprocating Refrigeration System (Sheet 5 of 21)

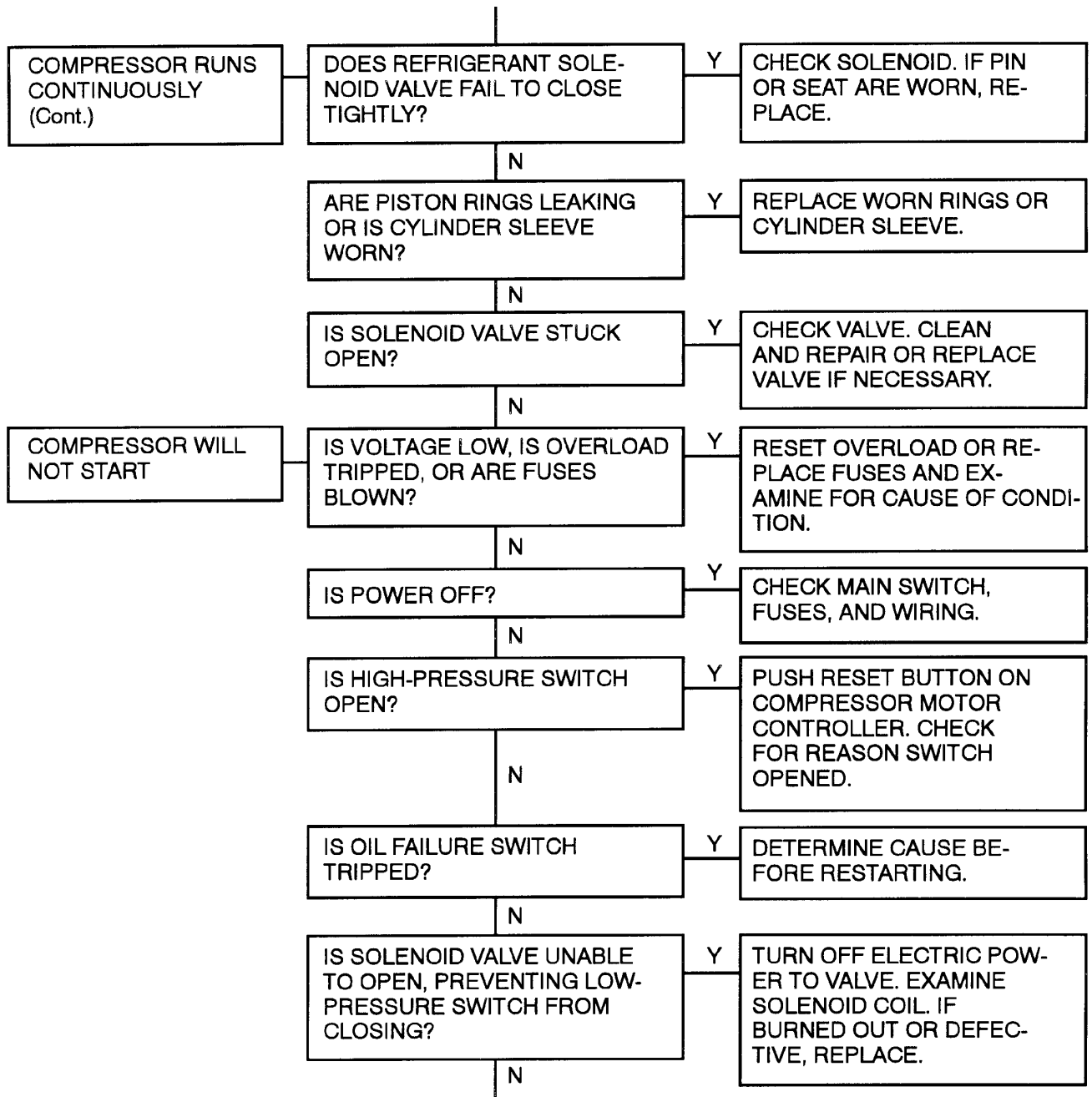


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 6 of 21)

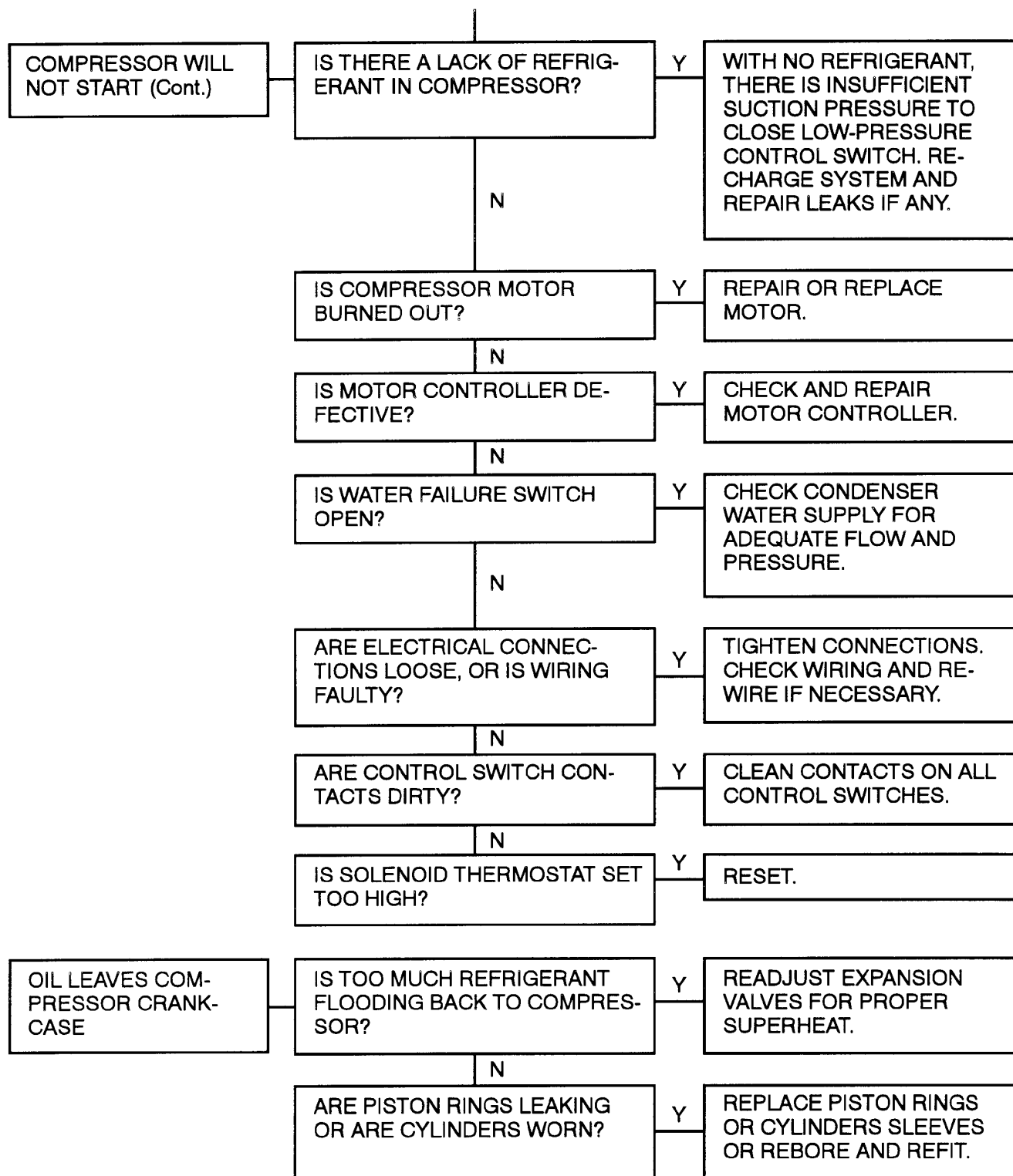


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 7 of 21)

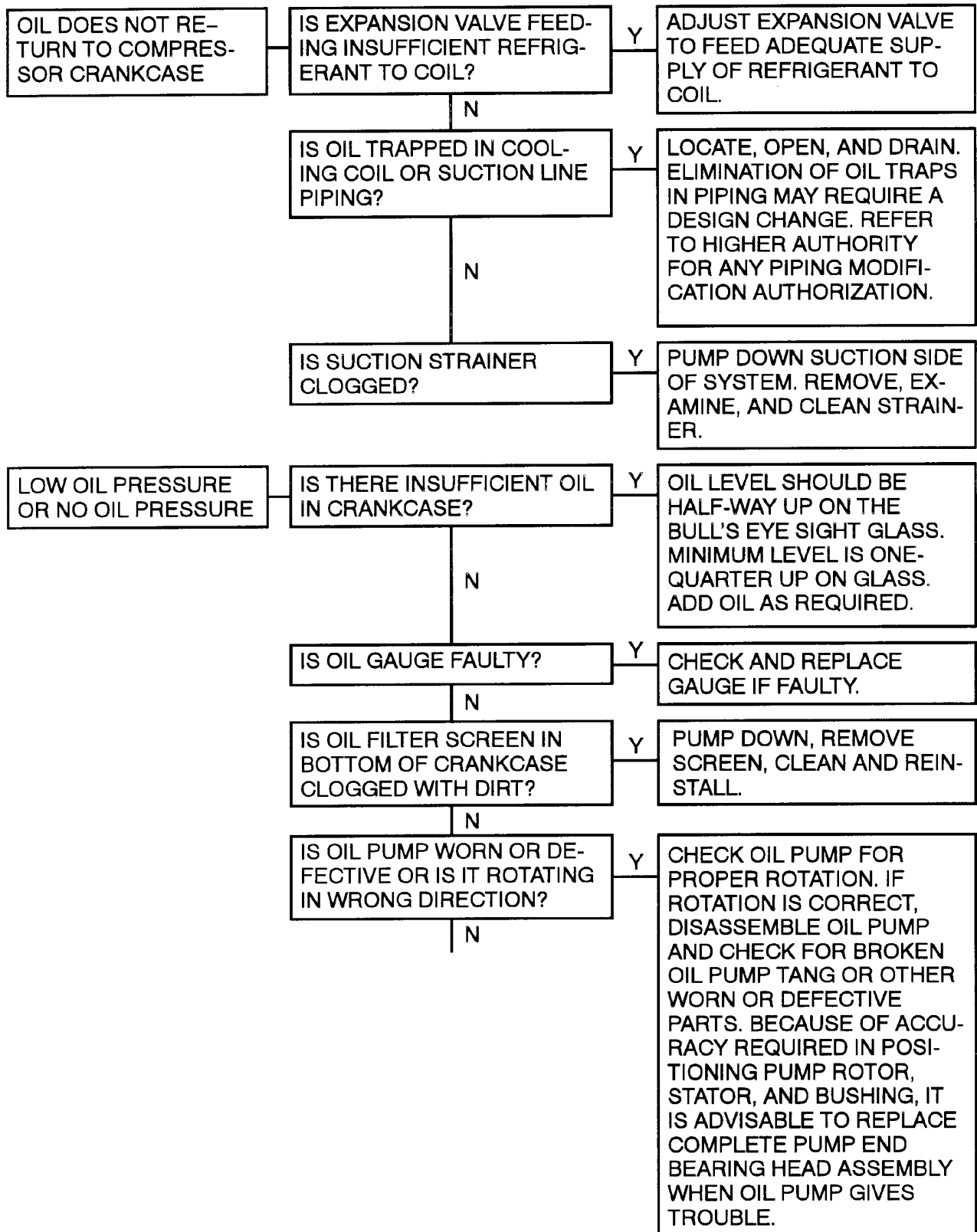


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 8 of 21)

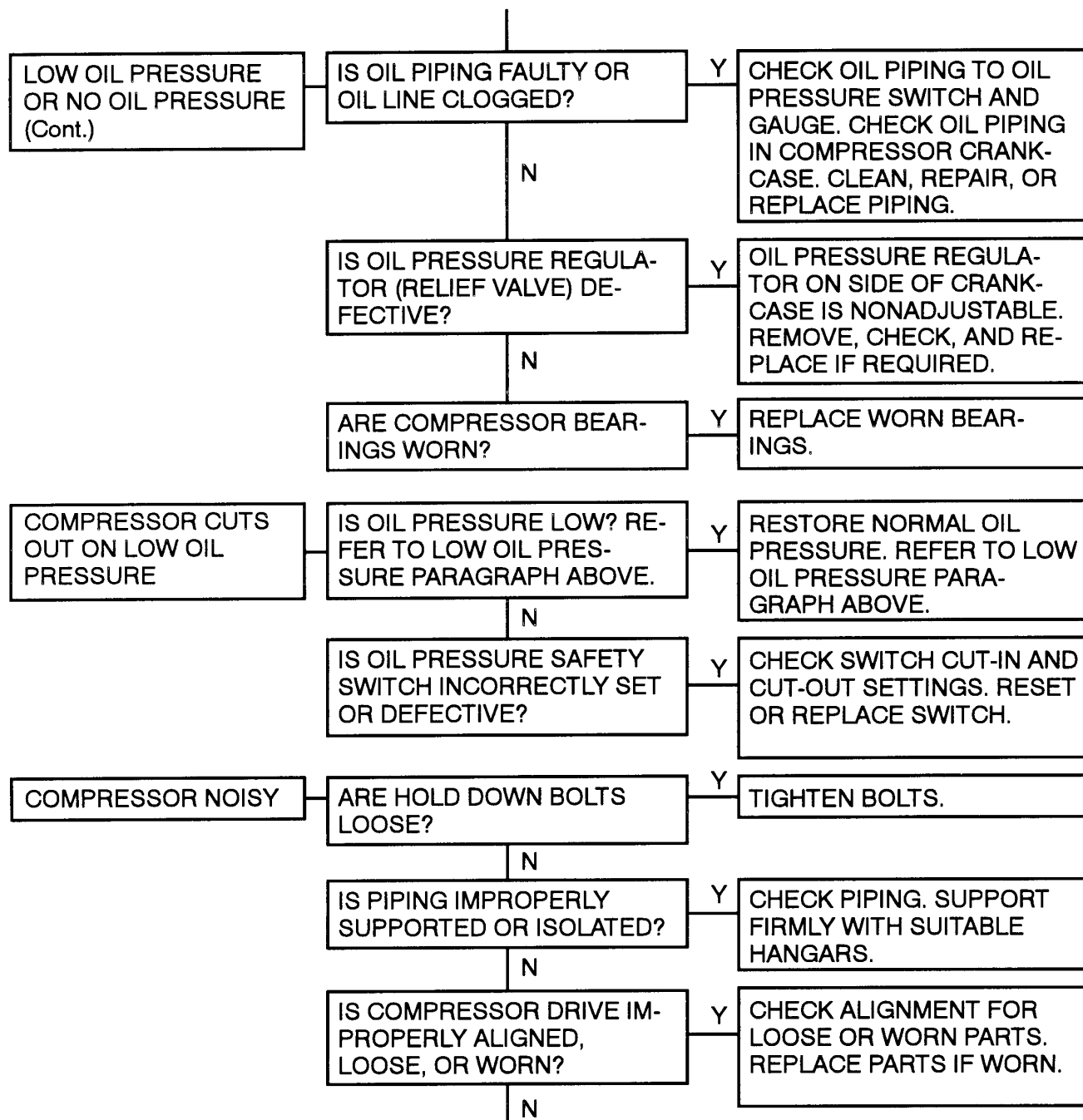


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 9 of 21)

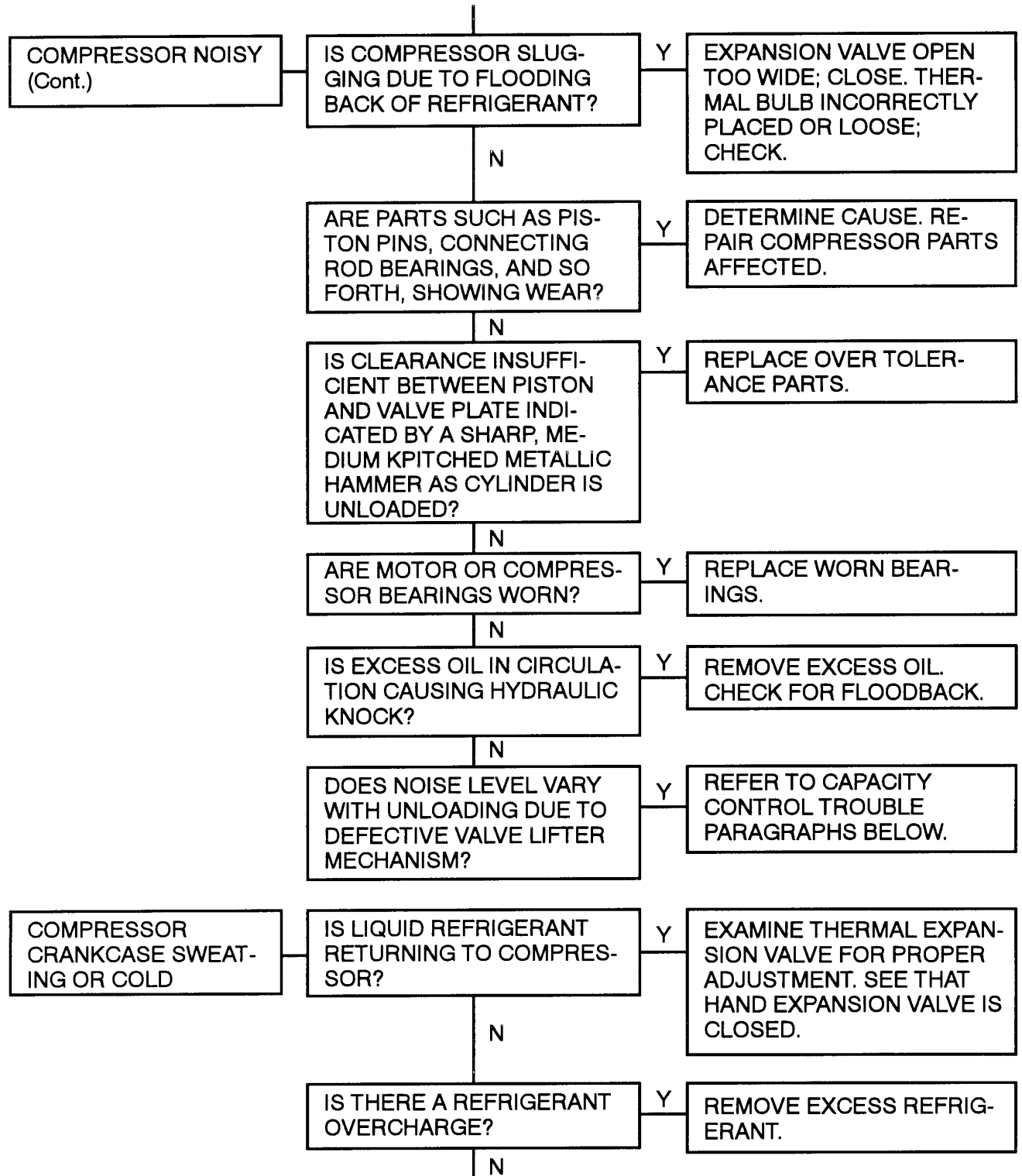


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 10 of 21)

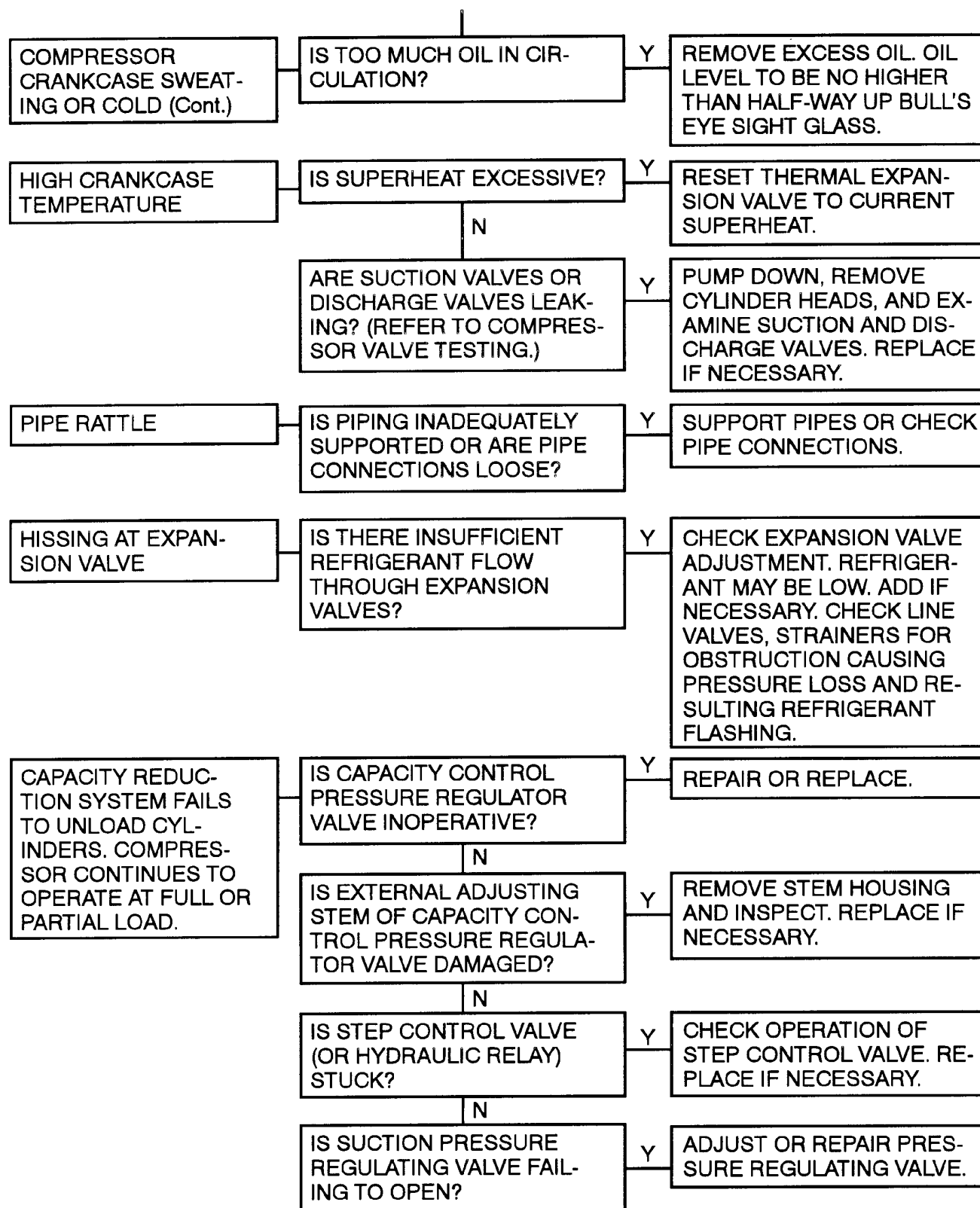


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 11 of 21)

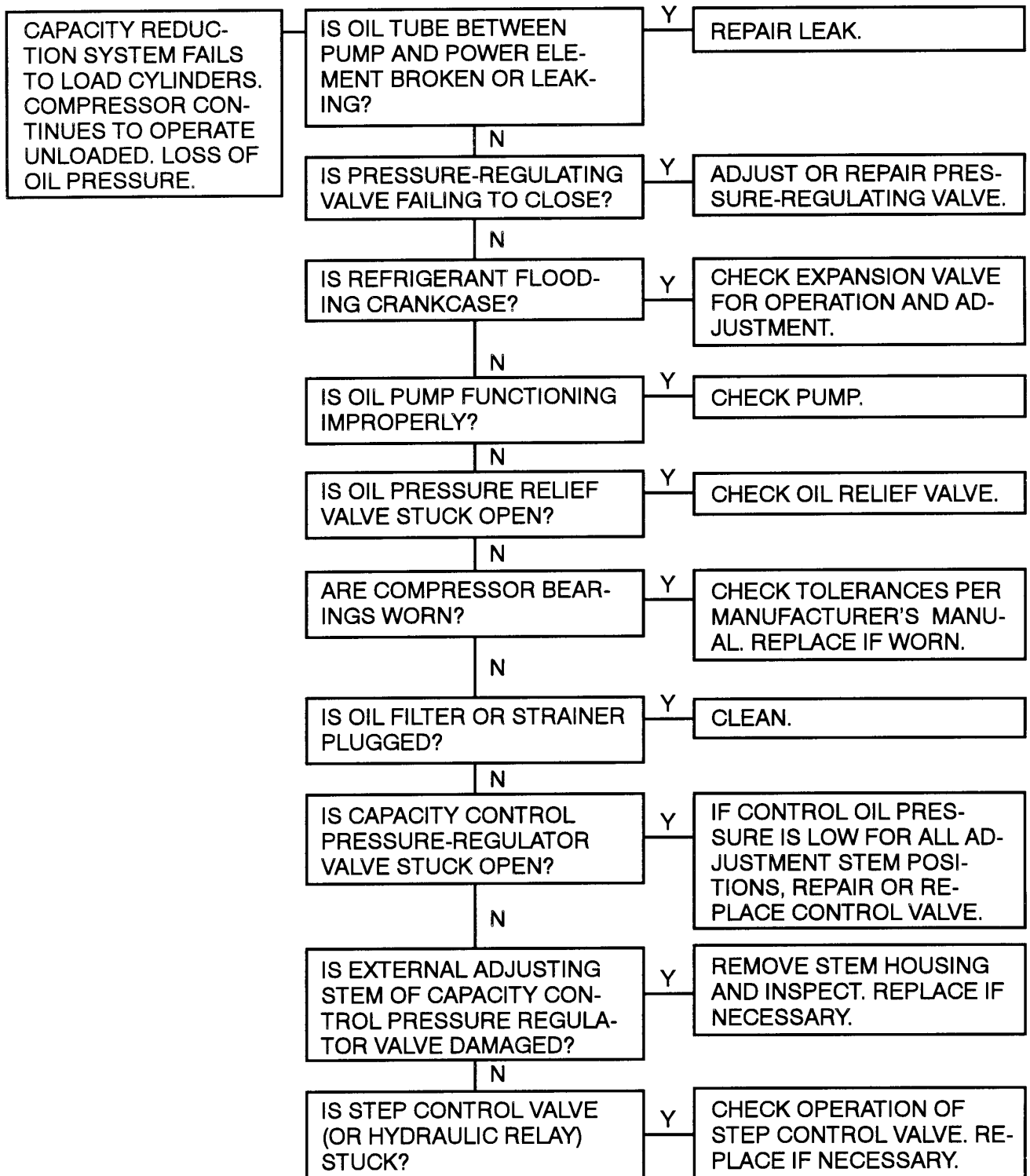


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 12 of 21)

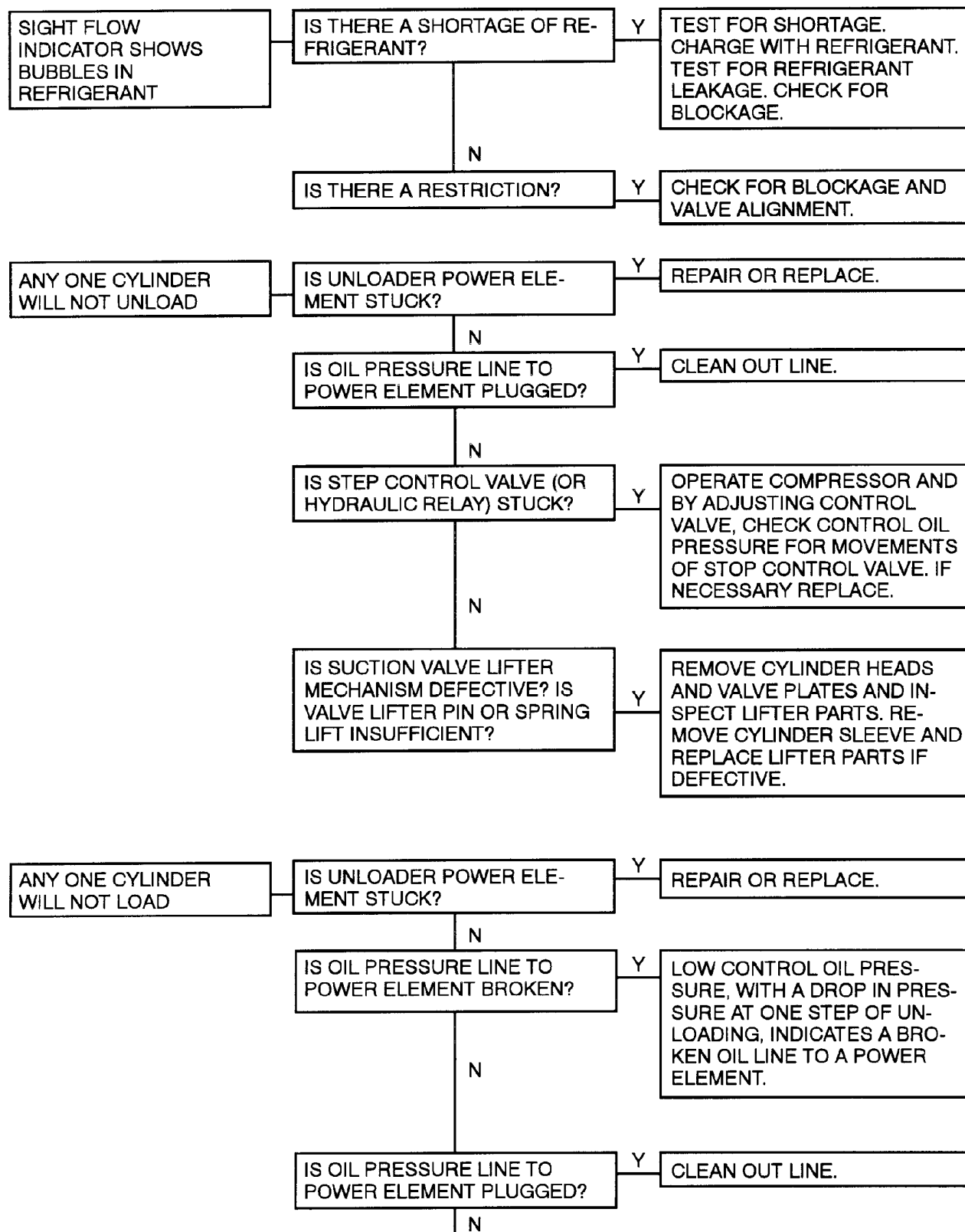


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 13 of 21)

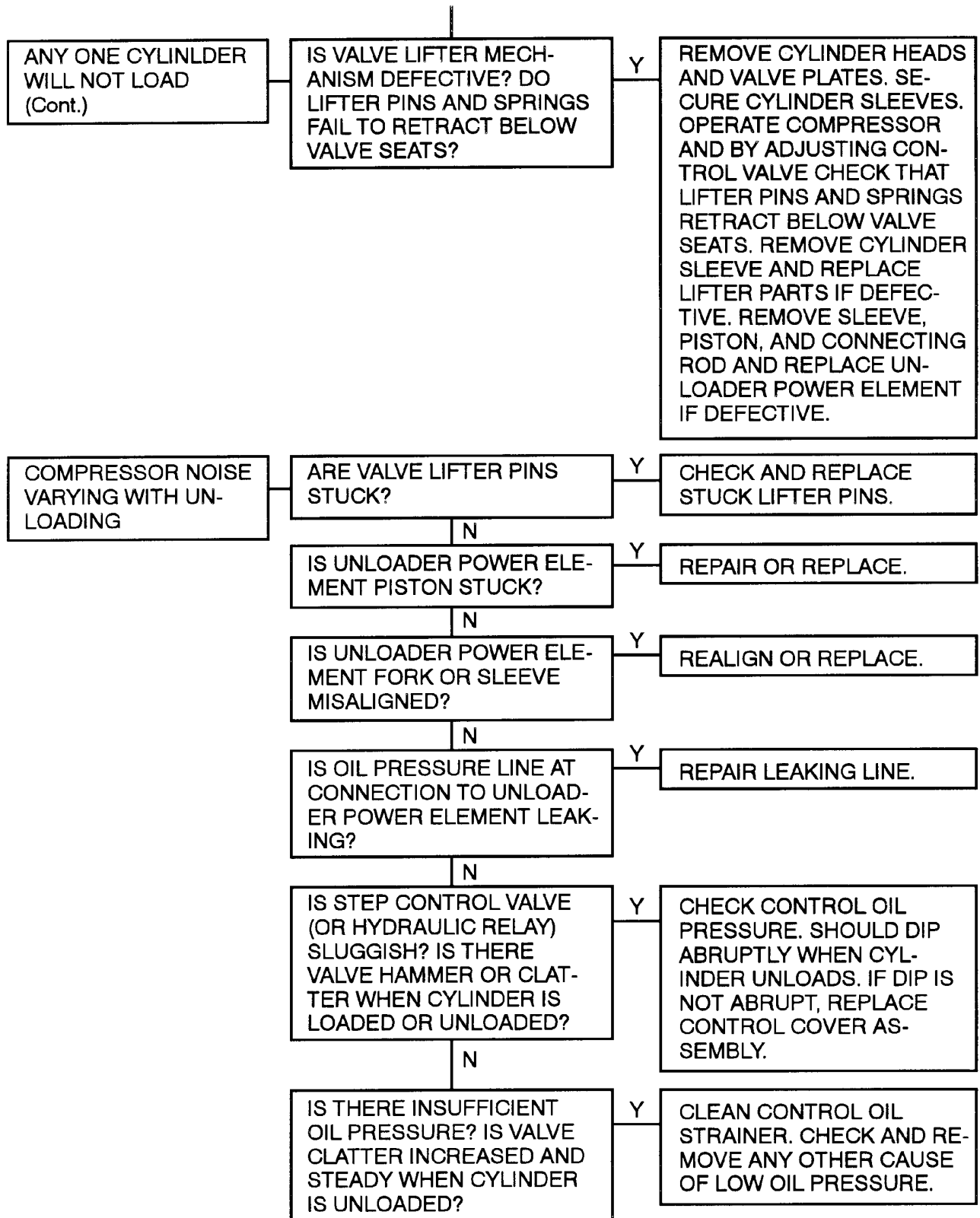


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 14 of 21)

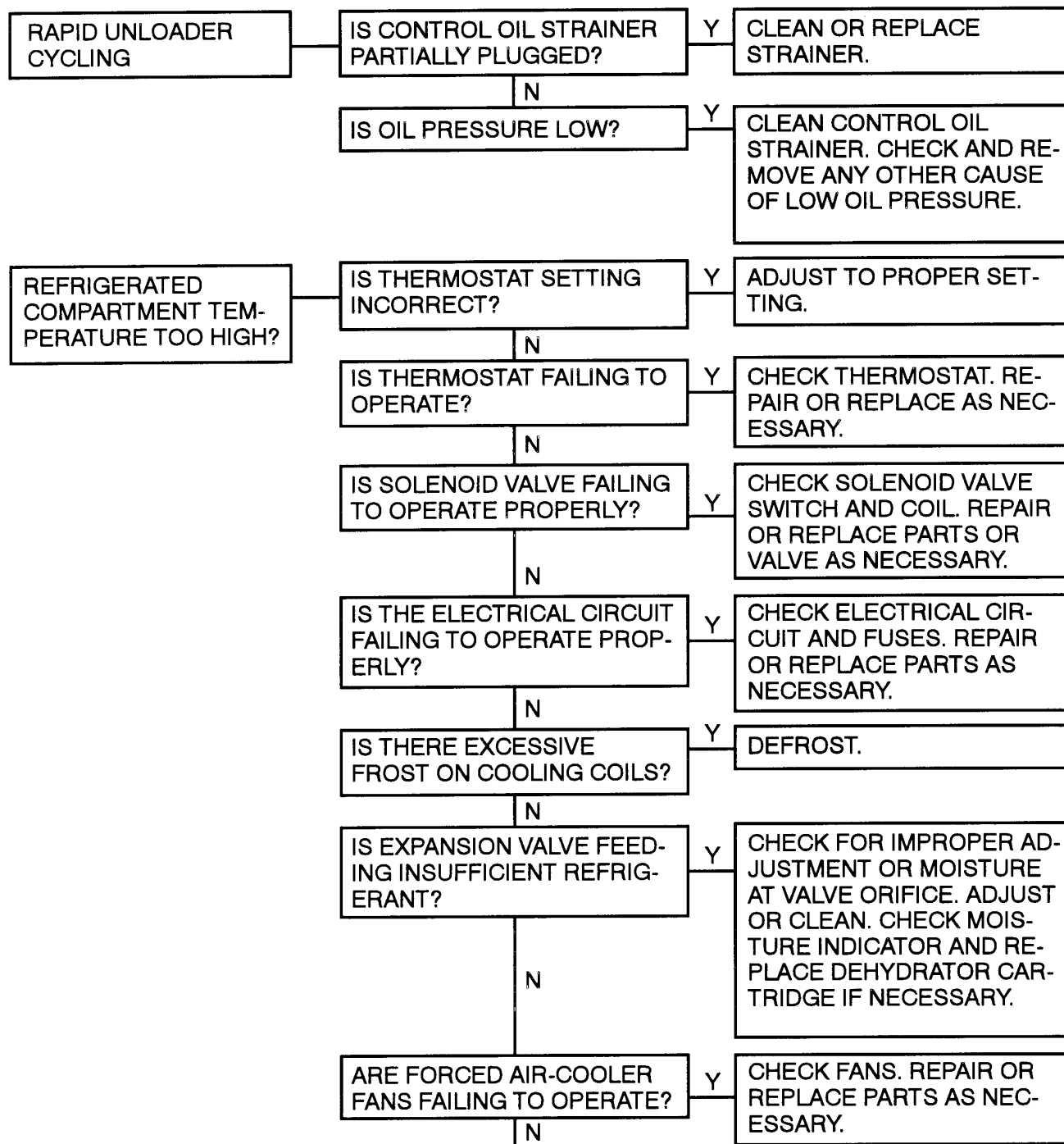


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 15 of 21)

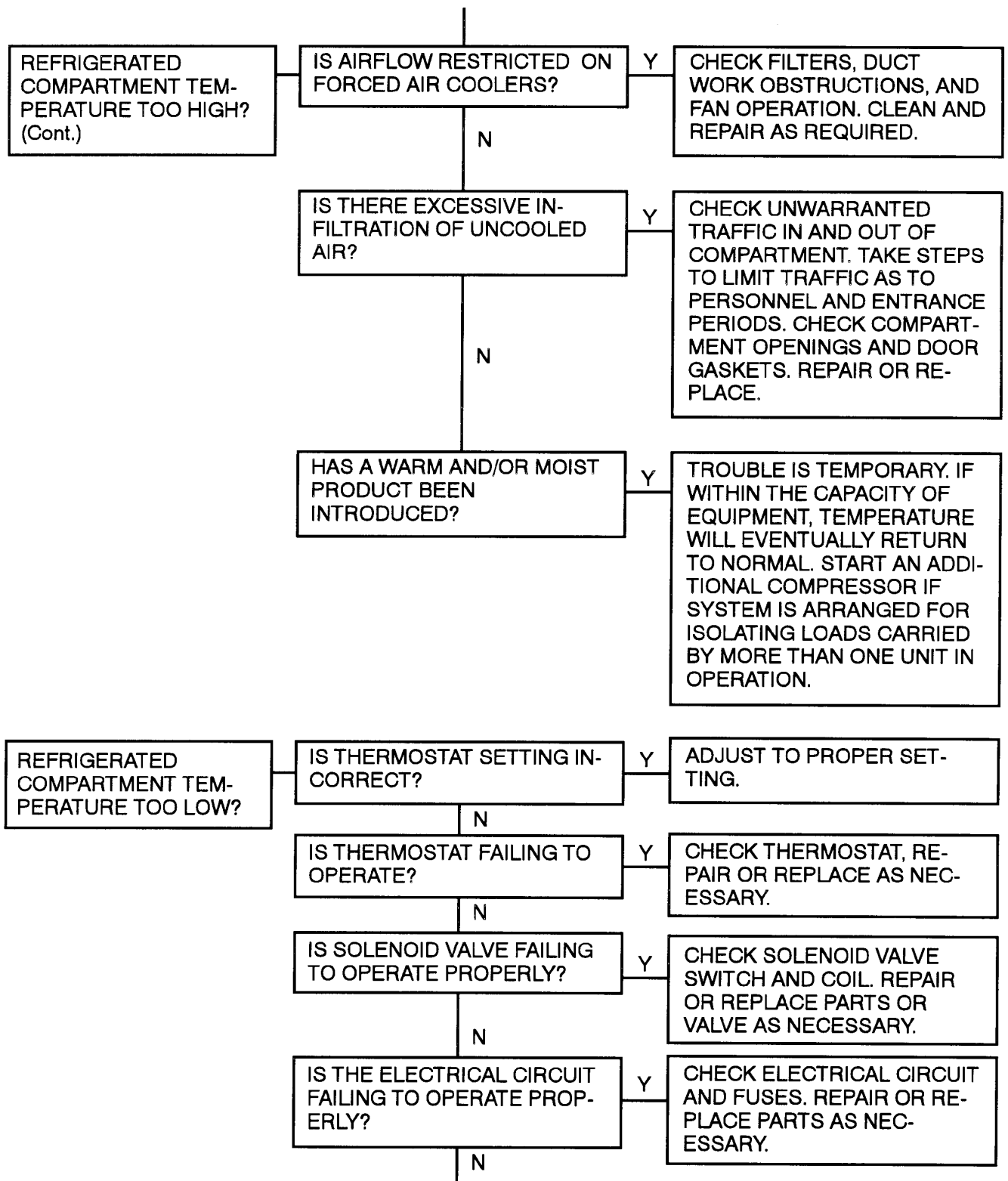


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 16 of 21)

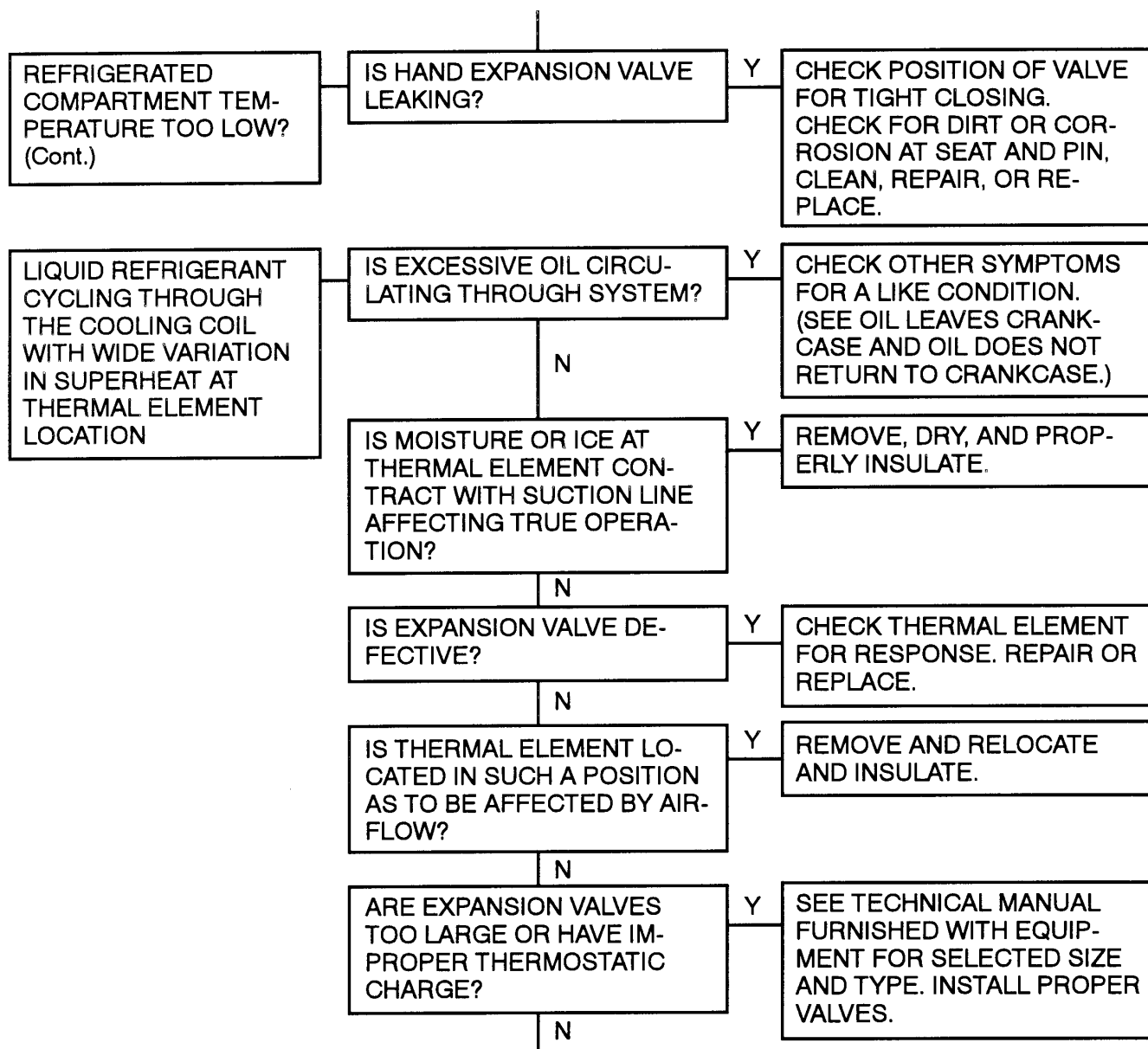


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 17 of 21)

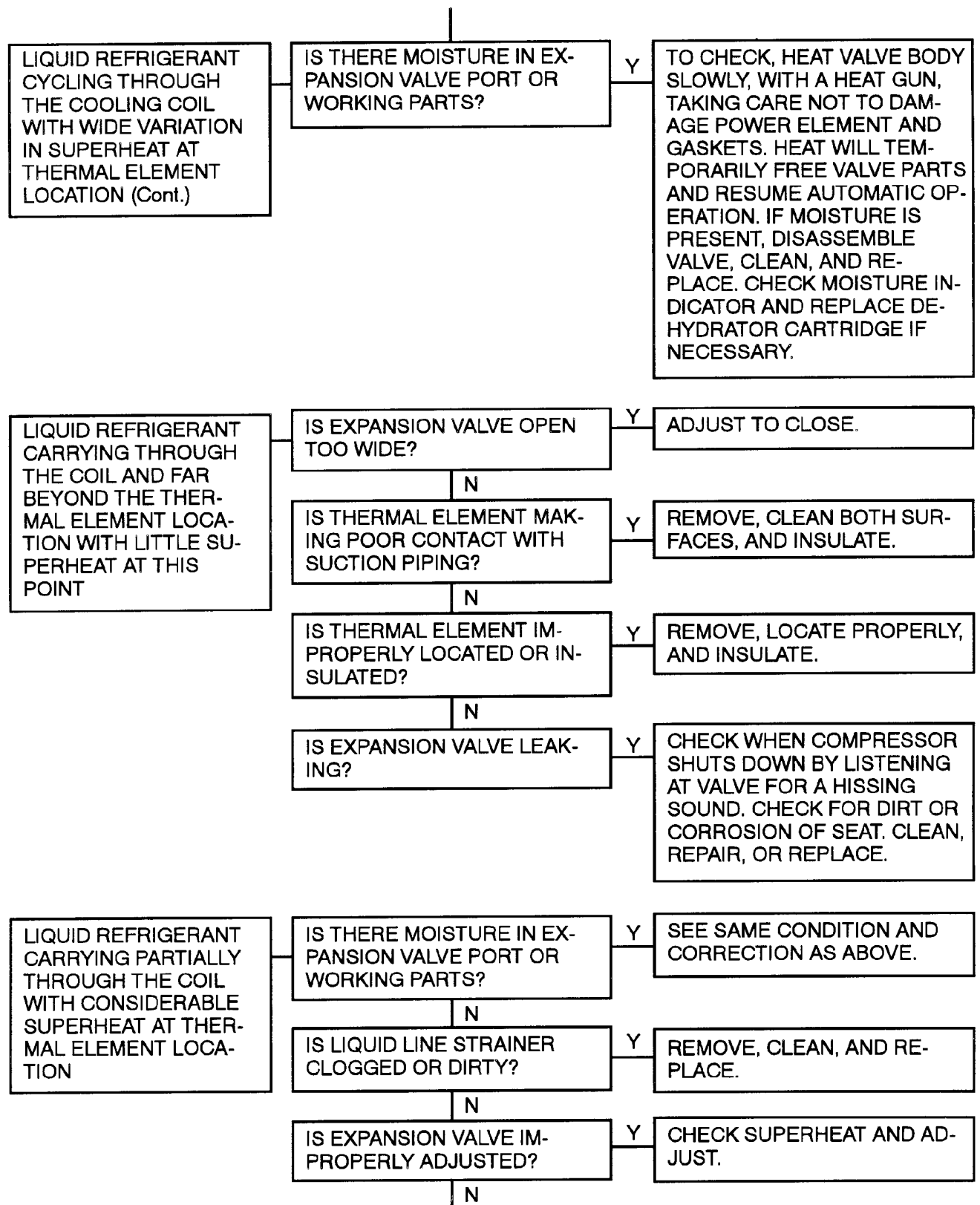


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 18 of 21)

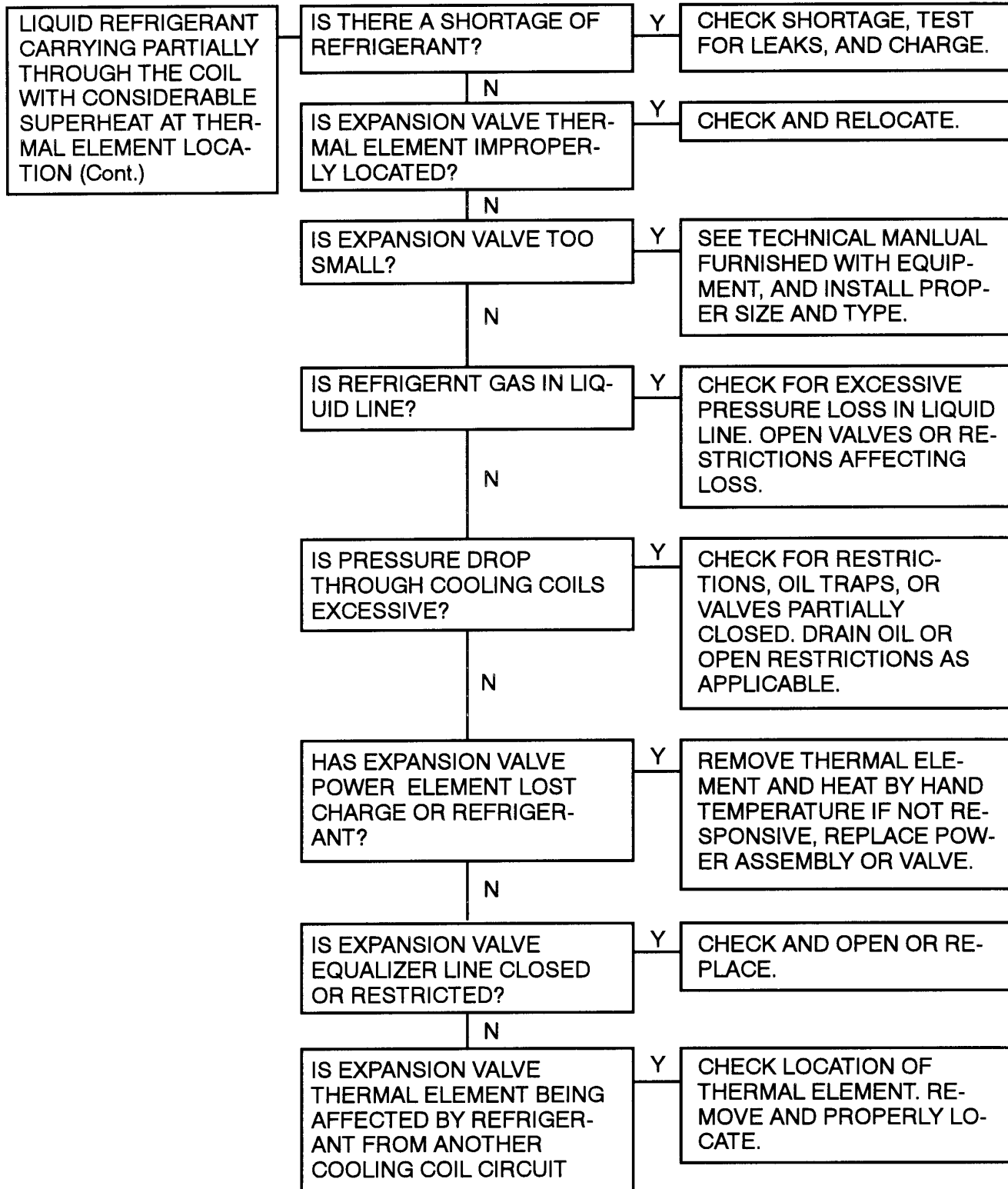


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 19 of 21)

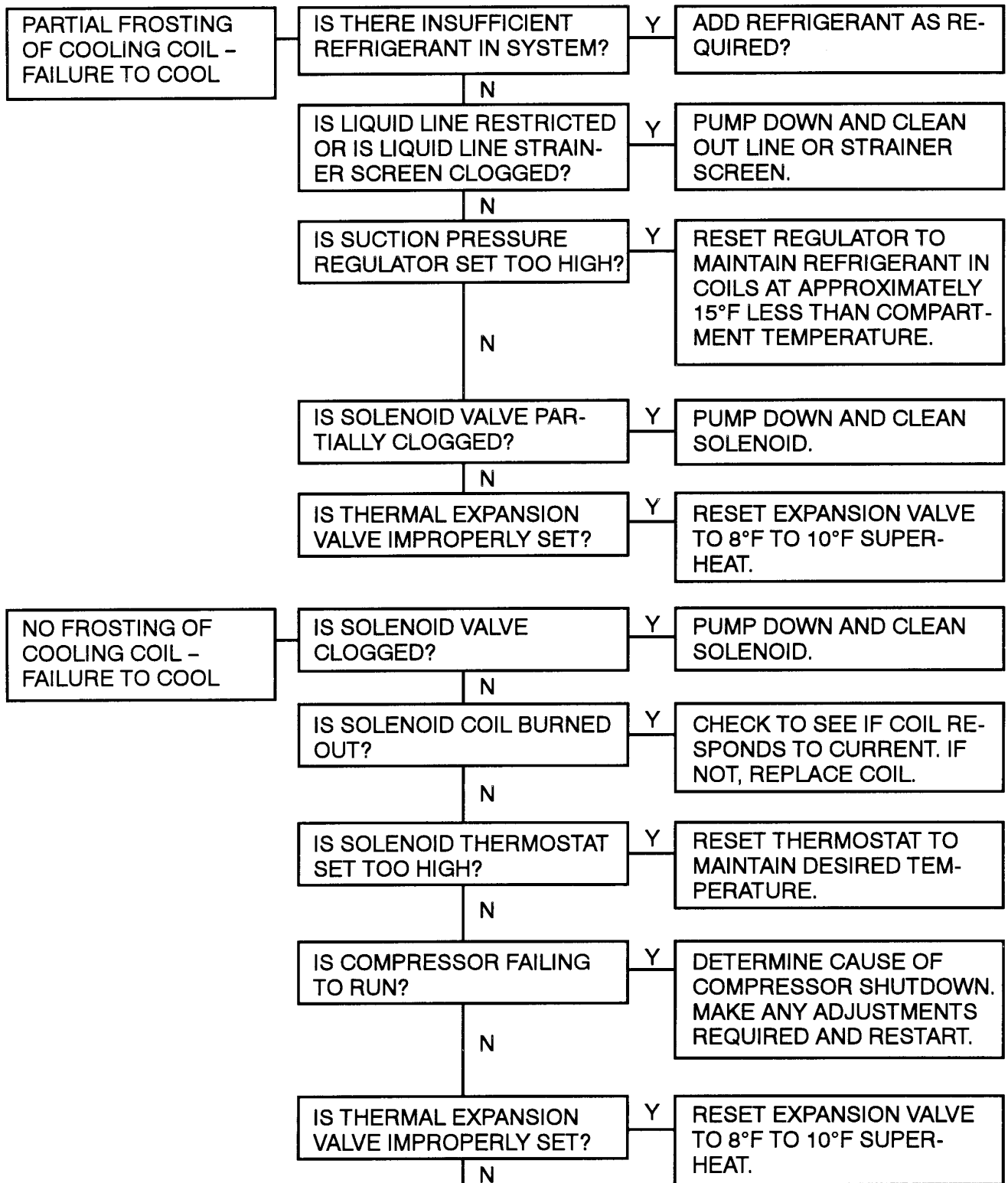
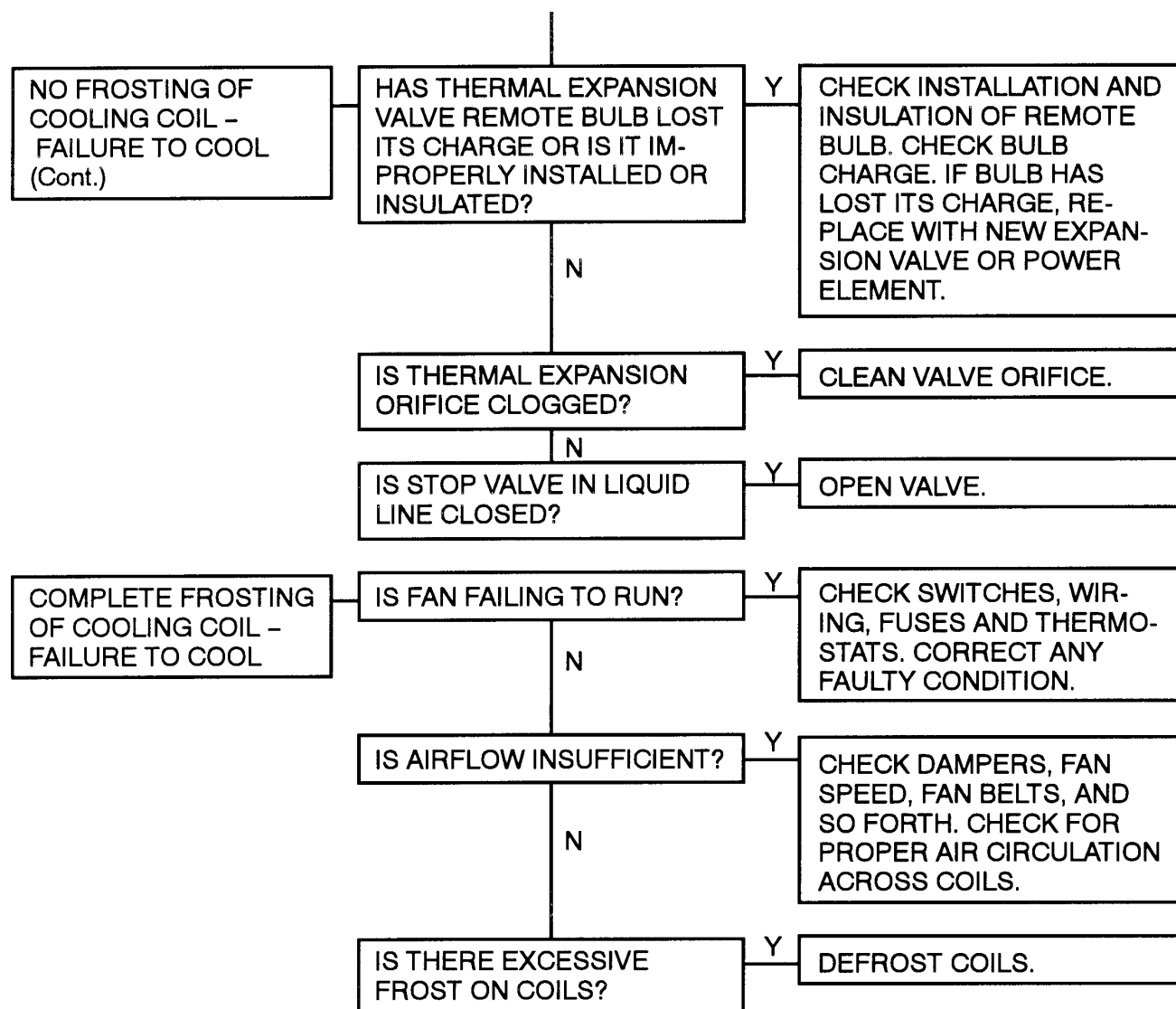


Figure 516-4-7. Reciprocating Refrigeration System (Sheet 20 of 21)



*CONTINUOUS COMPRESSOR OPERATION IS NORMAL IN FULL LOAD AIR-CONDITIONING APPLICATIONS.

Figure 516-4-7. Reciprocating Refrigeration System (Sheet 21 of 21)

516-4.1.42 Expert Systems. An Expert System is a computer program that provides the non-expert user with a highly interactive, user friendly mechanism for obtaining expert advice and decision making capabilities normally requiring an expert (A technical representative on a disk.). An Expert System is system specific and can be used for troubleshooting and maintenance diagnostics and for training. The objective of the Expert Systems diagnostic software programs, developed by FTSC LANT, FTSC PAC, and CDNSWC, is to provide personnel engaged in the operation and maintenance of shipboard air-conditioning and refrigeration systems with an affordable stand-alone tool that can be utilized without special equipment or procedures to enhance their ability to maintain operational readiness and attain maintenance self-sufficiency. Expert systems may also be available from other sources.

SECTION 5.

CENTRIFUGAL COMPRESSOR PLANTS

516-5.1 INTRODUCTION

516-5.1.1 PLANNING. The previous sections dealt with the fundamentals of refrigeration, including the behavior of common refrigerants; and a vapor-compression refrigeration cycle, its components, and accessories. Reciprocating compressors were described in detail as well as some of their operational characteristics when combined with other components to form a complete refrigeration plant. A given air-conditioning system may use any one of several refrigeration plants. In planning a ship air-conditioning system, a study precedes the actual design. Such a study will point out the advantages of various systems and refrigeration plants to select the optimum for the system.

516-5.1.2 SCOPE. This section will describe refrigeration plants employing a centrifugal compressor plus condenser, evaporator (water chiller), and control devices assembled to operate as an integral unit. The design and characteristics of the centrifugal compressor are discussed to give Navy personnel an adequate background on this type of unit and to help personnel analyze operating problems. For component details, arrangement, and specific maintenance requirements, refer to the applicable technical manual for each unit. The manuals on centrifugal plants are more specific and current than those for reciprocating plants.

516-5.2 COMPRESSOR PLANTS

516-5.2.1 CENTRIFUGAL REFRIGERATING PLANTS. From a thermodynamic standpoint the centrifugal refrigeration cycle is identical to vapor compression using a reciprocating compressor, but the means of compressing the refrigerant is different. As indicated, a reciprocating compressor is a positive displacement machine in which the pressure of the refrigerant vapor is increased by a piston squeezing gas in a cylinder. The centrifugal compressor is a variable displacement machine. It has one or more impellers, spinning in specially formed housing, which impart centrifugal force to the gas. Low-pressure, low-velocity vapor from the suction line is drawn into the inlet cavity, or eye of the impeller wheel, along the axis of the rotor shaft. On entering the impeller wheel, the vapor is forced radially outward between the impeller blades by action of the centrifugal force developed by the rotating wheel. The vapor is then discharged from the blade tips into the compressor housing at a high velocity. This high-velocity vapor is collected in specially designed passages in the casing. Velocity energy resulting from the centrifugal force is converted to pressure. Because flow is continuous, centrifugals have greater volumetric capacities, size for size, than do positive displacement machines. For effective momentum exchange, the rotative speeds of centrifugals are higher than that of reciprocating. Centrifugal compressor speeds may be as high or higher than 15,000 rpm. A centrifugal refrigeration machine is basically a large-capacity unit that handles large volumes of refrigerant gas. A centrifugal compressor is suitable for use with a refrigerant that has a high volume per ton.

516-5.2.2 REFRIGERANT SYSTEM TYPES. In the design of centrifugal machines, various halocarbons with varying physical properties can be used. [Table 516-5-1](#) shows the volume flow rates of several refrigerants that have been used in centrifugal refrigeration units. R-11, R-114, and R-236fa can be used in small capacity units; R-12 and R-134a can be used in units with capacities above 1,000 tons. R-113 has not been used in Navy applications. The smallest capacity centrifugal compressor installed in Navy ships is a 110-ton R-11 plant. The minimum R-114 capacity installed is 125 tons.

Table 516-5-1. VOLUME FLOW RATES FOR VARIOUS REFRIGERANTS

Refrigerant	Flow Rate Cfm per Ton
R-11	18.21
R-114	10.50
R-12	3.47
R-134a	3.36
R-236fa	later
Suction temperature 35° F Condensing temperature 105° F.	

516-5.2.2.1 The R-11 centrifugal plant will probably not be used in Navy ships in the future. The R-11 system operates at approximately 17 to 18 inches of mercury vacuum at the suction side. In a system with vacuum, any small leak will draw air and moisture into the plant. With the introduction of air and moisture into the system, acids form, causing considerable internal corrosion, lube oil breakdown, hermetic motor insulation damage, and other system problems, and finally complete breakdown. In addition, the R-11 refrigerant is less stable with moisture than some other refrigerants. Although an R-114 system operates at a slight vacuum on the suction side, this refrigerant is more stable and units using it have proved more reliable. Another advantage of R-114 is that, at standby, the R-114 plant is normally at a positive pressure, whereas the R-11 may be under a vacuum, depending on the ambient temperature. The positive pressure in the R-114 will minimize the entrance of contaminants if a small leak is present. R-114 will be replaced with R-236fa in the Navy's currently installed centrifugal chillers because R-114 and other ozone-depleting substances are being phased out of production. New centrifugal plant designs will use R-134a or R-236fa which have ozone depletion potentials of zero.

516-5.2.3 CENTRIFUGAL COMPRESSOR LIMITATIONS. Ship operating personnel often ask why not to use centrifugals for ship stores application or other low-capacity applications, particularly since centrifugals have better overboard noise characteristics than reciprocating machines. A low-capacity centrifugal design specification can be attained only if an impeller, small enough to meet the low capacity can be manufactured. In small impellers, gas passages are narrower. This presents a casting problem; there is also the problem of the overall efficiency of small-capacity machines. With two machines, one large and one small, of a fixed design and operating at a fixed speed, the efficiency losses of the smaller impeller will be almost as great as the larger capacity impeller. The final result is a minimum acceptable capacity from both a manufacturing limitation and efficiency losses in centrifugal machines. Because of these limitations, centrifugal machines are not generally built in capacities of under 100 tons of air-conditioning.

516-5.2.4 COMPRESSOR OPERATION. Centrifugal compressors cannot operate in the complete capacity range from rated flow to very low flow as can reciprocating compressors. Operation of centrifugal compressors at conditions of reduced capacity is limited by the surge or pulsation point. Surging is an operating characteristic of all centrifugal compressors in which the machine rapidly alternates between shutoff and a flow rate of near maximum, as indicated by rapid fluctuations of pressure and power input. This point usually occurs at less than

50 percent of design capacity. The surging condition, actually a flowback of gas, occurs when the compressor capacity is substantially greater than the evaporation rate in the cooler. Capacities below the surge point are said to be in the unstable range.

516-5.2.4.1 Avoid extended operation in the unstable range. Never permit a centrifugal compressor to surge for any length of time; immediately correct the condition or secure the compressor and correct the problem. The surge point of a compressor can be lowered by using suction dampers or it can be avoided at low capacity by using a hot gas bypass to increase the suction gas flow. In chilled water applications, the low-capacity point (lowest suction pressure) is the limit at which the water freezes.

516-5.2.5 COMPRESSOR SURGE. To illustrate the surging phenomenon, a typical head versus capacity curve for a centrifugal compressor is shown in Figure 516-5-1. B is the point of maximum pressure on the curve, and SP is the selection point for the compressor. Assume that the compressor is operating at SP. If the load on the compressor falls off, the operating point will move to the left on the curve past SP and finally reach point B. If the load continues to drop and a capacity less than Q_B is required, the pressure in the system will be higher than at the compressor outlet. The flow will actually stop momentarily, since the operating point quickly moves from B to A (shutoff). Refrigerant vapor will still be leaving the casing of the compressor, and the system pressure will fall below P_A . With the system pressure below P_A , the compressor begins to deliver refrigerant vapor again, but the discharge pressure will not build up fast enough to follow the curve AB. Thus, the compressor attempts to deliver a volume flow rate corresponding to its discharge pressure, which is Q_C or greater. This is characterized by a surge (a rapid increase in flow rate and a marked change in noise level of the compressor). A rapid change in discharge pressure occurs along with motor current fluctuation.

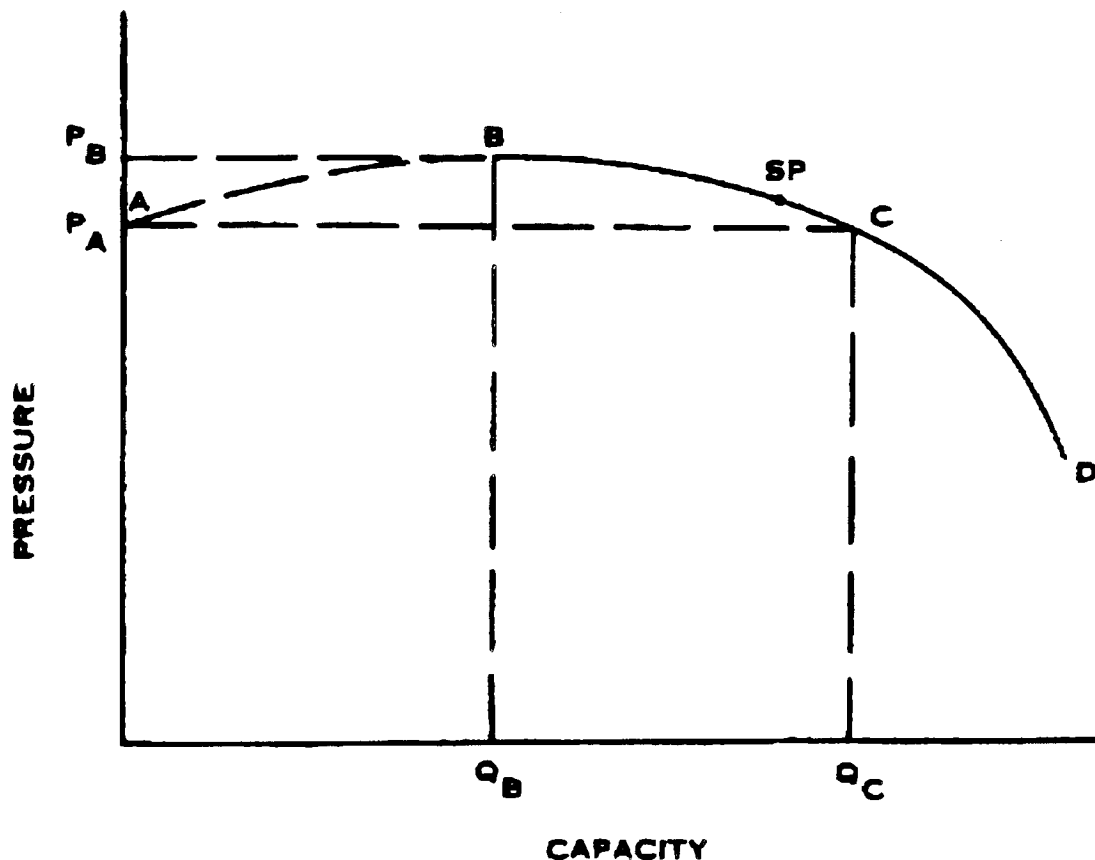


Figure 516-5-1. Head Vs. Capacity for Centrifugal Compressor

516-5.2.5.1 In attempting to deliver the volume QC, the compressor begins to operate between C and B. The discharge pressure begins to build up and the capacity decreases. As soon as point B is reached, flow immediately stops until the system pressure is lower than PA. Then the compressor surges again as it attempts to operate at point C. The cycle repeats itself until the load becomes greater than QB. SP is the proper operating point for a typical centrifugal compressor. The stable operating range, B to D, represents only a small change in pressure. As long as the compressor is delivering a volume flow rate greater than QB, it will be operating in the stable range.

516-5.2.6 OPTIMUM CAPACITY AND POWER SELECTION. The key problem in selecting a particular compressor for a job, or determining capacity ratings for an application, is where to make the compressor selection for full load. Practically, it may be on the 90-degree vane opening line as long as it is just far enough away from the surge line that the flatter system characteristic curve does not intersect the surge line at a point above the minimum capacity at which the machine shall operate. The selection point may be to the left of the 90-degree curve as long as the efficiency is not sacrificed appreciably, and as long as the system characteristic satisfies the minimum stable capacity range as mentioned above.

516-5.2.6.1 The use of variable inlet guide vanes is the most economical means of capacity control for centrifugal compressors. Not only does it move the surge point to a lower load and increase the stable operating range of the compressor, it also yields almost a direct relation between reduction in capacity and power. This method of capacity control is the only one that permits the centrifugal compressor to operate as low as 10 percent of rated capacity and still maintain stable and efficient performance.

516-5.2.7 CENTRIFUGAL COMPRESSOR CONTROLS. The subject of controls for centrifugal refrigeration systems can logically be divided into capacity control methods and safety control devices. The typical air-conditioning system requires maximum cooling only a few consecutive hours from time to time during a cooling season. Other load conditions for typical air-conditioning systems are generally long periods of almost constant partial load or a load varying from minimum to maximum in a relatively short time. The manufacturer of centrifugal refrigeration systems would like to design each machine in the series with enough flexibility to operate satisfactorily during these periods.

516-5.2.7.1 A simple solution would be to have the machine operate at its maximum output until the load was satisfied, then shut itself off and automatically continue on-and-off operation. If a centrifugal compressor were to operate only at rated capacity, it would have to start and stop frequently as the load varied. Even though the centrifugal compressor motor starts unloaded, starting and stopping a large motor six or eight times an hour would be prohibitive for satisfactory motor life. It would also be expensive from an operating and maintenance standpoint. Some reciprocating compressors can operate with off-and-on control, but this is an unsatisfactory means of capacity control for a centrifugal compressor. Since off-and-on control is unsatisfactory for centrifugal refrigeration compressors, some means is needed to vary the output from nearly zero load to full load and still keep the machine running. The stable range of a centrifugal refrigeration compressor is from full load to the surge point, which is normally about 1/2 to 2/3 capacity. The design engineer seeks ways to widen the stable operating range of the impeller and a means of lowering the surgepoint to as low a capacity as possible. Various methods of accomplishing capacity control have been used and are currently available. They vary considerably in their effectiveness and in the resulting efficiency at part load.

516-5.2.7.2 The current practice in capacity control for Navy applications is to use prerotation vanes (variable inlet guide vanes) and hot gas bypass control. Each control design will not be enumerated in this manual, as con-

trols applicable to the various compressors are indicated and explained in each technical manual. However, capacity control by prerotation vanes and hot gas bypass is indicated here so that the operator can better understand compressor characteristics and operation.

516-5.2.7.2.1 Compressor Prerotation Vanes. The prerotation vanes or variable inlet guide vanes consist of a number of wedge-shaped, center-pivoted dampers that divide the gas stream into several segments. [Figure 516-5-2](#) illustrates a typical damper assembly of this type. The vane shaft is in the center of each vane and extends through the damper housing, where it is connected to an actuator ring. A control device, through an operator and linkages, adjusts the position of the actuator ring and thereby positions all guide vanes simultaneously. The reduction in area between the vanes as they are moved from fully open toward closed position causes a pressure drop. This in turn increases the specific volume of the gas entering the impeller and reduces the mass flow. The guide vanes serve another purpose. They impart a spin to the gas flowing into the impeller in the direction of impeller rotation. This reduces the tendency for stall at the inlet edge of the impeller blades and provides greater stability. A velocity component in the direction of rotation at the impeller inlet can also be considered to push the impeller; the effect is to reduce horsepower as well as capacity.

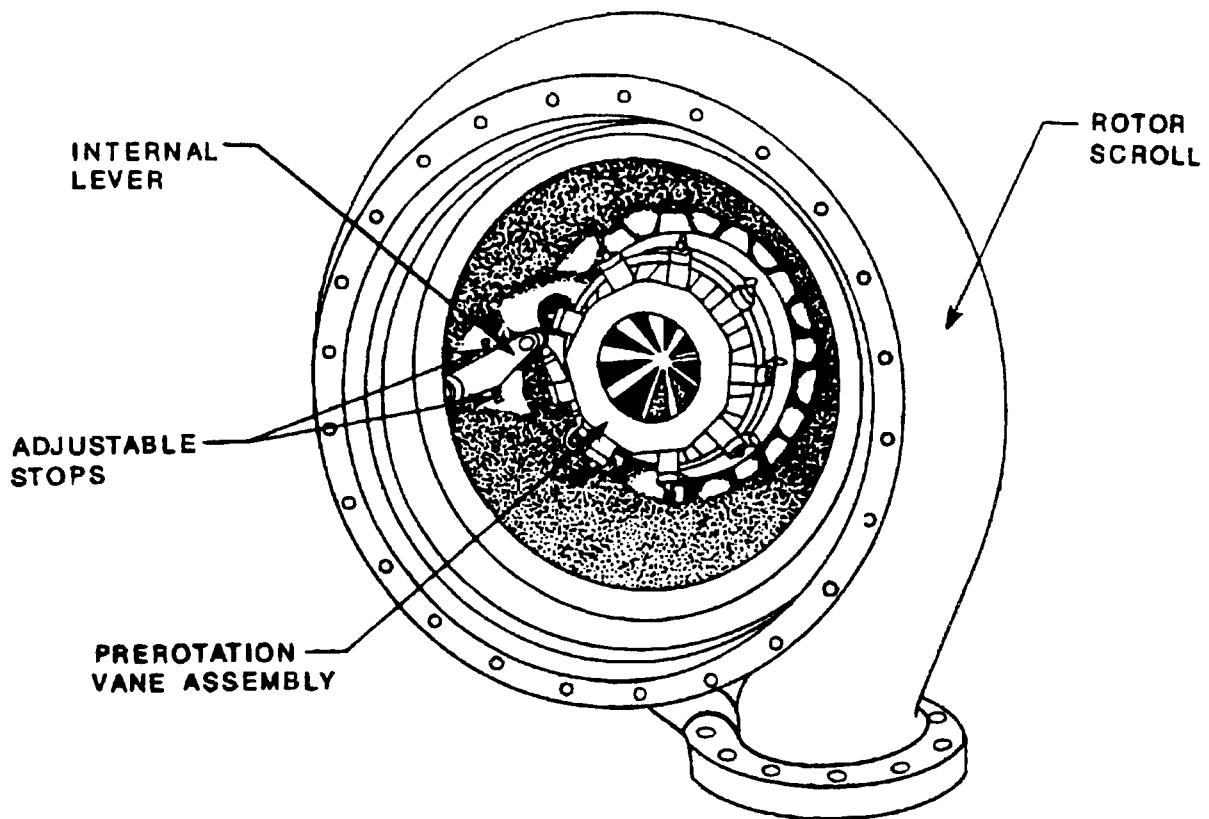


Figure 516-5-2. Rotor Scroll with Prerotation Vane Assembly

516-5.2.7.2.2 Compressor Performance with Prerotation Vanes. To illustrate how prerotation vanes or variable inlet guide vanes affect typical compressor performance, a capacity-versus-head curve is shown in [Figure 516-5-3](#). The 90-degree vane position curve in [Figure 516-5-3](#) is the 100-percent capacity-versus-head curve. The other capacity versus head curves in [Figure 516-5-3](#) have been plotted for various reduced vane angles. Thus, there is a family of curves, with each lesser vane angle producing a curve having less capacity and less head.

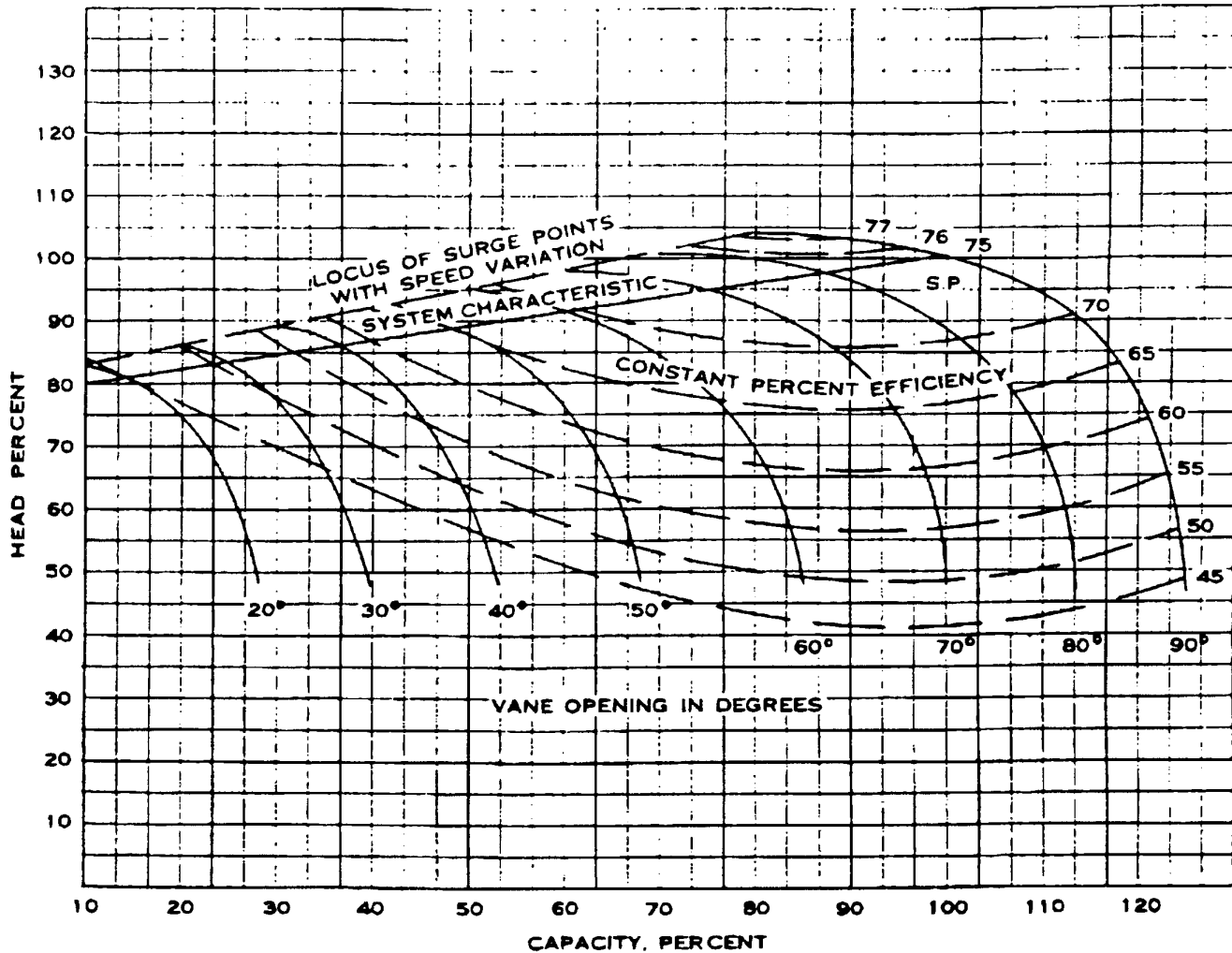


Figure 516-5-3. Variation in Capacity of Centrifugal Compressor with Prerotation Vane Control

516-5.2.7.2.3 Just as there is a stable range and a surge point for the 90-degree vane angle (100-percent capacity), there is a similar stable range and surge point for each curve in the family. The various surge points connected by a line form the surge line for this particular compressor. This surge line and the 90-degree vane opening line set the boundaries of the stable operating range of the compressor. Curves of constant compressor efficiency have also been plotted in [Figure 516-5-3](#). The efficiency falls off very slowly with the closing of the inlet vanes. The system head characteristic line can also be determined for any combination of compressor, evaporator, and condenser; and it has been plotted in the curve through an arbitrary selection point (SP).

516-5.2.7.2.4 Hot Gas Bypass Control. Although a compressor can be designed so the system surge point does not come into play at the various operating points, York includes a hot gas bypass control in the units it supplies to the Navy. The Carrier units do not include a hot gas bypass control. The hot gas bypass is installed between the discharge side of the compressor and the evaporator shell. When the load is reduced to the set point, a valve opens the bypass and permits high-pressure vapor from the discharge side of the compressor to enter the evaporator. Theoretically, the stable range is extended to zero load, although in practice the compressor may become too hot when all the vapor is recirculated through the bypass. Where no hot gas bypass is included, the low oper-

ating point would depend on where the chilled water is reduced to approximately 38° F, at which point the compressor will shut down. The low water temperature switch opens at 38° F and closes at 46° F. The Carrier units are arranged to automatically restart after a time delay following a shutdown on low chilled water temperature.

516-5.2.8 NAVY PLANTS WITH CENTRIFUGAL COMPRESSORS. Centrifugal compressor plants used in Navy applications are installed as package units. The components are close-coupled to keep the refrigerant line pressure losses to a minimum because of the inherent flat head capacity characteristics. This is compounded by the fact that the pressure differences between the evaporator and condenser are small relative to those of a reciprocating system. A flow for a typical R-114 centrifugal compressor plant, showing a flow diagram and a general arrangement, is shown in [Figure 516-5-4](#) and [Figure 516-5-5](#). Note the close-coupled, large pipe diameter of the suction connection, which is designed to minimize pressure drop and handle large volumes of refrigerant gases. These plants usually include a compressor with the following components:

- a. An open or a hermetic motor
- b. Controller
- c. Oil pump or pumps
- d. Oil coolers
- e. Oil filters
- f. Oil heaters
- g. Gauge board and indicating lights
- h. Purge and pump-out units to remove noncondensable gases and moisture, and to transfer the refrigerant to a receiver
- i. A remote receiver to retain the refrigerant
- j. Operating and safety controls, either pneumatic or electronic
- k. Basic components mounted on a common base with or without resilient mounts, depending on the application.

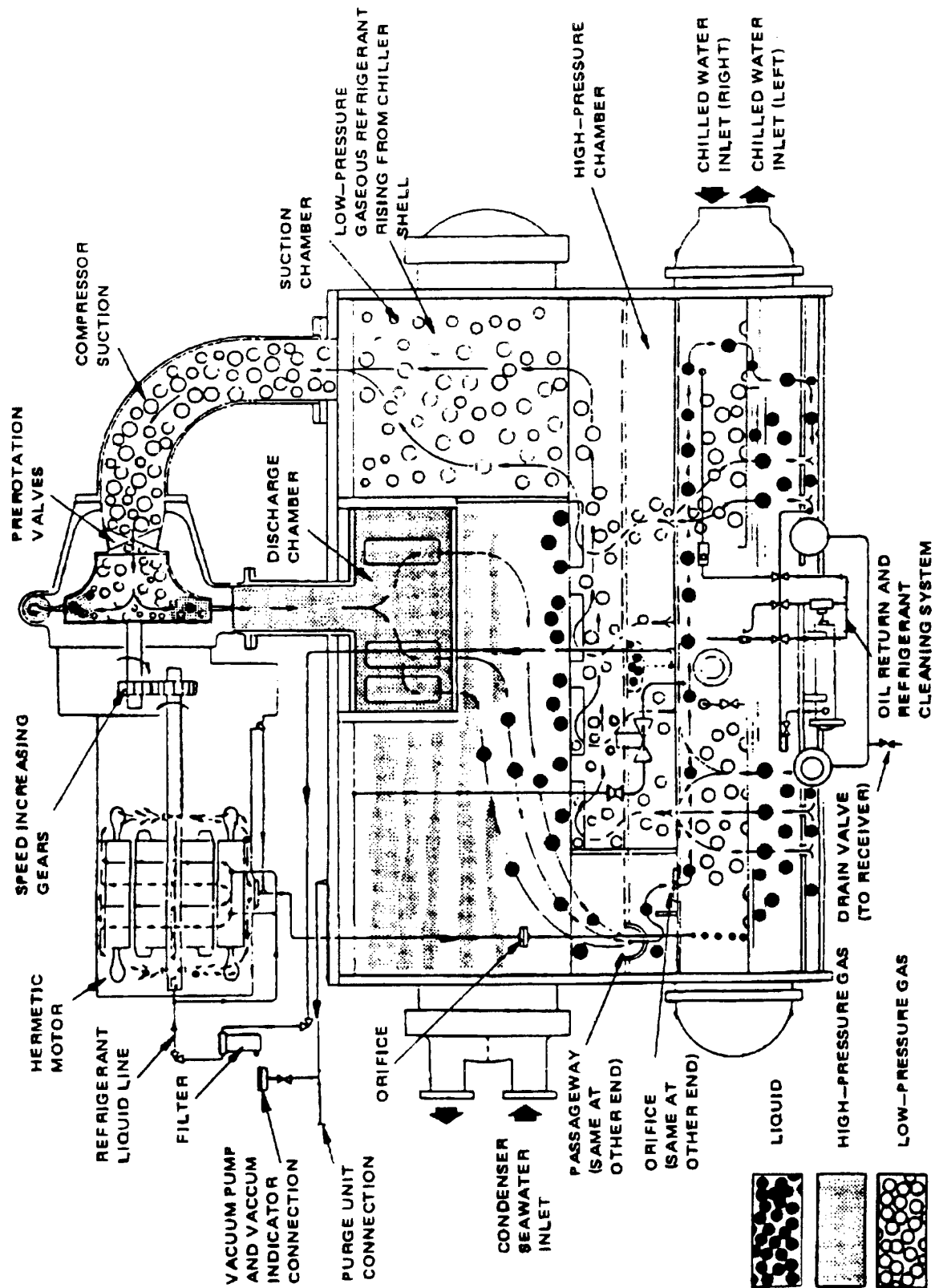


Figure 516-5-4. Refrigeration Flow Diagram

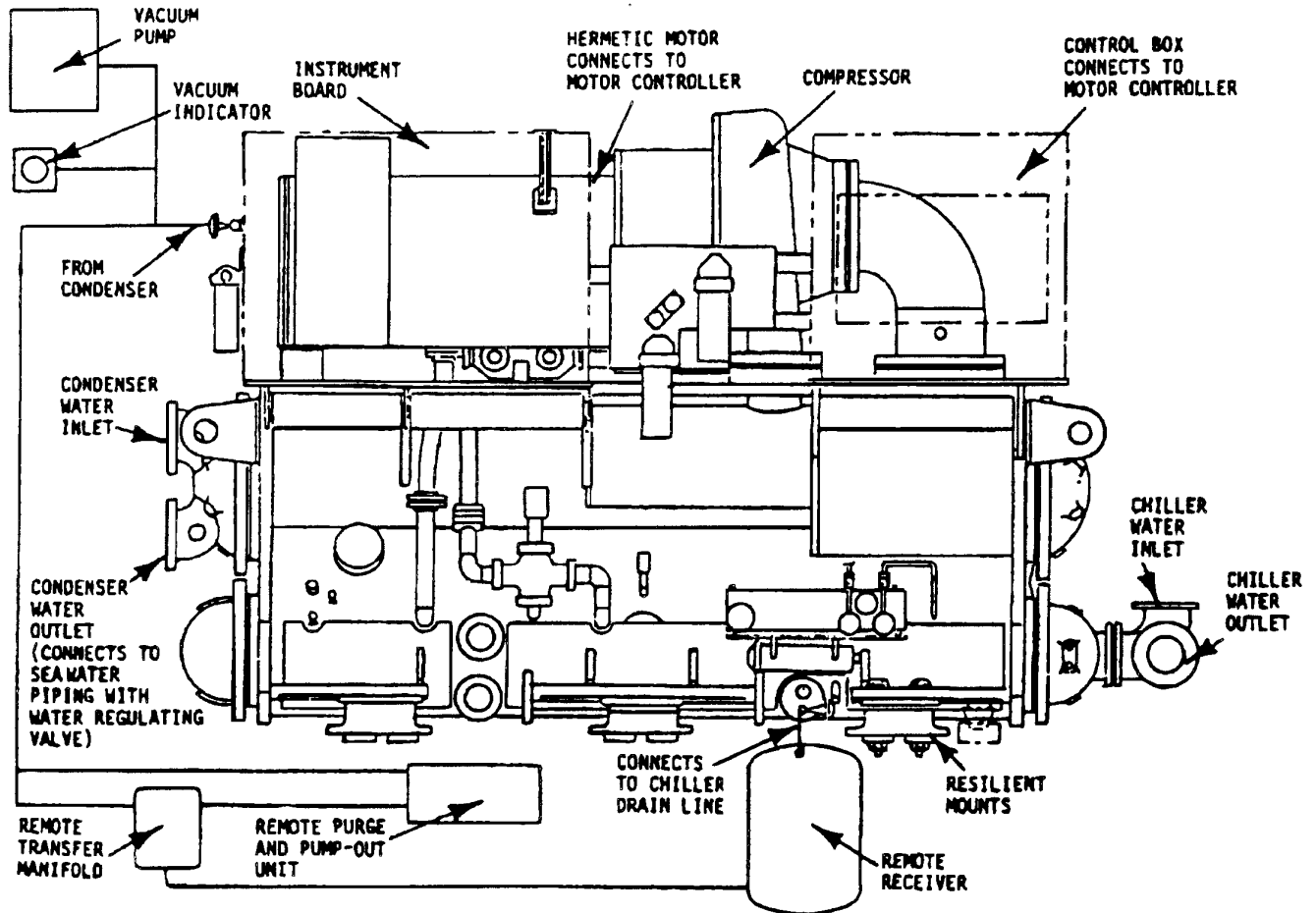


Figure 516-5-5. Relationship of Equipment Units

516-5.2.9 CENTRIFUGAL COMPRESSOR UNIT. The centrifugal compressor unit consists essentially of one or more impeller wheels mounted on a shaft enclosed in a casing, prerotation vanes, speed-increasing gears; and for open-type units, shaft seals, coupling, and motor; or, for hermetic units, a hermetic motor.

516-5.2.9.1 The rotor assembly is supported radially in the housing by two main bearings. A thrust bearing mounted on the discharge end of the shaft positions the rotor assembly axially in the casing. Single-stage compressors are generally of the overhung configuration with the impeller support on the end opposite to the suction inlet. As in the case of the open-type reciprocating compressors, a shaft seal is employed between the compressor housing and the rotor shaft to prevent inward and outward leakage.

516-5.2.9.2 The compressor is pressure lubricated by various methods; either by an oil pump driven directly from the rotor shaft(s) and a separate, externally-mounted, motor-driven (auxiliary), oil pump for starting and stopping; or by one electrically-driven oil pump that performs all the same functions. The auxiliary oil pump starts first to establish oil pressure before the compressor starts and runs for a period of time after the compressor is stopped to provide oil pressure during coast down.

516-5.2.9.3 The principal parts of the compressor requiring lubrication are the main bearings, thrust bearing, shaft seals, and internal speed increaser gears. The leakage of oil along the rotor shaft from the main bearings

into the refrigerant cavities is minimized by the use of oil seal glands, which are installed on the inboard side of each of the main bearings. Oil coolers maintain proper oil temperature during normal operation. Oil heaters installed in the oil reservoir prevent excessive refrigerant dilution of the oil during periods of shutdown. Oil filters are standard equipment on all centrifugal compressors. The lubrication systems for hermetically sealed compressors may differ somewhat because of their construction and the need to also provide lubrication for the hermetic motor bearings. To attain the higher-than-motor compressor speed with a maximum motor speed of 3,600 rpm, speed increasing gears are provided.

516-5.2.9.4 During periods of shutdown, the oil in the reservoir tends to absorb as much refrigerant as it can hold, depending on the temperature of the oil and the refrigerant pressure in the unit. As the temperature of the oil is lowered or the refrigerant pressure increases, the amount of the refrigerant absorbed will increase. If the amount of refrigerant absorbed by the oil becomes excessive, violent oil foaming will result during startup, as the pressure within the system is lowered on starting. The foaming of the oil is caused by absorbed refrigerant evaporating out of the oil as the pressure in the oil sump is lowered at the compressor startup. The gas will carry off oil droplets as it leaves the oil reservoir through connecting passages to the suction side of the compressor.

516-5.2.9.5 Foaming can also occur in the oil piping and could cause the pressure from the oil pumps to fluctuate, with possible temporary loss of lubrication and resultant damage to bearings and seals. Because of the dangers of foaming, oil heaters are provided in sumps. The heaters maintain the oil at a temperature sufficient to reduce the absorption of refrigerant (135° F minimum continuously during shutdown). Oil sump temperature shall be maintained at 135° F or higher for a minimum of one hour before a compressor start may be attempted (refer to individual technical manual for more details). The heaters are thermostatically controlled, automatically energized during shutdown, and automatically deenergized during operation. Some Carrier systems may cycle the oil heater on during compressor operation. These units should be periodically checked to verify that they are being energized and deenergized as required.

516-5.2.10 CONDENSER. As stated previously, the condenser is one of the most important components of a refrigerating plant. Although it appears simple, it nevertheless is a source of serious problems unless properly operated and maintained. The condenser in a centrifugal plant is a shell-and-tube heat exchanger similar in construction to those used in reciprocating compressor installations. Seawater is circulated through the tubes usually in a two-pass arrangement. The refrigerant vapor, discharged from the compressor, is admitted to the shell and condenses on the outer surfaces of the tubes.

516-5.2.10.1 The capacity of a water-cooled condenser is affected by the temperature of the water, quantity of water circulated, and the temperature of the refrigerant gas. The capacity of the condenser will vary whenever the temperature difference between the refrigerant gas and the water is changed. An increased temperature difference or greater flow of water will increase the capacity of the condenser. The use of colder seawater may cause the temperature difference to increase. Variations in seawater flow or temperature will vary the refrigerant discharge pressure. Throttling of the seawater is required whenever the condenser seawater temperature is cold enough that there is a possibility the evaporator pressure will become higher than the condensing pressure. If the evaporator pressure exceeds the condensing pressure, the cooling process will stop.

516-5.2.10.2 On some plants, an automatic water-regulating valve is provided in the condenser water discharge line to modulate seawater flow. At times, a manually-operated seawater throttle valve is used instead. The automatic valve maintains the correct condenser pressure and stable operation of the unit under varied seawater temperature conditions. If the seawater is cold and an automatic valve is not provided, the manual seawater discharge valve shall be throttled to limit the seawater and maintain the condensing (discharge) pressure at an adequate level. This ensures not only that the capacity can be maintained but also that refrigerant at the required pressure

is available to provide cooling for the purge unit, cooling for liquid-cooled hermetic motors, and gas to the educutors in the oil return system. Cooling water failure switches are provided on surface ships to secure the compressor if the circulating water supply fails. Cooling water pressure gauges (surface ships) and thermometers are also provided so that the pressure and temperature of the cooling water can be monitored.

516-5.2.10.2.1 Construction. The condenser in centrifugal plants is designed for a water velocity of 6 feet per second with an inlet water pressure of 25 to 35 psi. Any higher pressure increases water velocity above design. All the condensers are fabricated with copper-nickel, integral, finned tubes. The finned tubes for condensers are made with 19 or more fins per inch. The addition of fins significantly increases the heat transfer capabilities of the tube over that of a bare tube. Never install bare tubes in a condenser with finned tubes as the capacity will be seriously reduced. The tube sheets are welded at each end of a shell. Tubes are inserted through drilled openings in the tube sheets and are expanded or rolled onto the tube sheets to make a tight gas seal. Condenser heads (water boxes) are bolted to the tube sheets to complete the water side of the condenser.

516-5.2.10.2.2 Where dissimilar metals are used in parts of the condenser containing seawater and seawater piping systems, zinc anodes (wasting bars) are installed in the condenser heads to minimize electrolytic corrosion of the condenser parts in contact with the seawater. Where the condenser parts containing seawater and seawater piping systems are essentially made of the same material, such as copper-nickel; zinc anodes (wasting bars) have not been required in the condenser heads (except in nuclear ships). However, experience has dictated that zinc anodes are desirable and should be used in all refrigeration condenser applications. A purge unit, consisting of a compressor and heat exchanger, is installed to purge the condenser of noncondensable gases. In new condenser installations in surface ships, to protect the plant from overpressurization, a relief valve, a bursting disc upstream from the relief valve, and a sniffer valve between the relief valve and bursting disc will be installed to relieve excessive refrigerant pressure overboard.

516-5.2.10.2.3 Submarine Applications. Centrifugal plant condensers for submarine application use a double-tube sheet with a small void space between the two tube sheets. With this arrangement, a refrigerant or seawater leak at the tube sheet joint can be separately detected. For details of construction, see the applicable technical manual for a specific plant.

516-5.2.11 CONDENSER WATER SUPPLY. The circulating seawater for cooling air-conditioning condensers in most Navy ships can be provided from a dedicated seawater pump or some low-pressure seawater supply such as an auxiliary cooling water system. If the seawater circulating pump or auxiliary system fails, there is an emergency supply of seawater from the fire main. The fire main provides cooling water through a pressure-reducing valve or orifice directly to the condenser, or to the auxiliary cooling water system serving the condenser. Some ship classes may not have a low-pressure auxiliary system, but, may use the firemain directly, with or without a reducing valve.

516-5.2.12 WATER CHILLER. The water chiller in a centrifugal plant differs from that in a reciprocating plant. Although both types of plants have shell and tube evaporators, the reciprocating plant chiller has refrigerant in the tubes and water in the shell, and the centrifugal plant has water in the tubes and refrigerant in the shell. In the reciprocating plant, the refrigerant is regulated through an expansion valve, and the tubes have internal fins. This type of chiller is termed a dry expansion type. The centrifugal plant chiller is a flooded-type evaporator where chilled water is circulated through the tubes and is cooled by refrigerant evaporating in the shell. The tubes in this type of chiller have external fins. The chiller is filled with liquid refrigerant that surrounds the chiller tubes. When in operation, the heat from the water in the chiller tubes causes the liquid to boil and evaporate. To prevent the carryover of liquid into the compressor suction, either a vapor disengaging area in the top of the chiller shell or a baffle-type liquid elimination is provided.

516-5.2.12.1 Refrigerant Flow Control. Liquid refrigerant flowing to the evaporator from the condenser is controlled by a float valve or a restrictor device located in a flow control chamber. Liquid refrigerant collects at the bottom of the condenser shell and flows into the float chamber. As it accumulates in the chamber, it causes the float valve to open. The liquid refrigerant is then forced by condenser pressure into the chiller shell. As the liquid level in the float chamber drops, the float valve closes to prevent condenser gas from entering the chiller. The float chamber provides a seal between the gas and liquid sides of the system, maintaining condensing pressure similarly to the receiver in a reciprocating system. A sight glass in the float chamber permits observation of the liquid level and float operation.

516-5.2.12.2 Flow Restrictors. In systems with a flow restrictor, the refrigerant from the condenser flows into and collects in a high-pressure chamber. The refrigerant then drains from the chamber through an orifice or restrictor, located in the chamber, to the bottom of the chiller, where it rises through distributor plates into the tube bundle. In some units, at low load, a small amount of hot gas flows through the orifice, providing a minimum of hot gas bypass from the chamber into the chiller (evaporator). The hot gas agitates the liquid surrounding the evaporator tubes, improving the evaporating refrigerant heat transfer coefficient. A sight glass in the chiller shells permits observation of the liquid level in the chiller.

516-5.2.12.3 Potential Maintenance Problems. In noting the difference in the chiller types in the reciprocating and centrifugal systems, operating personnel should be aware that if chilled water freezes because of a maloperation, a more serious repair problem is involved with the centrifugal flooded type than the reciprocating chiller. In the reciprocating chiller, ice forms on the outside of the tubes, and the tubes may operate that way for some time without any serious rupture or derangement. In the centrifugal chiller, however, the freezing water inside the tubes expands, causing the tubes to balloon and a number to rupture. A serious repair problem then merges, in that the expanded tubes are difficult, and in many cases impossible, to remove through the tube sheet holes. The repair may require removing the tube sheet or gaining access through the shell. Personnel should be vigilant to prevent freezing in the chillers and ensure that safety controls are adjusted correctly and are in good working order.

516-5.2.13 CHILLED WATER SYSTEM. Although the chilled water system is not in the refrigerant circuit, the system, its function, and components are of importance in providing satisfactory cooling to the various compartments. The chilled water systems for centrifugal and reciprocating compressor plants are similar. For information on their operation and function, see paragraphs [516-4.1.26](#) through [516-4.1.26.2.1](#).

516-5.2.14 PURGE AND PUMP-OUT UNIT. The purge and pump-out (PPO) unit is a small compressor condensing unit designed to serve various functions in connection with the main unit. An understanding of these functions is essential for proper use of the equipment. The refrigerant PPO unit is designed to pump gaseous refrigerant. It can be used for three basic functions:

- a. To separate and remove noncondensable gases from the main system (purge)
- b. To remove refrigerant vapor from the main system before opening the system for repairs (pump-out)
- c. To help in transferring refrigerant between the main system and the remote receiver.

516-5.2.14.1 Basic PPO System. A basic PPO system is shown in [Figure 516-5-6](#). Refer to the technical manual for information on the specific unit installed in the ship and study its operation. The PPO unit consists of a compressor, concentrator shell, condenser, dehydrator, controls, valves, and gauges. Some older R-11 units may not have pump-out or transfer features. All R-114, R-134a, and R-236fa centrifugal units should include a receiver tank and transfer capability. The unit shown in [Figure 516-5-6](#) is for surface ships. In submarines, the

noncondensable gases are discharged into a closed foul gas tank, by way of a back-pressure valve, to prevent atmospheric contamination. The foul gases are then pumped overboard.

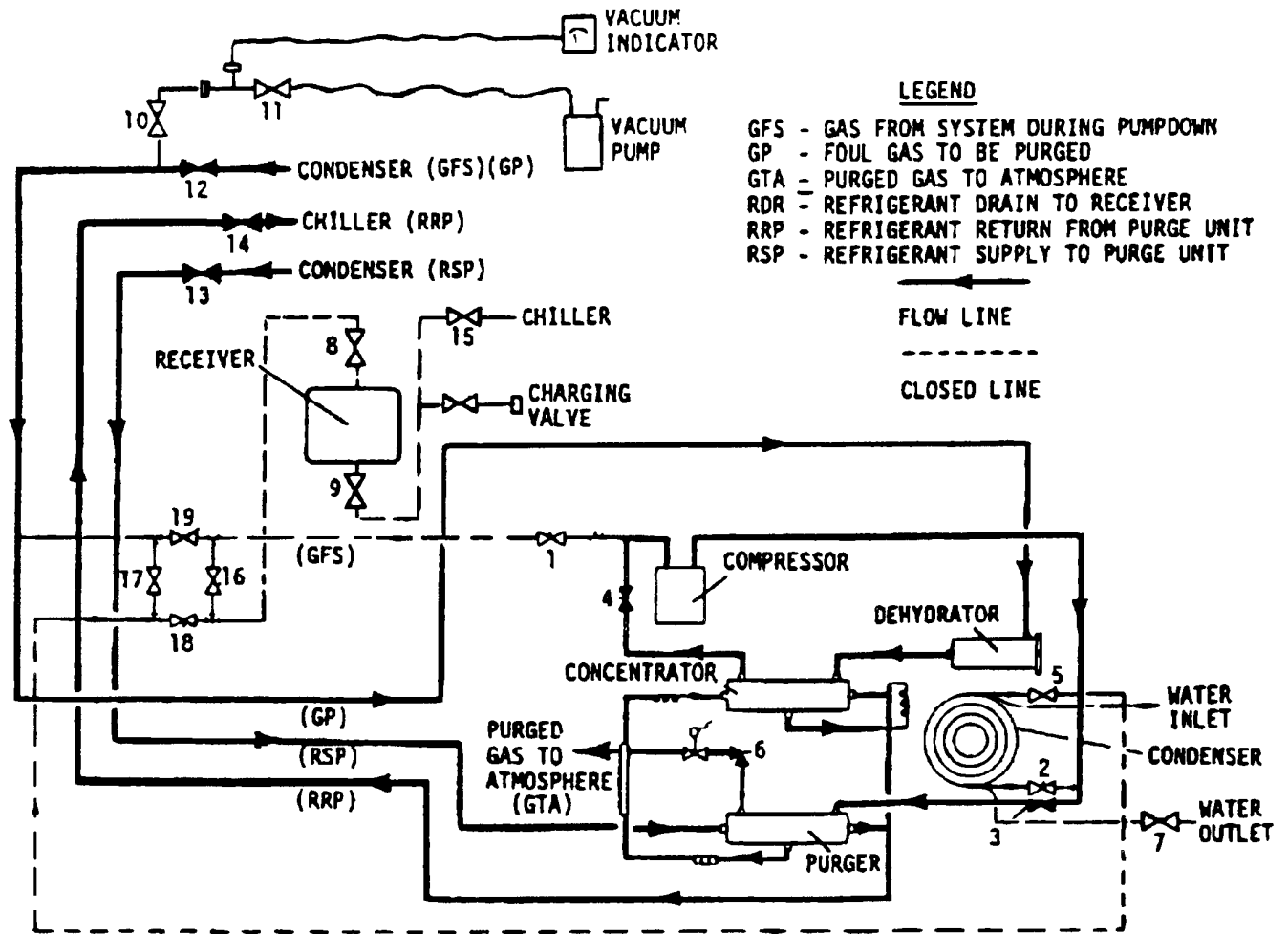


Figure 516-5-6. Purge and Pump-Out Unit - Purging Operation

516-5.2.14.2 Operation PPO Components. The PPO compressor is a small reciprocating compressor driven by an electric motor. It provides the compression for all PPO operations. An electric strip heater can be fastened to the side of the PPO compressor to keep the compressor lubricating oil warm and prevent absorption of refrigerant by the oil. The heater is energized through a normally closed contact in the controller, and is deenergized only when the PPO compressor is operated or the main power supply is switched off.

516-5.2.14.3 The concentrator and purger shells are identical in construction. Each shell consists of a tube with spiraled fins enveloped in a heat exchanger jacket. During purging operation, liquid refrigerant from the main system passes through the finned tubes, condensing most of the refrigerant vapor outside of the tubes. Float valves are included to drain the shells while maintaining a liquid seal in the shell drain. The PPO condenser is used only during refrigerant pump-out. At this time cooling water is used to condense refrigerant gas discharged by the PPO compressor. Also included are, instruments, valves, strainers, dehydrators, and moisture indicators. While most of the ancillary components in an R-114 system are the same for all halocarbon refrigerants, the moisture indicator element differs. The moisture indicator element for R-114 contains a different salt concentra-

tion which causes it to change color at a higher moisture level. R-114 is more tolerant of moisture than the other refrigerants and therefore the systems are not required to be as dry as R-12 and other systems. The functional descriptions of these items and various modes of operation with valve alignment are indicated in the applicable technical manuals.

516-5.2.15 INSTRUMENTATION. The centrifugal system has various pressure gauges, thermometers, and operating and safety controls. The gauges and thermometers are monitoring and troubleshooting aids. The controls maintain automatic operation and safeguard the plant in the event of derangement. The various instruments and specific controls, with their settings and method of adjustment, are adequately listed and indicated in the various technical manuals and need not be duplicated in this manual.

516-5.2.15.1 Controls. The controls may be pneumatic (air-actuated) or electronic. Most of the centrifugal plants in Navy ships have pneumatic controls, which have had problems. An investigation of some of these problems indicates that many are due to the control air, which was contaminated with moisture, oil, and dirt. The problem particularly affects the Johnson T-8000 thermostats, which have some very small orifices for actuation. With wet, dirty air the control internals restrict or plug up, causing erratic compressor operation. The operator then proceeds to readjust the control, putting the control out of adjustment. Control air supplied to air-conditioning pneumatic control components from ship source shall be clean and dehydrated. Operating personnel shall periodically check the actuating air to ensure that clean dry control air is being provided to the centrifugal plant controls at all times. This is particularly important while at dockside, when shore-based air can be used for controls.

516-5.2.15.2 Electronic Controls. Some centrifugal air-conditioning plants have electronic capacity control systems. Sets of electronic controls have been under evaluation to backfit present centrifugal plants that now have pneumatic controls. As soon as high shock electronic controls are developed, the intention is to begin a program to remove pneumatic controls and substitute electronic controls.

516-5.2.16 ALTERNATE POWER. In installing centrifugal units to a power source, it is important that electric power be supplied to the compressor motor without interruption. At shutdown these units need the auxiliary oil pump to provide lubrication until the compressor coasts down to a stop. In the event of a power failure or where a ship may be undergoing power failure exercises, the auxiliary lubricating oil pump would not receive electric power for operation. Possible bearing failure could result. To avoid this possibility, the installation of electric power should be such that an alternate power source is automatically supplied to the auxiliary oil pump if the primary power supply fails. Operating personnel should make sure that the lubricating oil pump is connected to a suitable alternate power source.

SECTION 6.

OPERATION OF CENTRIFUGAL COMPRESSOR PLANTS

516-6.1 INTRODUCTION

516-6.1.1 SCOPE. The following paragraphs include subjects of general interest in the operation of centrifugal plants. Centrifugal compressor plants contain high-quality machined parts and with proper operation and maintenance will give many years of trouble-free service. The requirement that a refrigeration plant be kept leaktight and free of air and moisture cannot be repeated often enough. It is also very important that an operator be trained, understand thoroughly and be familiar with the plant under operation.

516-6.1.2 OPERATOR REQUIREMENTS. Before operating a centrifugal refrigeration system, the operator shall become thoroughly familiar with the equipment including each component, its purpose and intended function; the procedures for checking oil and refrigerant charge, lining up seawater and chilled water, actuating air for controls and electric power; and general precautions concerning halocarbon refrigeration plants. The operator should be aware of normal system temperatures and pressures, the controls and their proper settings, and unusual noises or vibrations that indicate impending failures. The normal startup and shutdown sequence of events; scheduled maintenance; troubleshooting; and corrective maintenance such as filter changing, leak testing, repair of refrigerant and water leaks, and evacuating are adequately detailed in the applicable technical manuals for each plant, and are not included herein as it is impractical to cover all the differences in detail.

516-6.1.3 OPERATING PROCEDURES. Operating procedures applicable to specific centrifugal air-conditioning plants are posted on each air-conditioning plant. A copy of the procedures can be obtained from the Carderock Division, Naval Surface Warfare Center (CDNSWC), Philadelphia, PA (Code 9213).

516-6.2 OPERATION

516-6.2.1 GENERAL. The air-conditioning plant can be operated in automatic or manual mode. The equipment shall be checked periodically during automatic operation and observed continuously during manual operation. The air-conditioning plant is controlled automatically by the chilled water thermostat (T-8000), current limiter, and transducer. The manual loading valve controls the plant if the automatic controls become inoperative. During low-load conditions, the hot gas bypass valve(s) opens and places an artificial load on the air-conditioning plant. [Table 516-6-1](#) contains recommended centrifugal air-conditioning plant control settings.

Table 516-6-1. RECOMMENDED CENTRIFUGAL AIR-CONDITIONING PLANT CONTROL SETTINGS

Design Temp. (°F)	Equip.	Safety Switches								
		Oper. Thermo. Setpoint (°F)	Refr. HP Switch Cutout (psig)	Refr. HP Switch Cutin (psig)	Water* Failure Switch Cutout (psig)	Water Failure Switch Cutin (psig)	Low Chilled Water Temp. Cutout (°F)	Low Chilled Water Temp. Cutin (°F)	Low Refrig. Temp. Cutout (°F)	Low Refrig. Temp. Cutin (°F)
49-50 CW	R-11 Air-Cond. Plant	49 +0/-2	15 ±2	5 ±2	5 ±2	15 ±2	40 +2/-0	49 +0/-2	32 +1/-0	38 +0/-1
44-45 CW	R-11 Air-Cond. Plant	44 +0/-2	15 ±2	5 ±2	5 ±2	15 ±2	40 +2/-0	44 +0/-2	32 +1/-0	38 +0/-1
44-45 CW	R-114 Air-Cond. Plant	44 +0/-2	50 ±2	35 ±2	5 ±2	15 ±2	40 +2/-0	44 +0/-2	32 +1/-0	38 +0/-1
44-45 CW	R-134a AC Plant	44 +0/-2	TBD	TBD	5 ±2	15 ±2	40 +2/-0	44 +0/-2	32 +1/-0	38 +0/-1
44-45 CW	R-236fa AC Plant	44 +0/-2	TBD	TBD	5 ±2	15 ±2	40 +2/-0	44 +0/-2	32 +1/-0	38 +0/-1
If the condenser discharge is located more than 5 feet below the water line, the water failure switch setting will have to be increased accordingly to compensate for the water head in the discharge piping.										

516-6.2.2 PRESTART CONDITIONS. Before the air-conditioning plant can be started, the following conditions shall exist:

- a. The oil sump heaters shall have been energized continuously since the last shutdown. The oil sump heater POWER ON indicator light is on. The oil sump temperature has been maintained at 135° F or higher for at least 1 hour before a compressor start can be attempted. However, if a fresh oil charge is installed, the plant can be restarted immediately, because there is no refrigerant in the new oil. If electric power to the oil heaters has been interrupted, refer to [Table 516-6-2](#) for guidance.
- b. The compressor oil is at the proper level.
- c. The refrigerant charge is at the proper level.
- d. The chilled water valve to the chiller inlet is open and the chilled water pump is operating. Before starting the chilled water pump, vent it. After the pump is started, slowly open the pump discharge valve.
- e. Air service to the capacity control system is available.
- f. Seawater valves at the condenser inlet and outlet are open.
- g. The auxiliary oil pump (AOP) selector switch is in the AUTO position.

**Table 516-6-2. COMPRESSOR RESTART PROCEDURE FOLLOWING
POWER FAILURE**

Condition	Time Oil Heaters Have Been Off	Oil Temperature	Procedure
Unit has been operating for any period of time and shuts down due to a power failure or interruption which kept the oil heaters from being energized when the compressor stopped.	Less than 1 hour More than 1 hour More than 1 hour	-- Greater than 135° F Less than 135° F	Energize heaters. Compressor can be started immediately. Energize heaters. Compressor can be started immediately. Energize heaters to raise oil temperature to 135° F. Maintain a temperature above 135° F for a minimum of 1 hour; then start compressor.
Unit has been shut-down and while shut down, power to the oil heaters is lost.	Not known Not known	Less than 135° F 135° F or higher	Energize heaters to raise oil temperature to 135° F. Maintain a temperature above 135° F for a minimum of 1 hour. Then start compressor. Energize heaters and maintain a temperature of 135° F or higher for a minimum of 1 hour; then start compressor.

516-6.2.2.1 Close the breakers to energize the main compressor motor controller. When the controller is initially energized, the safety alarm may sound. Pressing the COMPRESSOR STOP-SILENCER pushbutton silences the safety alarm buzzer. With power to the panel, a white POWER ON indicator is illuminated. Pressing the COMPRESSOR RESET pushbutton aligns the safety interlock circuit. The safety circuit consists of safety switches (Table 516-6-1) and contacts. A green indicator light is energized for each of the closed safety switches. If all of the indicator lights except oil pressure are energized, then the air-conditioning plant is ready for normal startup. The cause of any unlighted light shall be corrected before starting the plant.

516-6.2.3 AUTOMATIC MODE AND THE NORMAL START SEQUENCE. The normal start sequence begins when the COMPRESSOR START pushbutton is pressed. The AOP operates for 25 seconds before the main compressor motor starts. A timing relay delays startup of the main compressor motor for 25 seconds while the auxiliary oil pump builds sufficient oil pressure. Before the end of the 25-second time period, oil pressure shall be sufficient to close the oil pressure safety switch. Otherwise, this safety switch will not permit the compressor to start. The main compressor motor starts when the timing relay closes (25 seconds). For the next 60 seconds, the AOP continues to operate, circulating oil through the compressor while the internal oil pumps build pressure. When the 60-second timing period ends, the AOP stops, the internal oil pumps circulate the oil, and the plant operates normally.

516-6.2.4 MANUAL OPERATION. Manual operation is necessary when the automatic controls become inoperative or out of adjustment. Manual operation is the same as automatic except for adjusting the manual loading valve. The manual loading valve is in series with the chilled water thermostat (T-8000) and will not exceed thermostat setting. The plant shall be observed at all times when it is operated in the manual mode. When operating the plant in the manual mode, observe the motor amperes ammeter and chilled water out-temperature. Ensure that the plant maintains a 44° F outlet temperature and the compressor motor does not exceed the maximum rated amperage.

516-6.2.5 NORMAL STOP SEQUENCE. Pressing the COMPRESSOR STOP-SILENCER pushbutton begins the normal stop sequence. During this sequence, the AOP operates for 45 seconds while the compressor coasts to a stop to ensure proper lubrication. The current amplifier is deenergized to allow the transducer to bleed air off the pilot positioner and close the prerotation vanes. The oil sump heaters are energized to keep refrigerant out of the oil.

516-6.2.6 AUTOMATIC SHUTDOWN SEQUENCE DUE TO ABNORMAL CONDITIONS. An automatic shutdown sequence will occur when an abnormal condition causes a safety switch (OP, HP, LRT, HOT, HDT, CWF, SWF, or LWT) to open, or when overloading of the main compressor motor causes an overload relay to be energized. Each safety switch is located in series with a relay. An opened safety switch will deenergize its green light indicator and the compressor motor. At the same time, the alarm circuit is energized. The audible alarm will sound until the STOP-SILENCER pushbutton is pressed. The AOP is operated for 45 seconds during the compressor coastdown period to ensure proper lubrication while the compressor coasts to a stop. The cause of the system shutdown will be identified by the extinguished green light except for the lube oil pressure light, which will remain lit for 45 seconds during operation of the AOP. If all green lights remain on, then the shutdown was caused by an overload failure.

516-6.2.7 OPERATING RECORD. A permanent daily record of system operating conditions (temperatures and pressures) recorded at 2-hour intervals shall be kept (Figure 516-6-1). An accurate record of readings can serve as a valuable reference in operating the system. Readings taken when a system is newly installed will establish normal conditions with which to compare later readings. Do not take daily readings solely for record purposes. An experienced operator who would be able to recognize trends in the data and possibly anticipate maintenance

requirements shall continuously analyze and evaluate the daily data. Operators are cautioned that they shall not continuously restart the refrigeration units after successive abnormal shutdowns without investigating and correcting the cause of the abnormal shutdown. Under no circumstances bypass operating or safety controls to keep the equipment running. When a compressor goes through several starts and abnormal stops and fails to pick up the load, something has occurred in the plant: either a valve has been misadjusted or some item or component is about to fail or has failed and become deranged. Successive starts and stops may easily burn out a motor or cause other serious casualties, requiring many hours of maintenance time.

MAKE:			UNIT OR PLANT IDENTIFICATION:										REFRIGERANT:						DATE:			
TIME	RUNNING TIME	AMMETER	CONTROL AIR PRESSURE	REFRIGERANT						OIL			SEAWATER			CHILLED WATER			PURGE UNIT			WATER REMOVAL
				SUCTION TEMP	SUCTION PRESS	DISCHG TEMP	DISCHG PRESS	LIQUID TEMP	LIQUID LEVEL (CHILLED)	LEVEL	PRESS	BEARING TEMP	SUMP TEMP	PRESS	TEMP IN	TEMP OUT	PRESS	TEMP IN	TEMP OUT	HIGH PRESS	LOW PRESS	
0200																						
0400																						
0600																						
0800																						
1000																						
1200																						
1400																						
1600																						
1800																						
2000																						
2200																						
2400																						

NOTES:

LOG DATA ELEMENTS EVERY 2 HOURS.
THIS IS A COMPOSITE CHART. ALL DATA ELEMENTS MAY NOT BE AVAILABLE ON ALL EQUIPMENT.

Figure 516-6-1. Air-Conditioning Equipment Operating Log - Centrifugal Compressor

516-6.2.8 CENTRIFUGAL COMPRESSOR SHAFT SEAL LEAKAGE CRITERIA. It is desirable to have no measurable shaft seal leakage, but some oil leakage is acceptable. The criteria for scheduling a replacement of a shaft seal are as follows:

- a. Whenever refrigerant leakage can be detected at the shaft seal, replace the shaft seal at the next available time. Compressors that have not been operated for a week or more may experience refrigerant leakage at the seal due to the seal being dry. In this case, operate the compressor and reinspect for leakage after it has been shut down for an hour.
- b. The shaft seal is satisfactory if the oil leakage rate is less than 1 drop of oil every 5 minutes. This leakage rate applies when the air-conditioning plant is operating under steady-state conditions (the centrifugal air-conditioning compressor shall not be surging during this inspection).
- c. The plant may be operated without any restrictions if the oil leakage rate is greater than 1 drop of oil every 5 minutes, but less than 1 drop of oil every minute. Monitor the plant oil level every 2 hours and add oil periodically to maintain the proper oil level. Replace the shaft seal at the next available time.
- d. If the oil leakage rate is continuous and greater than 1 drop of oil every minute, the plant should be operated only when no other plant is available. During operation, monitor the compressor sump oil level and shaft seal oil leakage. If the oil leakage rate exceeds 12 drops of oil every minute, complete shaft seal failure could occur at any time, resulting in total loss of compressor lubrication. Oil will have to be added at least once per day, as required, to maintain proper oil level. Replace the shaft seal as soon as possible.

NOTE

An oil leakage rate of 12 drops every minute corresponds to 1-1/8 quarts of oil lost per day, while 60 drops every minute corresponds to 5-1/2 quarts of oil lost per day.

NOTE

The leakage rate for a new seal might exceed an acceptable rate until it has a chance to wear in. The leakage rate for the first 50 hours of operation after seal replacement can be ignored unless it exceeds 15 drops per minute.

516-6.2.9 REFRIGERANT CHARGE. Overcharge causes overload and undercharge prevents attaining full load. The refrigerant charge for a centrifugal plant is determined by the manufacturer in the technical manual. The proper charge for optimum compressor performance is determined at design load. For optimum performance at full load, the refrigerant charge should completely wet the top row of the evaporator tubes with boiling refrigerant. To wet these tubes at less than full load, excessive refrigerant would have to be charged since the boiling action of the refrigerant would be less. Therefore, to prevent overcharging, obtain full-load conditions for the check. If full-load conditions cannot be maintained, it is possible to obtain them for a short period of time by stopping the compressor and permitting the chilled water temperature to rise 3° or 4° above full-load design temperature. Then by restarting the compressor, the chilled water temperature can be reduced so that normal full-load conditions will prevail for a short period of time. Be sure to adjust the chilled water flow to design. If seawater is below design temperature, throttle seawater flow to obtain design refrigerant discharge pressure; check the ammeter for full-load current, ensuring that design voltage and frequency are being supplied.

516-6.2.9.1 Do not exceed full-load current; excessive current may indicate overcharge. The optimum charge then is that which produces the design temperature differences between chilled water on and off the chiller (assuming design flow) with the least amperage drawn by the compressor. When proper charge has been deter-

mined, shut down the machine and mark refrigerant level on the sight glass. Maintain refrigerant at this optimum level. The level may change after a long period of shutdown. Subsequent checking of the level should be done after a period of operation. Nothing is gained by adding excess refrigerant in these flooded-type plants. An excess will cause a useless increase in motor amperage. A repeated need for refrigerant may indicate a system refrigerant leak. Locate the leak and correct it at once.

516-6.2.10 OIL FILTER CHANGEOUT. During normal operations with a clean filter, the lube oil pressure gauge on the air-conditioning plant control panel reads about 65 to 75 psig. This varies depending on the air-conditioning plant, the oil temperature, and the load imposed on the plant. Refer to the applicable Planned Maintenance System (PMS) documentation or equipment technical manual for specifics on the particular air-conditioning plant. Change the oil filter according to the following guidelines:

- a. The typical requirement for the oil filter change interval is to switch over to a clean filter when the oil pressure falls 30 percent or, for discussion purposes, when the lube oil pressure gauge reading is 46 to 53 psig.
- b. The two oil filters are valved in parallel as a duplex arrangement. By maintaining the out-of-service filter in the clean (new) condition, the operator can switch over to this filter at any time to determine whether a reduction in oil pressure is due to a dirty oil filter or to some other cause (such as an abnormality with the compressor). When a filter pressure drop approaches the 30-percent limit, switch to the clean filter and replace the dirty filter with a new one. This method uses the installed gauge to indicate the oil filter condition.

516-6.2.11 LAYING UP THE SYSTEM. If the system is to be shut down for an extended period of time, take the precautions outlined in the following procedures:

- a. After the system pressure has risen above atmospheric, test all system joints for refrigerant leaks with a leak detector. For R-11 plants when the machinery room temperature is below 70° F, circulate hot water (not to exceed 100° F) through the chiller tubes to raise the system pressure. If any leaks are found, repair and dehydrate the system before allowing the system to stand for a long period of time. During long idle periods, periodically check the tightness of the system. If refrigerant is retained in the plant, mark the sight glass level. Watch for any change in level that may indicate a leak.
- b. If any of the equipment is to be exposed to freezing weather, drain all water from the system. Open vents in the chiller and condenser to ensure complete drainage.
- c. Close the refrigerant valves between the purge unit and the main system.
- d. Open all disconnect switches except those supplying power to oil heaters. If possible, power shall be available to oil heaters at all times during the shutdown. If this is not possible, transfer the entire refrigerant charge to storage tanks as soon as the unit is shut down. The refrigerant side of the system shall be retained with a positive charge of refrigerant or laid up with a 5-psig holding charge of nitrogen. When returning the system to service after a prolonged shutdown, remove all oil from the compressor and charge with fresh oil. Install a new oil filter element. Install new dehydrator cartridges. If the refrigerant charge was removed, charge the system. If a nitrogen blanket has been added, evacuate the nitrogen before charging. Energize the sump oil heaters. If the system was drained of water because of possible freezing, circulate chilled water and cooling water through the chiller and condenser, and carefully vent. Manually operate the auxiliary oil pump until a steady oil pressure is established.

516-6.2.12 CONDENSER SEAWATER SUPPLY. For condenser water supply and condenser operating precautions, refer to [Section 4](#). The information on condenser operation for reciprocating plants generally applies to centrifugal plants.

516-6.2.12.1 Operation of Centrifugal Air-Conditioning Plants with 95° F Seawater. Of the centrifugal air-conditioning plants used by the Navy, only those on DDG 993 class ships are designed to produce full-rated capacity with seawater temperatures up to and including 95° F. Most centrifugal air-conditioning plants were designed to produce rated capacity at a chilled water outlet temperature of 44° F to 45° F with 88° F seawater. These plants are not expected to produce rated capacity and 44° F to 45° F chilled water when operating in 90° F to 95° F seawater. Warm seawater causes the plant to operate at higher pressures, draw more power, and run hotter. With this understood, measures can be taken to minimize problems with plants operating with higher temperature seawater while optimizing their cooling ability. The following discussion is for centrifugal air-conditioning plants in general. Refer to the applicable technical manual for specifics.

- a. Check calibration of the capacity control system, especially the current limiter, because the proper calibration will allow the motor to work up to its maximum safe level. Revised technical manuals have about 24 pages devoted to this control system.
- b. In the event of motor controller overloads, if using the dashpot type, check them to ensure that they are full of oil and are at the right setting.
- c. Noncondensable gases trapped in the condenser severely reduce its capacity. Ensure that all noncondensable gases and air are removed from the refrigerant system by purging it.
- d. Oil-rich refrigerant is less able to cool the chiller tubes, resulting in an inability to produce full load at design conditions. Operate the oil return system continuously to extract any oil that has accumulated in the chiller.

NOTE

When oil is returned, it is carried to the compressor sump. With a grossly oil-logged chiller, the excess oil will have to be removed from the sump to maintain the correct level.

- e. If the operating chilled water plants are overloaded, start up another plant and redistribute the load. The chilled water systems on most ships are designed to carry all vital loads during cruise with one plant down for maintenance. Even with the 15 percent or so loss of capacity due to the warm seawater, there is sufficient capacity with all plants operating. The success of this effort also depends on how well the chilled water load is split out.
- f. Check the amount of refrigerant in the plant in accordance with the procedure in the plant technical manual to ensure that the charge is correct. If it is too low, find the leaks before adding refrigerant. If it is too high, restore it to the correct level.
- g. Even when all parts of the plant are operating at their best, a centrifugal air-conditioning plant compressor may surge when operating with 90° F to 95° F seawater. Surging is indicated by rapid changes to the compressor motor ammeter reading, fluctuating compressor discharge pressure, and obvious pulsating compressor noises. This happens when the compressor discharge pressure (controlled by the seawater flow and temperature) is disproportionately greater than the compressor suction pressure (controlled by the chilled water thermostat setting). A plant operating with warm seawater while under a light load (low suction pressure) is also susceptible to surging. Although the compressor head may be somewhat less than the head with a heavy load, the gas flow rate is reduced and flow direction may momentarily reverse, causing the compressor to surge. When surging occurs, the compressor is being operated beyond its design head capability. The noise and fluctuating readings are caused by gas from the condenser periodically flowing back through the compressor. To eliminate surging, reduce this pressure differential across the compressor. When in warm seawater, assuming the procedures in steps c, d, e, and f above have been accomplished, the only way to reduce this pressure differential is by increasing the exiting chilled water temperature. Raise this in two- or three-degree increments by adjusting the thermostat until surging stops. Surging harms the compressor by causing thrust and torque

reversals on the rotating parts. Besides the obvious noise, it also causes premature wearout of the thrust bearing and the oil seal. A plant running in surge mode does not have to be shut down, but the cause of the surging shall be corrected.

- h. Many chilled water system pumps are capable of flows that are 25 percent above the air-conditioning plant design flow rate. If this situation exists, the chilled water differential temperature across the evaporator will be less than that indicated in the air-conditioning plant technical manual. However, the air-conditioning plant will still produce full capacity with this lower differential temperature.

516-6.2.12.2 Condenser Problems. The degradation in plant performance and increase in chilled water temperature can be minimized by maintaining the condenser in a clean condition according to the following guidelines:

- a. The volume (gallons per minute) of water flowing through a condenser determines the water velocity in the tubes. Seawater-cooled air-conditioning and refrigeration condensers are designed for velocities of 6 feet per second (fps). This is a conservative value, selected to protect the condenser tube inlet regions. The flow of water is the most turbulent at the tube inlet due to the change in flow pattern. Even though the overall tube velocity is 6 fps, erosion can occur at the tube inlets, where damage is limited to the first 4 to 5 inches. To protect this area, nylon and metallic tube inserts have been installed. Both types of inserts have been effective in this application. Under controlled circumstances, average tube velocities of up to 7.5 fps can be maintained without causing accelerated erosion in the tubes. When operating with seawater flows above design, the main concern is condenser tube fouling. A few partially obstructed tubes will force the remaining clear tubes to pass more water at a higher velocity. Unless corrected, accelerated flow will damage the clear tubes, while partially obstructed tubes will also be damaged due to crevices, localized eddies, and cavitation formed by the obstruction. The condenser flow will appear to be correct; but, due to fouling, the tubes will be eroding.
- b. When in warm seawater, increasing the seawater flow rate beyond design can help to correct higher than normal compressor discharge pressures. This shall not be done to compensate for fouling in the condenser. It may be done occasionally, when the condenser is known to be entirely clean, and all other plant parameters discussed above are known to be operating correctly. This is the last technique to use to force the plant to carry a heavy load. Overlooking the requirement that the condenser shall be entirely clean will result in failed condenser tubes.
- c. A condenser tube leak can put the plant out of commission for a long time (6 weeks to 9 months), depending on the corrective action required.
- d. If a seawater regulating valve (WRV) is suspected of malfunctioning and it is equipped with a manual actuator, open the valve for full flow through the condenser in accordance with the WRV drawing in the air-conditioning plant technical manual. Do not open the WRV bypass valve. Clean the pilot control section of the WRV whenever the condenser is secured for cleaning or when the WRV is malfunctioning. If the problem still exists, there is nothing wrong with the WRV. Look elsewhere for the cause, such as air or other noncondensable gases in the refrigerant circuit, or insufficient seawater flow due to a clogged seawater strainer or a fouled condenser. Refer to the equipment technical manual or paragraph [516-4.1.17](#) for a testing procedure for noncondensable gases.
- e. If condenser fouling from silt is suspected, vent the seawater side of the condenser, flush it by ensuring seawater inlet and outlet valves are open fully, and open the WRV bypass fully for maximum flow for 5 minutes. This will flush out the silt. Then, close the WRV bypass valve. If the symptoms continue even with the silt flushed out, the problem is elsewhere.
- f. Keep the seawater strainer baskets clean to allow unrestricted flow. Also keep the seawater side of the condensers clean. If fouling is still suspected, secure the plant and drain seawater from the condenser. Follow the procedure for the PMS quarterly condenser inspection and use a fiber optic borescope to look through the zinc

anode plug openings. Check the inlet end of each condenser pass for plugged tubes and debris. If tube or tube sheets cannot be inspected without removing the condenser heads, remove them, water-lance the tubes, and if necessary, brush the tubes clean. Marine growth and debris shall be removed from the tube sheets and heads so that flow is not restricted.

- g. Once the condenser is clean and free of noncondensable gases, verify proper condenser seawater flow. With a high seawater temperature, sufficient flow is mandatory before plant capacity can be maximized. Despite the lack of a flow-measuring device, seawater flow can be deduced by carefully reviewing the plant instrumentation and log sheets. Note that the plant shall be fully loaded before the automatic seawater flow-regulating valve will provide full seawater flow. The plant technical manual defines full-load conditions. Full seawater flow is indicated by the seawater differential temperature across the condenser and the refrigerant condensing temperature and pressure. These shall be compared with equivalent temperatures and pressures of the plant or sister plants on the ship operating under equivalent conditions. The seawater differential temperature will be similar to operation at design seawater temperature. If the differential is greater, insufficient seawater flow is likely. The refrigerant temperatures and pressure will be higher than normal due to the high seawater temperature. Log sheet data from plant operation with cooler seawater cannot be used as a basis for comparison.
- h. The heat transfer characteristics of the condenser are more or less fixed by the design. Two factors that change over time are seawater side fouling and the accumulation of noncondensable gases in the condenser shell. Because the effect of noncondensable gases and fouling on machine operation are very much the same, always purge the machine first to eliminate the effect of these gases before troubleshooting the cause of high pressures and reduced performance.

516-6.2.13 CENTRIFUGAL WATER CHILLER. The water chiller, as indicated, is part of the compressor condenser package. Since the water is in the tubes and refrigerant is on the outside of the tubes, the leak-testing procedure is the same as for a condenser. However, one important precaution in centrifugal chiller operation is prevention of chiller freezeup. When freezeup occurs, the freezing water causes the tubes to balloon out, making it impossible to remove them for repair. Repairing the chiller may require removing the tube sheet or cutting holes in the shell to remove the expanded tubes. Operating personnel shall be vigilant in ensuring that the safety controls that prevent freezeup are correctly set and operating properly.

516-6.2.14 CHILLED WATER SYSTEM CENTRIFUGAL PLANTS. While the chilled water system is not in the refrigerant circuit, it is important that operators become familiar with the system and its operation. The chilled water system for centrifugal plants is similar to that for reciprocating plants. Refer to [Section 4](#) for a description of the system.

516-6.2.15 COMPRESSOR MOTOR BURNOUT. A number of centrifugal compressors are the hermetic type. If hermetic motor burnout occurs, the refrigerant side of the system may be contaminated to some degree with carbon, organic residue, acids, and other general products of decomposition. The actual degree of system contamination cannot be predicted. Many variables are involved and each has influence on the extent or seriousness of the aftereffects. Access should be gained to various parts of the system so that visual examination can be made and the extent of contamination determined.

516-6.2.15.1 Inspect motor for damage first. If charring in the area of failure is limited and debris is not visible in the sight glasses, dehydrators, or in the top portion of the condenser, it assumes that the contamination is limited to the motor housing. If any doubt exists, remove the suction elbow and visually inspect the prerotation vanes and the eye of the impeller. If debris is found around the vanes or impeller, the system has been badly contaminated. Before working on equipment, ensure that power is off and switches are tagged. Acid and toxic fumes may be present following burnout. Ventilate the area thoroughly and continuously. Wear rubber gloves, eye protection,

and protective garments. If fumes persist, use gas masks suitable for acid gases. If products of decomposition and burnout have remained mostly in the compressor motor, the following should take place immediately after burnout to minimize acid attack on the system.

- a. Remove the refrigerant charge from the system by transferring the charge to refrigerant cylinders. Contaminated refrigerant shall not be transferred to the remote receivers, as this will result in contamination of any refrigerant in the receiver and the receivers themselves.
- b. Remove the contaminated oil immediately. Fill the compressor sump completely full of new oil so that the compressor parts are submerged. Leave the compressor parts in the oil until the components can be washed. This will protect the internal mechanical components from any attack by acid or contaminants. If the components cannot be washed out immediately, lay up the refrigeration system with a 5-psig holding charge of dry nitrogen in accordance with paragraph [516-6.2.11](#).
- c. If contamination has not spread throughout the system to any great degree, clean the system by wiping all accessible parts with a lint-free cloth and petroleum solvents. Maintain supplemental ventilation.
- d. . After cleaning the parts, install the new motor. Proceed to reassemble the system and drain the oil from the compressor. Follow with dehydration, pressure testing, evacuation, and oil and refrigerant charging of the system. However, if the contamination has been pumped throughout the system and a visual examination indicates a serious degree of contamination, a cleaning of the system is required. For cleaning, refer to the technical manual and obtain the services of an industrial activity to assist in the cleaning operation. Immediately remove the refrigerant and oil charge, fill the compressor reservoir completely full of oil, and leave the oil there until ready to disassemble the compressor; maintain a neutral atmosphere of nitrogen in the system until system cleaning can be scheduled.
- e. After a burnout, with or without extensive contamination, replace all dehydrator cartridges once a week for the next month. It is also recommended that the oil charge be replaced after 1 month of operation.

516-6.3 PNEUMATIC CAPACITY CONTROL SYSTEM, OPERATION, AND ADJUSTMENTS

516-6.3.1 PNEUMATIC CAPACITY CONTROL SYSTEM OPERATION. The capacity control system maintains the chilled water outlet temperature at 44° F while preventing compressor motor overload. The typical capacity control system consists of a chilled water thermostat, pilot positioner and prerotation vanes motor, current amplifier and transducer, manual loading valve, and hot gas bypass valve(s). These components control the position of the prerotation vanes in the compressor. [Figure 516-6-2](#) depicts typical capacity control systems for centrifugal air-conditioning plants.

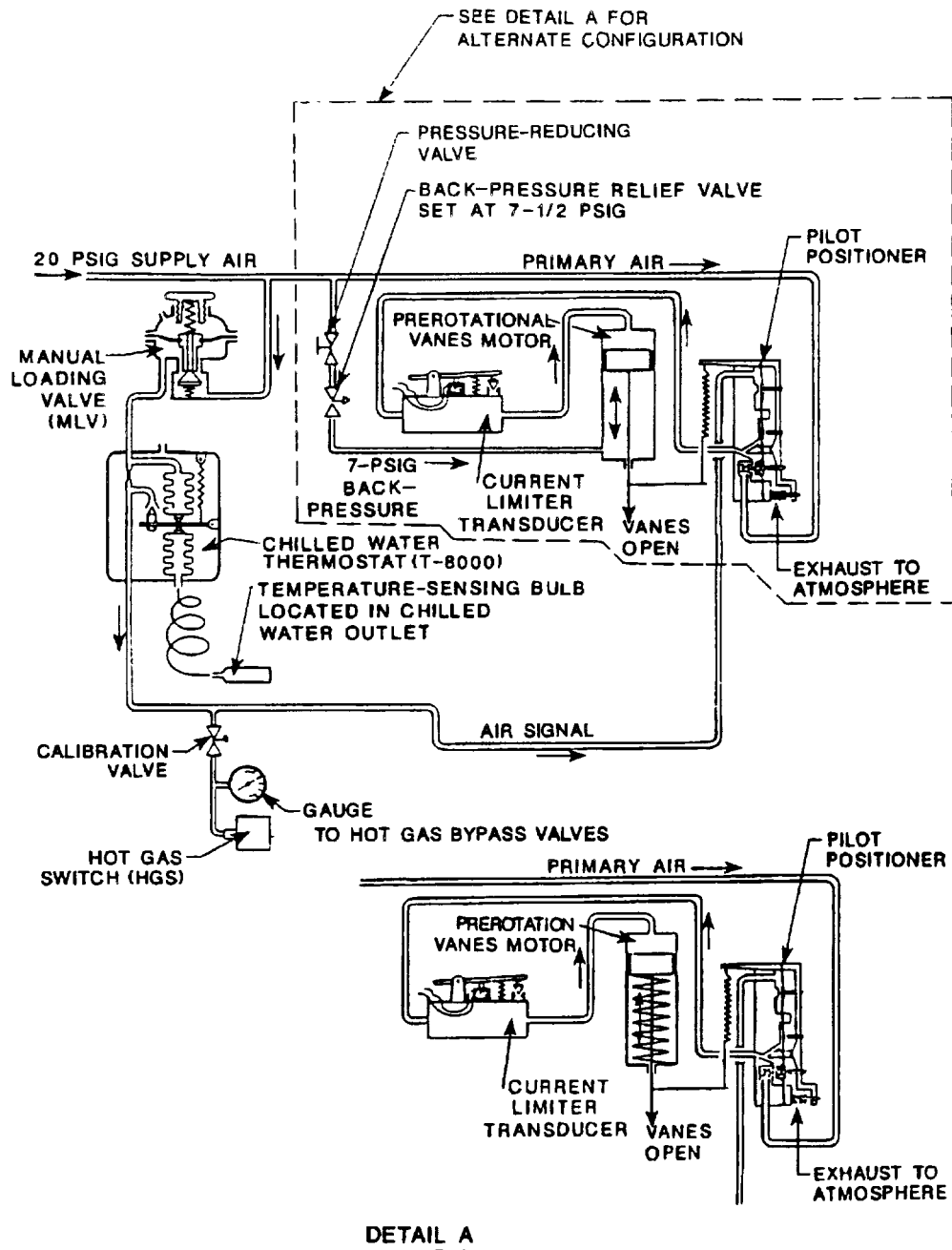
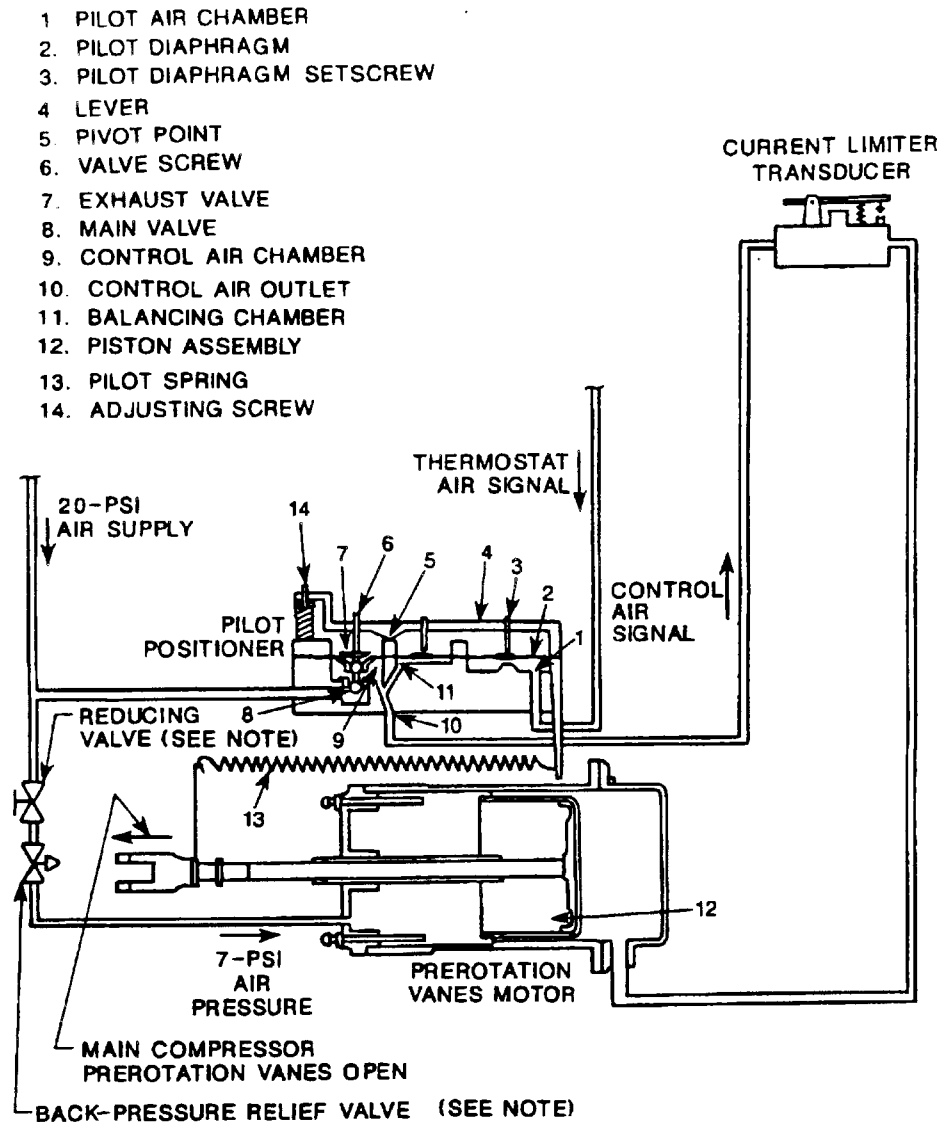


Figure 516-6-2. Typical Capacity Control System for Centrifugal Air-Conditioning Plants

516-6.3.1.1 T-8000 Chilled Water Thermostat. The T-8000 chilled water thermostat controls the compressor capacity to maintain the chilled water leaving the chiller at 44° F. At 44° F, the thermostat maintains the air signal to the pilot positioner at 8 (± 0.5) psig. When the thermostat senses a rise in chilled water temperature, the air signal to the pilot positioner increases. The increased air signal opens the prerotation vanes of the main compressor to increase compressor capacity. A drop in chilled water temperature decreases the air signal to the pilot positioner, which closes the prerotation vanes and decreases compressor capacity.

516-6.3.1.2 Pilot Positioner and Prerotation Vanes Motor. The pilot positioner and prerotation vanes motor operate the prerotation vanes to control plant capacity. The pilot positioner controls the actuation of the vanes motor, which is an air-driven piston and cylinder device ([Figure 516-6-3](#)). The sequence of operations is as follows:

- a. A rise in chilled water temperature increases the thermostat air signal pressure to the pilot positioner.
- b. Control air from the pilot positioner flows through the current limiter transducer to the vanes motor. The current limiter transducer limits the air supplied to the vanes motor to prevent the compressor motor from overloading.
- c. When control air enters the vanes motor, the piston assembly (12) moves outward to open the prerotation vanes. The vanes open in proportion to the movement of the piston assembly. The vanes are fully open when the piston is all the way out and fully closed when the piston is all the way in.
- d. The pilot spring (13) provides feedback from the vanes motor to the pilot positioner. The spring extends and increases tension on the lever, which counteracts the air signal pressure on the pilot positioner. When the chilled water temperature increases, the control signal to the vanes motor increases, moving the piston further outward to increase plant capacity.
- e. When the chilled water temperature decreases, the thermostat air signal decreases, causing the pressure in the pilot positioner to decrease. Air is exhausted from the vanes motor by the pilot positioner, causing the vanes motor piston to move inward and close the prerotation vanes. The piston assembly will move inward until the pilot spring (13) and pilot positioner are in equilibrium. Backpressure to move the piston inward is provided by air (as shown in [Figure 516-6-3](#)) or a spring.

**NOTE:**

THE CONFIGURATION SHOWN DEPICTS THE PILOT POSITIONER AND PREROTATION VANES MOTOR WHEN AIR IS USED FOR BACK-PRESSURE ON THE PISTON ASSEMBLY. REDUCING VALVES AND BACK-PRESSURE RELIEF VALVES ARE NOT SUPPLIED ON ALL SYSTEMS.

Figure 516-6-3. Pilot Positioner and Prerotation Vanes Motor

516-6.3.1.3 Current Amplifier and Transducer. The current amplifier, with the transducer, limits main motor amperes by limiting the air supply from the pilot positioner to the prerotation vanes motor. The current amplifier provides a signal to the transducer that is related to the motor amperes. The transducer uses this signal to limit the compressor motor to its rated full-load amperes. The current limiting devices automatically monitor and limit motor amperes to the full-load setpoint. When the full-load setpoint is exceeded, the current limiting devices reduce the air pressure to the prerotation vanes motor. This causes the prerotation vanes to partly close until motor amperes are reduced. The current limiting devices allow the prerotation vanes to open quickly during startup. This automatic action occurs only when the manual loading valve is maintained in the open (fully clockwise) position.

516-6.3.1.4 Manual Loading Valve. The manual loading valve is a pressure-reducing valve that manually controls the main compressor load when the automatic control devices fail. It is mounted on the control panel cover and is hand-operated. Turning the manual loading valve adjusting screw counterclockwise closes the prerotation vanes. Whenever the manual loading valve is used, the ammeter shall be watched to avoid motor overloads, and the chilled water thermometer shall be watched to maintain correct water temperature. When the air-conditioning plant is running in the automatic mode, the manual loading valve should be open (fully clockwise).

516-6.3.1.5 Hot Gas Bypass Valves. The hot gas bypass valves, which are solenoid-operated, open to place an artificial load on the main compressor during low-load conditions. When cooling demand decreases, the hot gas bypass switch energizes solenoids to open the valves. Whenever the valves are open, hot refrigerant gas bypasses the condenser and flows directly to the chiller. The bypassed refrigerant keeps a relatively constant load on the main compressor motor.

516-6.3.2 PNEUMATIC CAPACITY CONTROL SYSTEM ADJUSTMENTS.

516-6.3.2.1 Preliminary Procedure. The preliminary procedure for adjusting the pneumatic capacity control system is as follows:

1. Obtain the following equipment, tools, and materials:
 - a Multimeter
 - b Pneumatic controls test set
 - c Small, flat tip screwdriver
 - d Small Phillips screwdriver
 - e 1/16-inch Allen wrench
 - f 3/32-inch Allen wrench
 - g Rubber band or masking tape
2. Secure the air-conditioning plant.
3. Allow sufficient time for the air-conditioning plant refrigerant and chilled water outlet temperatures to stabilize.
4. Verify 20-psig supply air to the air-conditioning plant pneumatic capacity control system.

WARNING

To avoid injury or death, disconnect all power sources when deenergizing the plant. Follow ship operating procedures when deenergizing the air-conditioning plant. The air-conditioning plant may be energized by multiple power sources.

5. Deenergize the air-conditioning plant. Verify that the air-conditioning plant is deenergized and tag, Out of Service.

516-6.3.2.2 Back-Pressure Relief Valve and Reducing Valve for Prerotation Vanes Motor Adjustment. Many capacity control systems are equipped with back-pressure relief and reducing valves for the prerotation vanes motor. Ensure that these components are operating properly before adjusting the pilot positioner. Use the following procedures to correctly adjust these components:

NOTE

Refer to the specific plant technical manual for the correct back-pressure reducing valve and back-pressure relief valve pressure settings.

1. If not installed, temporarily attach a pressure gauge to the test fitting located downstream of the back-pressure relief valve.
2. Temporarily adjust the back-pressure reducing valve so that the output pressure (read from the pressure gauge) is 1 psig higher than specified in the technical manual. Then set the back-pressure relief valve by pulling up on the lockring and adjusting the relief valve so that it just starts to vent (clockwise to increase, counterclockwise to decrease the relief setting). Push down the lockring to lock the pressure setting.
3. Set the back-pressure reducing valve so that the output pressure is as specified in the technical manual (clockwise to increase, counterclockwise to decrease the output pressure).
4. Remove the temporarily installed pressure gauge.

516-6.3.2.3 T-8000 Thermostat Setpoint and Sensitivity Adjustment. Use the following procedure to adjust the T-8000 thermostat setpoint and the sensitivity ([Figure 516-6-4](#)) of the pneumatic capacity control system:

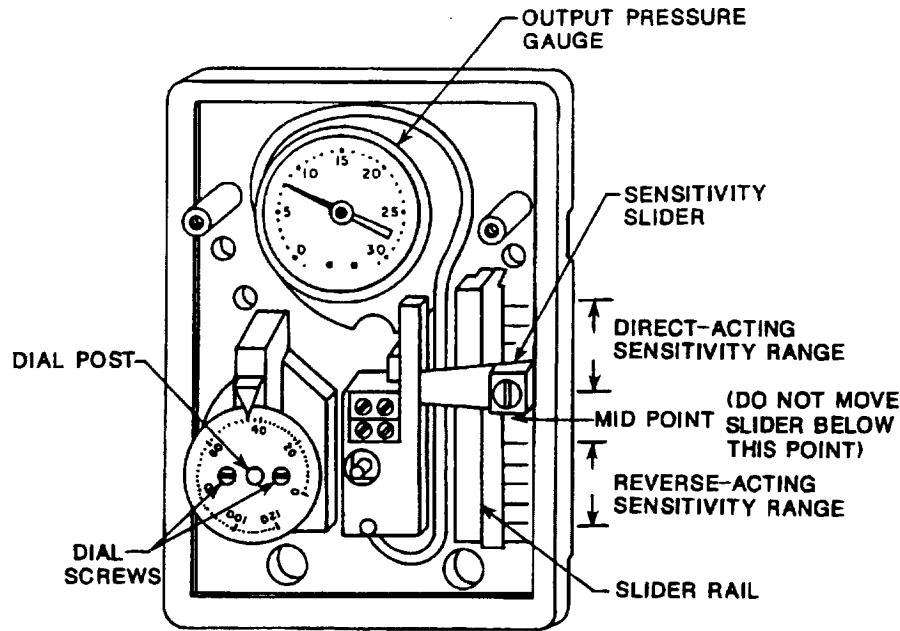


Figure 516-6-4. Temperature Control Thermostat (T-8000) Adjustment

CAUTION

Do not use the T-8000 thermostat pressure gauge. Use the calibrated control panel gauges for reading pilot signal air pressure and chilled water outlet temperature.

NOTE

The T-8000 thermostat setpoint is 44° F with an 8.0 ± 0.5 psig output and a sensitivity of 1.75 ± 0.25 psi/°F. Its sensitivity is factory set and should require no further adjustments. Nevertheless, the sensitivity should be checked to verify correct operation.

516-6.3.2.3.1 T-8000 Thermostat Setpoint Adjustment. Check and, if necessary, adjust the T-8000 thermostat setpoint as follows:

1. Turn the manual loading valve adjusting screw clockwise so that the valve does not bleed off air.
2. Remove the T-8000 thermostat cover.
3. Turn the T-8000 thermostat temperature dial so that the pilot signal air pressure is 8.0 ± 0.5 psig (clockwise to decrease, counterclockwise to increase the pressure). Compare the dial position with the chilled water outlet temperature. The temperatures should be the same. If not, adjust the thermostat setpoint as follows:
 - a Loosen the two screws on the T-8000 thermostat temperature dial so that the dial face turns **independently** of the shaft.
 - b Turn the dial face to match the chilled water outlet temperature. Ensure the pilot signal air pressure is still

8.0 $\pm$ 0.5 psig. Then tighten the two screws so that the dial face is mounted tightly to the shaft with the dial face temperature matching the chilled water outlet temperature.

516-6.3.2.3.2 T-8000 Thermostat Sensitivity Adjustment. Check and, if necessary, adjust the T-8000 thermostat sensitivity as follows:

CAUTION

The chilled water outlet temperature, as sensed at the T-8000 thermostat sensing bulb, shall not change during steps 1 through 5; otherwise, the sensitivity will not be set correctly. If the temperature changes, repeat the steps.

1. Read and record the air-conditioning plant chilled water outlet temperature.
2. Ensure that the T-8000 thermostat temperature dial is adjusted so that the pilot signal air pressure is 8.0 $\pm$ 0.5 psig.
3. Turn the T-8000 thermostat temperature dial down 4 degrees. Record the pilot signal air pressure.
4. Turn the T-8000 thermostat temperature dial up 8 degrees. Again record the pilot signal air pressure.
5. Verify that the air-conditioning plant chilled water outlet temperature (recorded in step 1) has not changed.
6. Calculate the T-8000 thermostat sensitivity as follows:
Sensitivity = (psig (step 3) - psig (step 4)) / 8°F
7. If the sensitivity is not 1.75 $\pm$ 0.25 psig/°F, adjust sensitivity as follows:

CAUTION

For correct T-8000 thermostat operation (direct acting), position the sensitivity slider above the slider track midpoint. Moving the slider 1/16 of an inch will change the sensitivity by approximately 0.3 psi/°F. Changing the thermostat sensitivity will change its setpoint.

- a Note the position of the T-8000 thermostat sensitivity slider on its track.
- b Loosen the sensitivity slider holding screw (the Allen screw mounted on the side of the slider) so that the slider can be moved up or down the slider track.
- c Move the slider up the track to increase the sensitivity or down the track to decrease the sensitivity. Moving the slider 1/16 of an inch will change the sensitivity by approximately 0.3 psi/°F.
- d Verify that the slider is level with the track, then carefully tighten the holding screw so that the slider is locked in place.
- e Repeat steps c and d until both the setpoint and the sensitivity are correct.
- f Ensure that the T-8000 thermostat pressure output is 8 $\pm$ 0.5 psig when the dial is set at the chilled water temperature.

g Ensure that the T-8000 thermostat pressure output is 8 ± 0.5 psig when the dial is set at the chilled water temperature.

516-6.3.2.4 Hot Gas Bypass Switch Open and Close Setting Adjustments. Most plants are equipped with hot gas bypass valves. Use the following procedures to correctly adjust these components.

NOTE

Refer to the specific plant technical manual for the correct hot gas switch open and close settings.

1. Turn the T-8000 thermostat temperature dial to 0° F.
2. Remove the hot gas bypass switch cover.
3. By changing the pilot signal air pressure with the manual loading valve, verify that the hot gas bypass switch opens and closes at the pressures specified in the technical manual.
4. If the switch operates correctly, go to step 5. If not, adjust the switch as follows:
 - a Turn the manual loading valve adjusting screw so that the pilot signal air pressure is as specified in the technical manual.
 - b If the switch contacts are open, slowly turn the range adjustment clockwise until the contacts just close. If the contacts are already closed, turn the range adjustment counterclockwise until the contacts open, then slowly turn it clockwise until the contacts just close.
 - c Return to step 3.
5. Install the switch cover.

516-6.3.2.5 Pilot Positioner Starting Point and Span Adjustments. The following procedure shall be used to adjust the pilot positioner starting point and span (Figure 516-6-5):

CAUTION

Only adjust the pilot positioner starting point and span. Normally, it should not be necessary to touch the factory-set screws. If necessary, reset pilot positioner factory-setscrews (paragraph 516-6.3.2.5.3).

NOTE

The pilot positioner starting point and span are 3.0 (+ 0.5, -0.0) psig and 10.0 (± 0.5) psid (differential), respectively. If starting point and span are outside these limits, adjust as necessary (paragraphs 516-6.3.2.5.1 and 516-6.3.2.5.2).

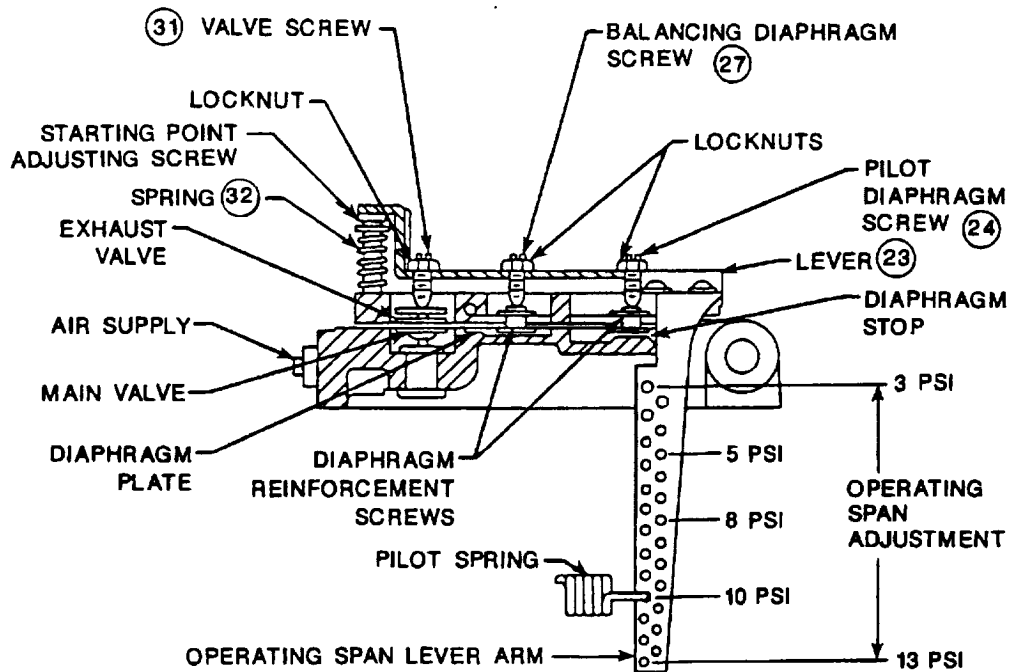


Figure 516-6-5. Pilot Positioner Adjustments

516-6.3.2.5.1 Pilot Positioner Starting Point Adjustment. Check and, if necessary, adjust the pilot positioner starting point as follows:

1. Close the N-6800 transducer bleed port by attaching a rubber band between the inlet and outlet ports and across the transfer lever. Masking tape can also be used to hold down the transfer lever.
2. Turn the T-8000 thermostat temperature dial to 30° F.
3. Turn the manual loading valve adjusting screw so the air pressure is 0 psig.
4. Verify that the prerotation vanes are in the closed position indicated by the indent labeled C on the vanes arm.
5. Check that the pilot positioner spring is attached to the lever arm and that the spring is relaxed. Some sag is allowed.
6. Slowly increase the air pressure to 3.0 (± 0.5 , -0.0) psig with the manual loading valve, while having someone observe the (vanes arm) vanes. The vanes should start to open (the vanes arm should move).
7. If the vanes start to open, go to paragraph [516-6.3.2.5.2](#). If not, adjust the pilot positioner starting point as follows:

CAUTION

Always remove the screwdriver from the screw before checking vane position. Downward pressure on the screw will move the prerotation vanes.

- a Remove the pilot positioner cover and adjust the pilot positioner starting point screw. Turn the screw counter-clockwise to increase and clockwise to decrease the setting.

- b Repeat steps 3 to 7 until the starting point is correct.
- c Install the pilot positioner cover. Ensure that the cover does not interfere with the lever arm.

516-6.3.2.5.2 Pilot Positioner Span Adjustment. Check and, if necessary, adjust the pilot positioner span as follows:

1. Use the manual loading valve to decrease the pilot signal air pressure to 0 psig.
2. Slowly increase the air pressure to 13.0 ± 0.5 psig with the manual loading valve, while having someone watch the prerotation vanes. The vanes should be full open when the air pressure is 13.0 ± 0.5 psig.
3. If the vanes are full open when at 13 psig, go to step 4. If not, adjust the pilot positioner span as follows:

CAUTION

Only adjust the pilot positioner spring when it is in the relaxed position to prevent spring distortion.

- a Turn the manual loading valve adjusting screw so that the air pressure is 0 psig and the pilot positioner spring is relaxed.
 - b If the prerotation vanes are fully open before the pilot signal air pressure reaches 13.0 ± 0.5 psig, move the spring out (away from the pilot positioner body) one lever arm hole.
 - c If the prerotation vanes are not fully open when the air pressure is 13.0 ± 0.5 psig, move the spring in (toward the pilot positioner body) one lever arm hole.
 - d Repeat steps b and c until the pilot positioner span is correct.
4. Remove the masking tape or rubber band from the N-6800 transducer lever (installed in paragraph [516-6.3.2.5.1](#), step 1). Verify that the lever moves freely.

516-6.3.2.5.3 Pilot Positioner Factory Screws Reset Procedures. The following procedure shall be used to reset the pilot positioner factory-set screws. Factory-set screws consist of the valve, balancing diaphragm, and pilot diaphragm screw ([Figure 516-6-5](#)).

CAUTION

Normally the factory-set screws should not be touched. Usually the only pilot positioner adjustments needed are for its starting point and span. See paragraph [516-6.3.2.5](#).

1. Ensure that the pilot spring is relaxed. Remove spring. Ensure a 20-psig air supply to the pilot positioner. Ensure that manual loading valve adjusting screw is turned counterclockwise so the air pressure is 0 psig.
2. Refer to [Figure 516-6-5](#) and loosen locknuts to screws (24, 27, and 31). Loosen valve screw (31) and balancing diaphragm screw (27) by turning each screw two turns counterclockwise.
3. Adjust the starting point screw to remove all slack from spring (32) without applying tension.

4. Adjust screw (24) until lever (23) is parallel with diaphragm plate.
5. Turn screw (27) clockwise until a slight resistance is felt.
6. Turn screw (31) in either direction until airflow stops or airflow can be heard venting from the exhaust port. Tighten the locknut for the screw (31).

NOTE

During step 7, you will hear airflow. This is normal because the pilot spring is disconnected.

7. Turn screw (27) counterclockwise 3/4 turn and tighten locknut.
8. Turn screw (24) counterclockwise 1-1/2 turns and tighten locknut.
9. Reattach pilot spring in hole 12 or 13, counting down from top.
10. Repeat starting point screw adjusting procedure (paragraph 516-6.3.2.5.1).

516-6.3.2.6 LC-3000 Motor Current Amplifier Adjustment. The following procedure shall be used to test and adjust the LC-3000 motor current amplifier using the pneumatic controls test set. This will verify that the LC-3000 is operating properly. The adjustment should yield a curve similar to the bandwidth 5 curve of Figure 516-6-6.

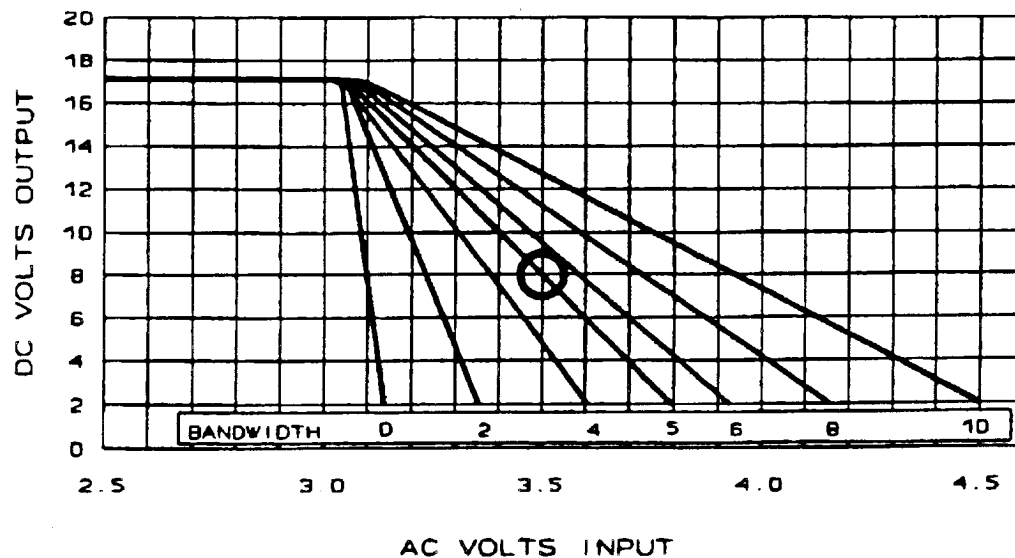


Figure 516-6-6. LC-3000 Bandwidth Curves

WARNING

Dangerous voltages may be present. Do not work alone.

NOTE

Multiple power sources may be installed for the air-conditioning plant and auxiliary oil pump.

1. Deenergize all A/C plant power supplies and tag start button, motor controller, and circuit breaker Out of Service. Verify that there is no electrical power to any components in motor and control panel and motor controller.
2. Remove compressor motor end control panel cover and LC-3000 current amplifier cover.
3. Set percent load adjustment at 100-percent mark ([Figure 516-6-7](#) and [Figure 516-6-8](#)).

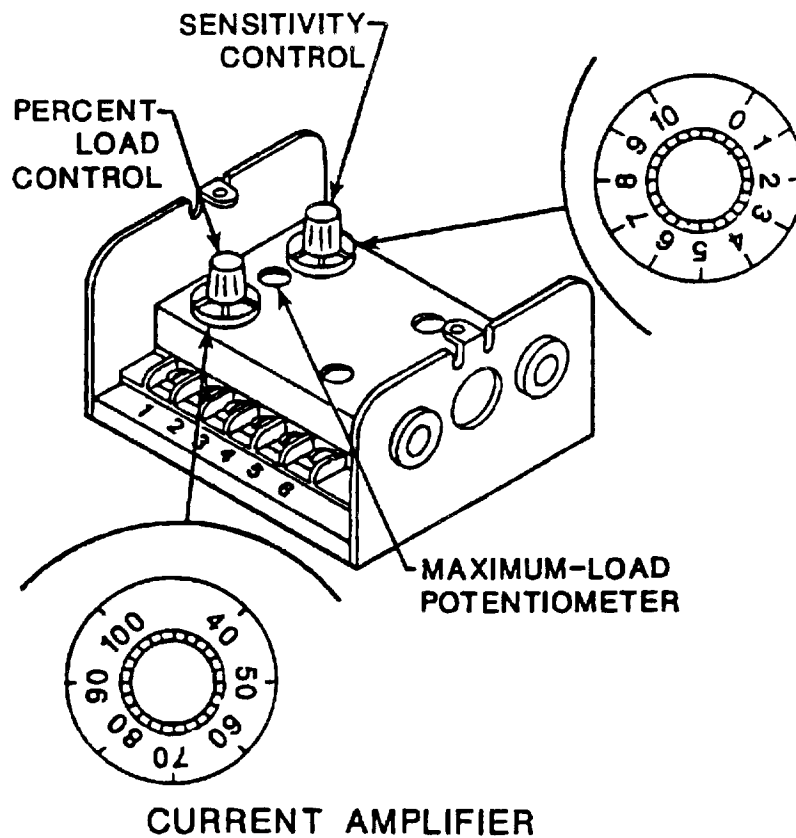


Figure 516-6-7. LC-3000 Current Amplifier Adjustments

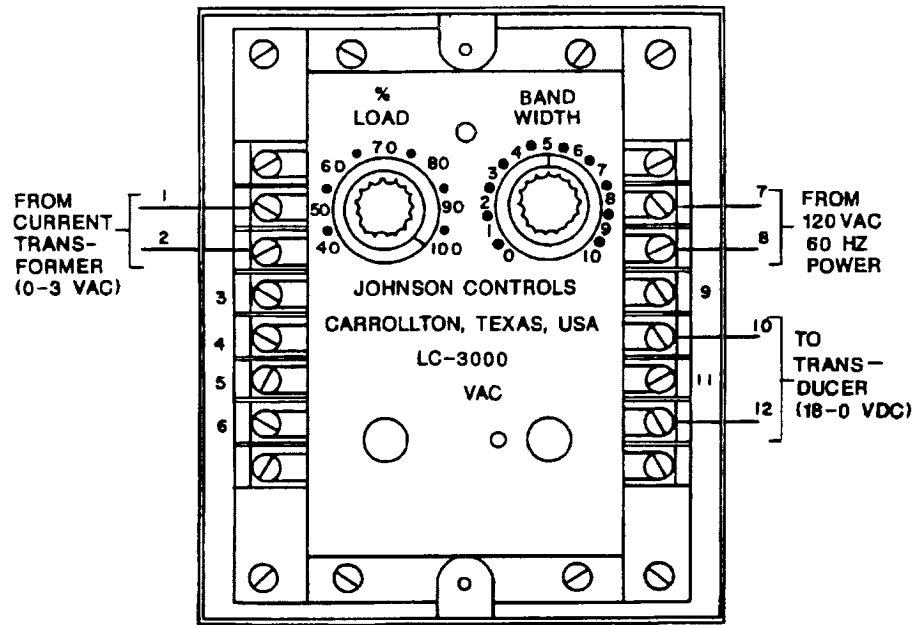


Figure 516-6-8. LC-3000 Current Amplifier Front View (Cover Removed)

4. Set bandwidth/sensitivity control at 5.
5. Tape and number wires connected to LC-3000 current amplifier terminals 1, 2, 7, and 8 (Figure 516-6-8).
6. Disconnect wires connected to terminals 1, 2, 6, and 8.
7. Connect digital multimeter capable of reading 0 to 20 Vdc to terminals 10 and 12 of LC-3000 current amplifier using cable 1M-T10/T12 from the test set.
8. Connect deenergized 110 to 115-Vac power source (leads J3/J4-T7/T8) from terminals J3/J4 of test set to terminals 7 and 8 of current amplifier. Polarity is not important.

CAUTION

Do not disconnect leads to terminals 10 and 12 and supply power to terminal 1 and 2. Damage to current amplifier may result if 900- to 1100-ohm resistance is not present across terminals 10 and 12 when power is applied to terminals 1 and 2.

9. Connect a multimeter capable of reading 0 to 5 Vac to terminals J1/J2 of test set using short cable J1/J2-2M.
10. Connect deenergized 0 to 5-Vac power source from test set terminal J1/J2 to terminals 1 and 2 of current amplifier using cable J1/J2-T1/T2.

CAUTION

Do not supply voltage in excess of 4.5 Vac to terminals 1 and 2 of current amplifier. A voltage in excess of 5 Vac applied to terminals 1 and 2 may damage current amplifier.

11. Turn 0 to 5-volt test set potentiometer (R1) fully counterclockwise to ensure that, when energized, output to LC-3000 current amplifier terminals is less than 0.5 Vac.
12. Energize test set.
13. Adjust test set potentiometer (R-1) from 2.5 Vac from terminals J1/J2 (to LC-3000 current amplifier terminals 1 and 2).

NOTE

If the LC-3000 does not yield the proper output and cannot be adjusted, replace or repair the LC-3000 per paragraph 516-6.3.3.

14. Ensure that output from LC-3000 current amplifier terminals 10 and 12 is 16 to 19 Vdc (polarity is not important). If not, adjust maximum load adjustment potentiometer (Figure 516-6-7) until 16 to 19 Vdc is obtained.

NOTE

Turning the maximum load potentiometer clockwise or counterclockwise may increase allowable load (voltage to the transducer). There is no standard configuration; therefore, proper direction must be determined by observation.

15. Slowly increase ac voltage input to terminals 1 and 2 of the LC-3000 current amplifier by adjusting test set potentiometer R-1 and observing the following conditions:
 - a With an input voltage of up to 3 Vac, output voltage to the transducer is 16 to 19 volts. If necessary, adjust the maximum load adjustment potentiometer to increase voltage.

NOTE

Turning the maximum load potentiometer clockwise or counterclockwise may increase allowable load (voltage to the transducer). There is no standard configuration; therefore, proper direction must be determined by observation.

- b As input voltage exceeds 3 Vac (approximately 3.05 Vac), output voltage to the transducer decreases. Adjust the maximum load adjustment potentiometer (Figure 516-6-7) to accomplish this. The voltage change from 3 to 3.05 Vac should produce approximately 0.1 to 0.2 Vdc at the transducer.
 - c At an input voltage of 3.5 Vac, output voltage to the transducer should be 7 to 9 Vdc (see Figure 516-6-6). Adjust bandwidth if necessary to obtain this condition.
16. Repeat steps 15.a through 15.c until the conditions specified in step 15.c are satisfied without additional adjustments of the maximum load potentiometer or bandwidth.
17. If the bandwidth is not reading 5, loosen screw(s) securing bandwidth knob, rotate knob (without turning shaft) to indicate a bandwidth of 5, tighten knob, and repeat steps 15.a through 15.c to ensure bandwidth has not changed.
18. With an input voltage of approximately 3 Vac, slowly turn the percentage (%) load dial and verify that the output voltage decreases. The output curve is shown in Figure 516-6-9.

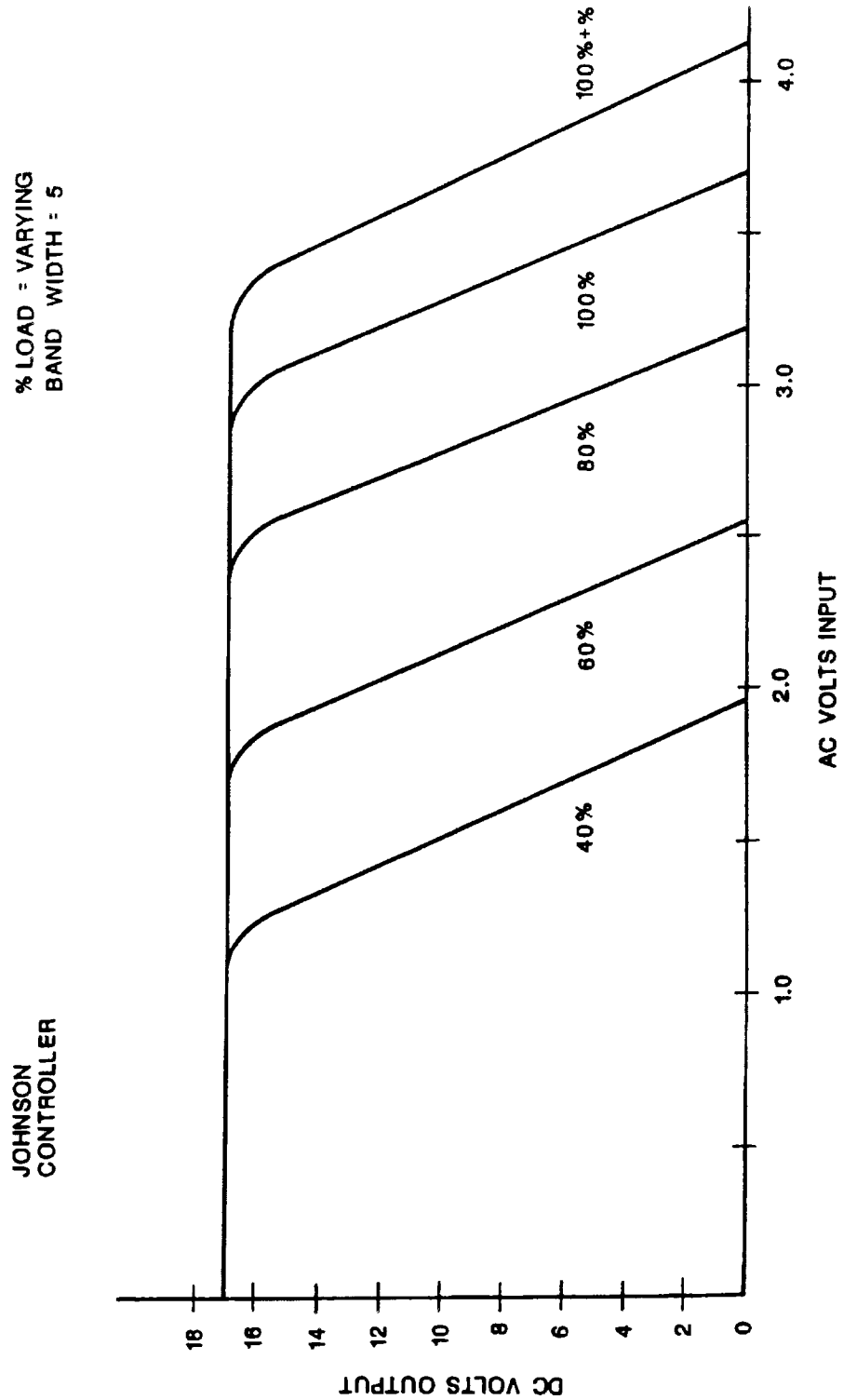


Figure 516-6-9. Percent Load Variation Graph for LC-3000 Current Amplifier (Typical)

19. Deenergize the test set assembly.

516-6.3.2.7 Test and Adjust N-6800 Transducer. The following procedure shall be used to check and adjust the N-6800 transducer zero and sensitivity (Figure 516-6-10) using the test set and LC-3000 (motor current amplifier). A transducer is a device that converts a control signal from one form to another. The N-6800 transducer converts an electrical signal from the LC-3000 into a pneumatic signal. Whenever the compressor drive motor current exceeds full load, the transducer bleeds off air pressure to the vane motor to close or prevent further opening of the vanes and to prevent the motor current from exceeding full load amps. The output air pressure of the transducer will vary with the input signal voltage coming from the LC-3000. The goal of this adjustment is to make the sensitivity of the N-6800 match the recommended curve shown in Figure 516-6-11. Input voltage signals of 0, 9, and 18 Vdc (obtained using the test set and LC-3000) should yield approximately $0 \pm (0.25)$, 7-, and 20-psig output, respectively. Some 363-ton plants have 30-psi supply air to the vane motor. For those plants, the output should be 0, 11, and 30 psig.

NOTE

The N-6800 transducer is factory set and should require no further adjustments. Check the transducer, however, to verify correct operation. When adjusting the transducer, be sure that a gap is always present between the stop screw and the transducer base. If not gap is present, the transducer will not bleed off air.

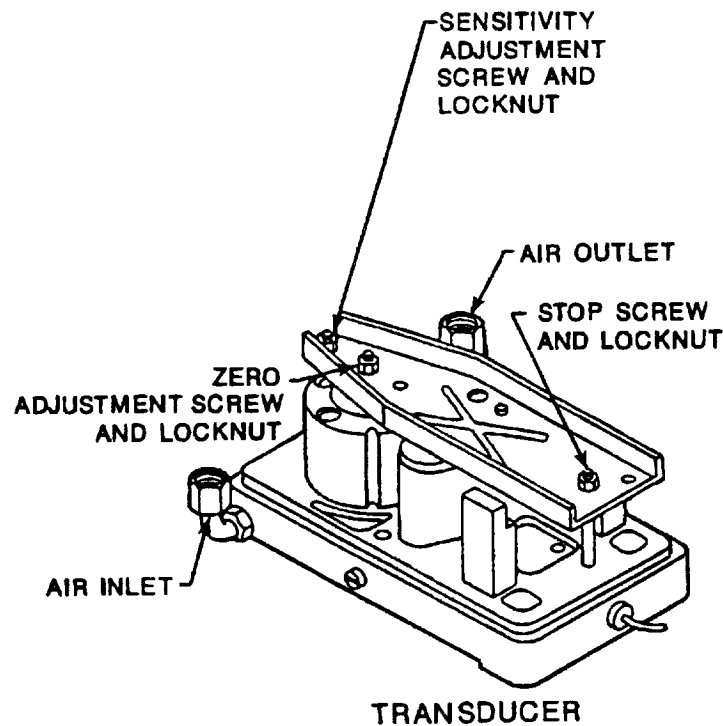


Figure 516-6-10. N-6800 Transducer Adjustments

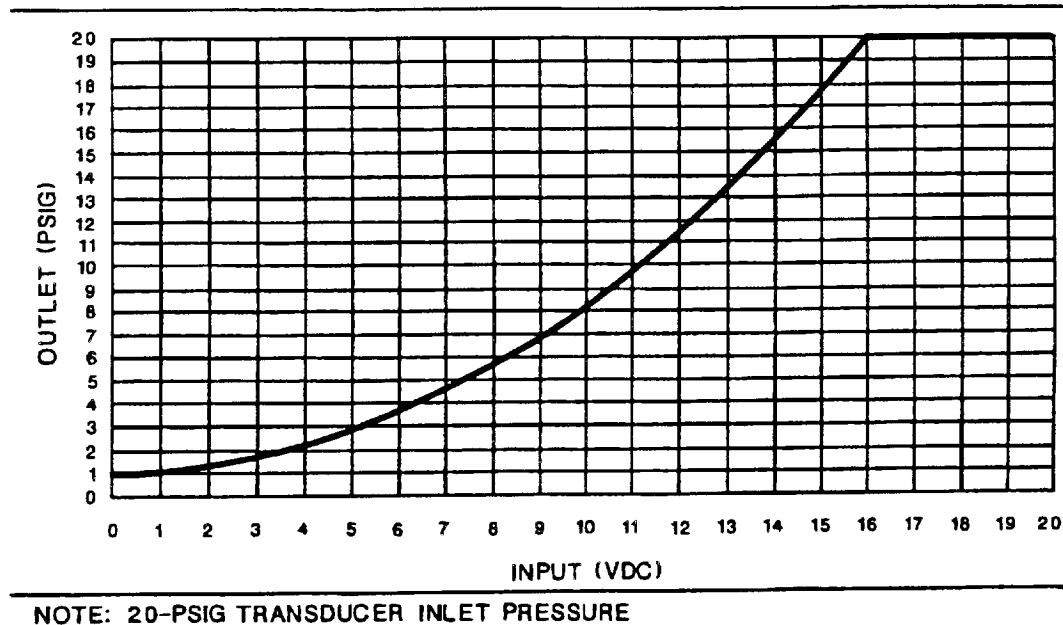


Figure 516-6-11. N-6800 Transducer Performance Curve

1. Set up test set, LC-3000, and multimeter in accordance with paragraph 516-6.3.2.6, steps 3 through 10.
2. Disconnect transducer wires from terminals 10 and 12 of the LC-3000 current amplifier.

NOTE

The transducer coil resistance shall be 900 to 1100 ohms. If not, the transfer lever may vibrate and output pressure will fluctuate.

3. Measure resistance of transducer coil using a digital multimeter via wires disconnected from terminals 10 and 12 of current amplifier. Replace transducer if resistance is less than 900 or more than 1100 ohms.
4. Reconnect wires from transducer to terminals 10 and 12 of current amplifier (polarity is not important).
5. Remove covers from T-8000 thermostat and N-6800 transducer.
6. Turn T-8000 thermostat to 0° F to ensure full air pressure from the T-8000.
7. Turn manual loading valve counterclockwise so that 0 psig is indicated on the control panel pressure gage.
8. Disconnect air piping at transducer outlet (right side) and connect pressure gage and fittings supplied with test set to transducer outlet.

NOTE

Gage should be installed in an upright position for accurate reading.

9. Adjust manual loading valve so that the maximum air pressure of 20 psig is read on control panel air pressure gage (control air pressure). If necessary, adjust pressure-reducing valve to obtain 20 psig.

NOTE

Always remove screwdriver from zero and sensitivity adjustment screws before reading transducer outlet pressure.

10. With the test box deenergized, the pressure gage at the transducer discharge should read 0+ (0.25 to 0.5) psig. If not, turn the zero adjustment screw ([Figure 516-6-10](#)) counterclockwise to increase, clockwise to decrease. **For the first time through only:** if the proper pressure cannot be obtained with the available screw travel, proceed with steps 10.a through c; otherwise continue with step 11.
 - a Back off transducer stop screw so gap is greater than 1/8 inch, but less than 1/4 inch. Ensure free movement of lever arm while adjustments are being made.
 - b Turn zero adjustment screw clockwise until it just seats. Turn zero adjustment screw counterclockwise five turns.
 - c Turn sensitivity screw until 0.25 to 0.5 psig is obtained on the gage. Go to step 11.
11. Energize and adjust variable 0 to 5-Vac (J1/J2) power supply potentiometer (R1) to obtain a 9-Vdc output from current amplifier terminals 10 and 12 (to transducer).

NOTE

With the input pressure at 20 psi, two points on [Figure 516-6-11](#) will yield the desired curve.

Some 363-ton air-conditioning plants use 30-psig air pressure to the motor current limiter transducer and vane motor. In this case, the pressure at 9 Vdc should be 10 to 12 psig (step 9), and the pressure at 16 to 19 Vdc should be 30 psig (step 8).

12. Ensure pressure gage at the transducer outlet reads 6 to 8 psig. If it does, proceed to step 14.

NOTE

When following the adjustment procedure, the pressure will appear to be changing in the wrong direction. The pressures will be correct, however, after the transducer is rezeroed.

13. If the transducer outlet pressure is less than 6 psig, turn sensitivity screw counterclockwise (one turn for every 3 psig under 6 psig). If transducer outlet pressure is greater than 8 psig, turn sensitivity screw clockwise (one turn for every 3 psig above 8 psig) and return to step 10.
14. Adjust voltage input to terminals 1 and 2 of current amplifier to obtain 16 to 19-Vdc output to the transducer from terminals 10 and 12 of the current amplifier. Ensure pressure gage attached to outlet of transducer reads 20 psig. If the proper pressures are read at 0 and 9 Vdc, then the 20 psig should be read at 16 to 19 Vdc; if not, replace the transducer.

NOTE

The purpose of the transducer stop screw is to prevent the flexure hinge from being overstressed. When adjusting the transducer ensure a gap is always present between the stop screw and the base. If there is not gap, the transducer will not operate properly.

15. Set a 1/32-inch gap between the stop screw and transducer body with the transducer in a relaxed (deenergized) state to limit flexing of the metal hinge on the transducer.

16. Demonstrate smooth performance of the transducer by slowly cycling the test set potentiometer (R1), and observe transducer outlet pressure. Replace transducer if transducer chatter is heard or if a change in transducer outlet pressure does not smoothly follow the voltage change.

516-6.3.2.8 Set Up of Air-Conditioning Unit for Fine Tuning. The following procedure is for final adjustment of the operating air-conditioning plant. This includes the final adjustment of the LC-3000 potentiometer.

1. Deenergize test set.
2. Disconnect multimeters and disconnect all test set connections and cables from current amplifier.
3. Reconnect wires marked 1, 2, 7, and 8 to their respective current amplifier terminals.
4. Turn manual loading valve screw counterclockwise so that 0 psig is read on the control air pressure gage.
5. Disconnect air pressure gage at transducer outlet and reconnect air piping from vane motor to transducer outlet.
6. Install cover on transducer.
7. Set T-8000 thermostat to design temperature (44° F).
8. Install cover on T-8000 thermostat.
9. Turn current amplifier percentage (%) load adjustment dial to 100 percent and the bandwidth to 5.
10. Remove safety tag(s).
11. Energize air-conditioning unit.

CAUTION

Prior to starting the air-conditioning unit, see Table 516-6-2 for oil temperatures.

NOTE

A chilled water load greater than the unit's rated tonnage is required to ensure electric-pneumatic load-limiting control system is the correct value. See technical manual for motor full load amperage.

CAUTION

Dangerous voltages exist when equipment is open and energized. Do not work alone.

12. After the oil sump has reached satisfactory conditions and available chilled water load is greater than the unit's rated tonnage, start unit.
13. After motor amperage has stabilized at a point below full load rated motor amperage, adjust the manual loading valve as follows:
 - a Slowly turn manual loading valve adjustment screw clockwise to increase control air pressure. Do not allow the motor to exceed motor full load amperage. Constantly monitor air-conditioning motor amps.

- b Adjust maximum load potentiometer as necessary so motor amperage is limited to motor full load amperage when full control air pressure (13 psi or greater) is available and percentage (%) load dial indicates 100 percent.

NOTE

Turning the maximum load potentiometer clockwise or counterclockwise may increase load. There is no standard and the setting must be determined by observation. If the air-conditioning plant does not load, ensure that 120 Vac is available at terminals 7 and 8 of LC-3000. If the air-conditioning plant cannot be limited to full load motor amperage, the resistor (usually adjustable), located in the main controller, is probably incorrectly set. The voltage from the resistor to the LC-3000 motor current amplifier (terminals 1 and 2) should be 3 Vac at full load amps. A voltage significantly less than 3 Vac at full load amps will prevent the motor current limiter from limiting the plant. If the air-conditioning plant cannot attain motor full load amperage, the plant may be undercharged or the resistor may be incorrectly set as just described. An input signal of 5 Vac or higher will cause the motor current limiter to limit the plant to less than full load (see paragraph 516-6.3.2.9 for checking and setting the resistor).

14. Reinstall cover on current amplifier.
15. Close compressor end control panel.
16. Monitor air-conditioning plant operation for at least 1/2 hour.
17. Return air-conditioning unit to readiness condition.

516-6.3.2.9 1RES (R) Resistor (Input Resistor for the LC-3000) Adjustment.

NOTE

The 1RES resistor, located in the air-conditioning plant motor controller, provides a 0- to 4-Vac input signal (proportional to motor amperage) to the LC-3000. The proper value for the resistor can be found in the air-conditioning plant technical manual or motor controller drawing.

1. The 1RES resistor is sized to give an approximately 3-Vac signal to the LC-3000 at motor full load amps. Check the 1RES resistor if a problem with the LC-3000 input signal voltage is suspected.
2. Tag out air-conditioning plant.
3. Verify that the manufacturer's drawing is applicable to the motor controller installation.
4. Open the motor controller and verify that it is deenergized.
5. Locate the 1RES resistor and isolate it from the circuit. In most cases the resistor is a variable one; however, some installations do use fixed resistors.
6. Measure the resistance across the 1RES resistor using a multimeter. The resistance should be +0 to -10 percent of design.
7. If the value is not at design, adjust the resistor as follows:

- a Loosen the resistor slider holding screw.
- b Adjust the slider so that the resistance is within +0 to -10 percent of design.
- c Lock the slider in position and remeasure the resistance. Readjust if necessary.
- d Reconnect the resistor to the circuit and close the motor controller.

516-6.3.3 LC-3000 TROUBLESHOOTING AND REPAIR PROCEDURE.

1. Deenergize and secure the air-conditioning plant. Tag Out of Service. Ensure that the LC-3000 is deenergized by testing across terminals 7 and 8 ([Figure 516-6-8](#)) with a voltmeter.
2. Remove the LC-3000 from the plant.
3. Disassemble the LC-3000.
4. Visually inspect the component side of the circuit board. If there are any disconnected wire leads from the potentiometers, solder the wires in accordance with the schematic diagram and the circuit diagram. Look for any discoloration of the circuit board or component leakage due to excessive heat. If heating damage is present in individual components, replace them with the proper replacement components listed in [Table 516-6-3](#).

Table 516-6-3. JOHNSON CONTROLS LC-3000 PARTS LIST

Component	Description	Johnson Controls Component Number
T1	Transformer, 120 Vac	20-61380
R11	Resistor, Carbon Film, 1W, $\pm 5\%$, 200 ohm	02-5619-603
CR11	Zener Diode, 18V, $\pm 5\%$, 3W	49-61438
CR1-CR9, CR12, CR13	Diode Array Plastic Dip	49-22141
CR10	Zener Rectifier, 7.5V, 400 MW	49-60173
R6	Resistor, Carbon Film, 0.5W, $\pm 5\%$, 100 ohm	02-5005-531
C1, C2	Capacitor, Electrolytic, Aluminum, 100 μ F, 35 Vdc	02-42-1168
C4	Capacitor, Electrolytic, Aluminum, 50 μ F, 25 Vdc	02-42-72
C3	Capacitor, Electrolytic, Aluminum, 100 μ F, 63 Vdc	02-5412-224
R9	Resistor, 5W, $\pm 5\%$, Wire Wound, 200 ohm	02-5081-184
R4	Resistor, Carbon Film, 0.5W, $\pm 5\%$, 10K ohm	02-5005-1074
Q2	Transistor, 2N3645, PNP	02-181-259
R10	Resistor, Carbon Film, 0.5W, $\pm 5\%$, 1.3K ohm	02-5005-833
Q1	Transistor, 2N3711, NPN	49-60181
R5	Resistor, Carbon Film, 0.5W, $\pm 5\%$, 1K ohm	02-5005-809
Not Shown		

Table 516-6-3. JOHNSON CONTROLS LC-3000 PARTS LIST - Continued

Component	Description	Johnson Controls Component Number
R1	Potentiometer, 1K ohm, $\pm 20\%$	49-60344
R3	Potentiometer, 750 ohm, $\pm 5\%$	49-60348
R2	Potentiometer, 150 ohm, $\pm 5\%$	02-5341

5. Test the individual components on the circuit board as follows:
- a Using the digital multimeter, test each capacitor (Figure 516-6-12) (components C1 to C4) to see that each holds a charge. All these capacitors have better reliability characteristics than the originally installed aluminum electrolytic capacitors. Replace each faulty component with the following replacement parts:

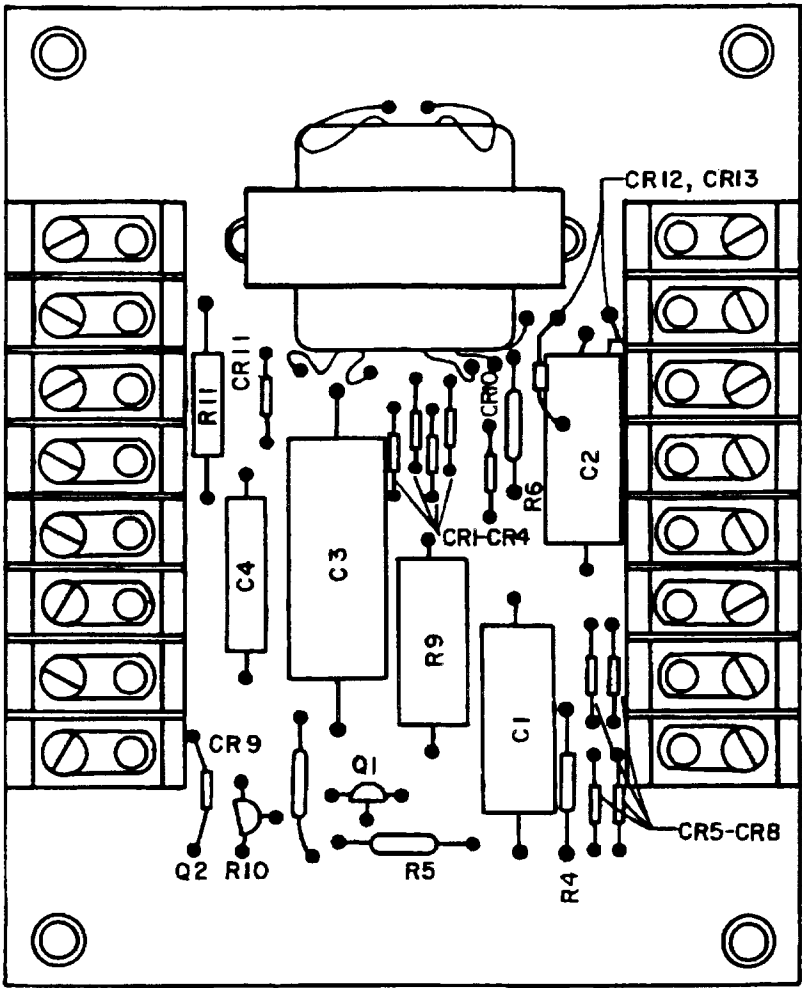


Figure 516-6-12. LC-3000 Current Amplifier Detailed Layout

- (1) Replace capacitors C1 and C2 with MIL-C-39003, style CSR23 or style CSR33, solid electrolyte 68 microF (35-Vdc rating) tantalum capacitors (NSN 9N5910-01-241-1742).
- (2) Replace capacitor C3 with MIL-C-39006/22, style CLR79, nonsolid gel electrolyte 86 microF (100-Vdc rating) tantalum capacitors (NSN 9N5910-01-119-8372).

- (3) Replace capacitor C4 with MIL-C-39006/22, style CLR79, nonsolid electrolyte 50 microF (60-Vdc rating) tantalum capacitor (NSN 9N5910-01-119-4309).
 - b Test each resistor (components R4, R5, R6, R9, and R10) to verify the values specified in [Table 516-6-3](#). Replace each faulty component with the correct replacement part.
 - c Test each diode (components CR1 to CR9, CR12, and CR13) using the diode check function on the digital multimeter. Replace each faulty component with the correct replacement part.
6. Reassemble the LC-3000.
 7. Install the LC-3000.
 8. Energize the air-conditioning plant.
 9. Perform the LC-3000 test procedure (paragraph [516-6.3.2.6](#)).
 10. Adjust the LC-3000 (paragraph [516-6.3.2.8](#)).

516-6.4 ELECTRONIC CAPACITY CONTROL SYSTEM (INSTALLED AS MACHALT ECP 360)

516-6.4.1 MAIN COMPONENTS (Figure 516-6-13):

- a. THERMISTOR. The thermistor senses the temperature of the chilled water leaving the evaporator and sends an electrical temperature signal to the TEMPERATURE/CURRENT MODULE (TCM).
- b. TEMPERATURE/CURRENT MODULE. As the main control element, the TCM compares the signal from the thermistor to the chilled water temperature setpoint. If required, the TCM pulses the ELECTRIC ACTUATOR to make an adjustment of the compressor pre-rotation vanes (PRV) in the appropriate direction. The TCM also acts as a Load Limiter for the air conditioning (A/C) plant drive motor.
- c. ELECTRIC ACTUATOR. The electric actuator controls the position of the prerotation vanes (PRV) ([Figure 516-6-14](#)). The actuator also controls the Hot Gas By-pass Valve (HGBP) via cam operated switches located inside the actuator.

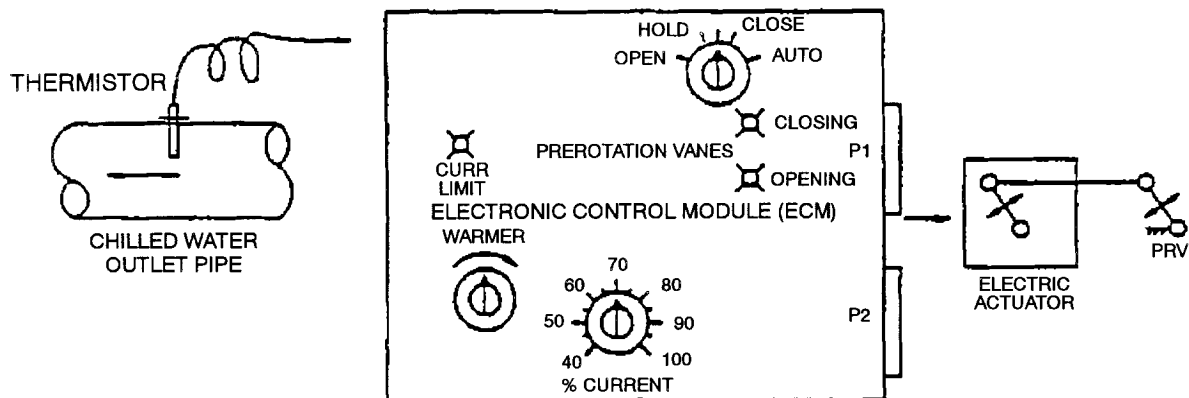


Figure 516-6-13. Basic Electronic Capacity Control System

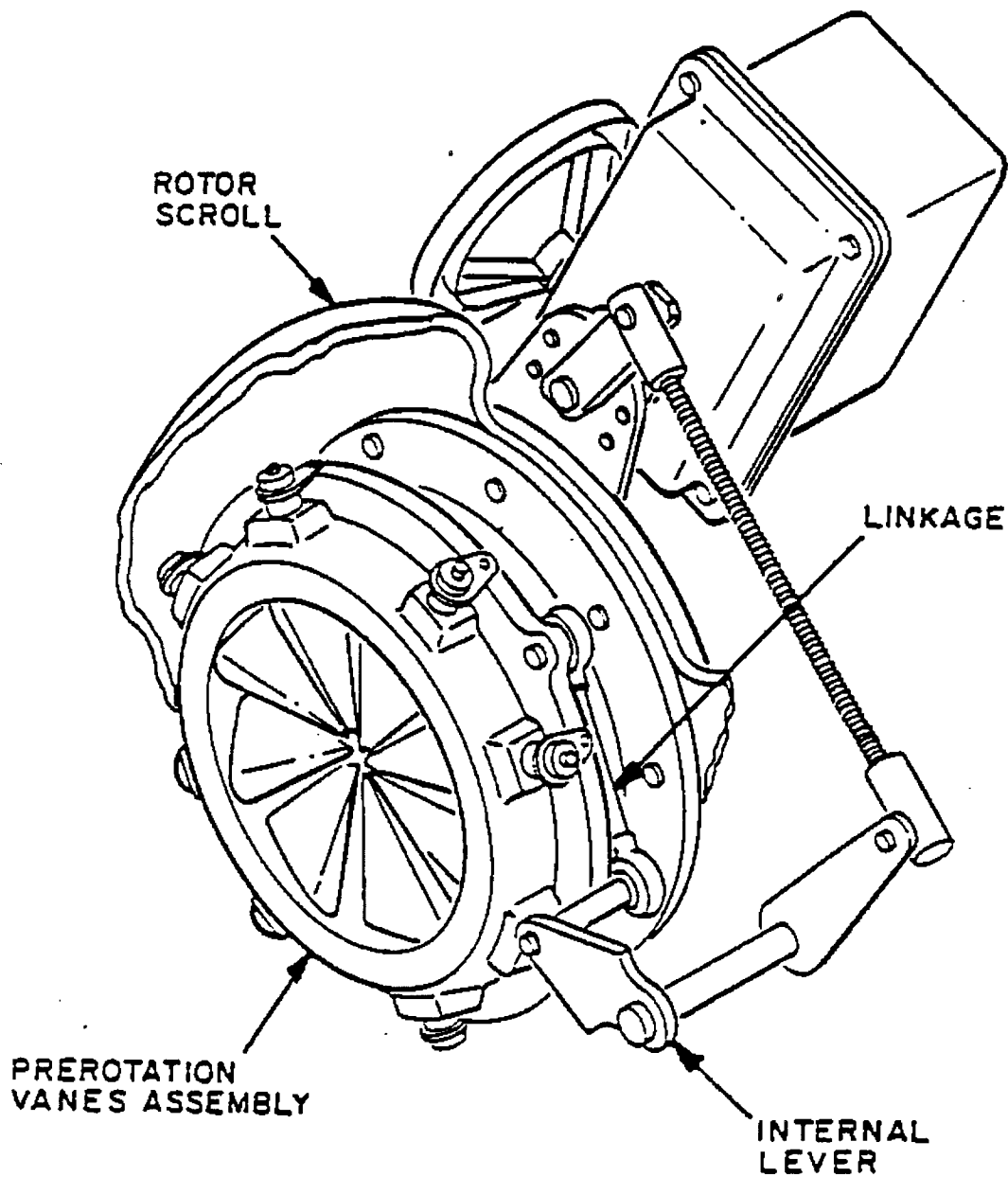


Figure 516-6-14. Compressor Prerotational Vanes and Electric Actuator

516-6.4.2 DESCRIPTION OF OPERATION

516-6.4.2.1 The thermistor is a temperature sensing device whose resistance varies with the temperature. The thermistor is furnished as a sealed unit with 20 feet of cable. This design ensures that the thermistor and the TCM are properly matched, and avoids problems with incorrect cable and poor splices.

516-6.4.2.2 The electric actuator is a geared down, reversible electric motor for use in applications requiring motion of a quarter turn or less. Forward and reverse motor windings are activated to open or close the PRV by separate Solid State Relays located in the TCM. The actuator has a visual position indicator mounted on the case to indicate the shaft, or PRV, position.

516-6.4.2.2.1 A handwheel is provided which can be used to manually position the PRV, but only when the plant is shut down and there is no power to the control system. During normal operation, the control system overrides the handwheel. When the system is energized, manual PRV control is accomplished electrically via the "open", "close", and "hold" positions on the control switch.

516-6.4.2.2.2 Cam operated switches inside the actuator are used to set travel limits and to provide operation of the HGBP. When no signal is being sent to the actuator, its position does not change.

516-6.4.2.2.3 The actuator has four cam operated switches, with switch No. 1 located closest to the base, or the PRV end of the actuator. Open and close limit cams are approximately 30 degrees apart, HGBP cams are between the open and close cams and above the PRV close limit cam.

516-6.4.2.2.4 Cam/switch No. 1 controls the PRV open limit. Cam/switch No. 2 controls HGBP SOL-1 and is set to provide hot gas at 70% plant capacity. Cam/switch No. 3 controls the PRV close limit. Cam/switch No. 4 controls HGBP SOL-2 and is set to provide hot gas at 50% plant capacity.

516-6.4.2.3 Temperature/Current Module (TCM)

516-6.4.2.3.1 "PREROTATION VANES" switch positions are only effective while the plant is operating.

- a. "AUTO" - Temperature control is automatic.
- b. "HOLD" - No signal is sent to the actuator, and the PRV do not move.
- c. "OPEN" - Continuous "open" signal is sent to the actuator.
- d. "CLOSE" - Continuous "close" signal is sent to the actuator.

516-6.4.2.3.1.1 Indicator lights show "open" and "close" signals (green); and "current limit" (yellow).

516-6.4.2.3.1.2 The prerotation vanes switch on the module can be used to manually control the position of the PRV. In the "OPEN" or "CLOSE" position, a continuous signal is sent to the actuator to cause PRV movement in the selected direction. In the "HOLD" position neither signal is sent and the PRV are held in the last position set. During overload conditions, the Load Limiter feature will override all PRV switch selections.

516-6.4.2.3.2 TCM Temperature Control

516-6.4.2.3.2.1 "TEMPERATURE CONTROL POINT" adjusts the chilled water leaving temperature between 39°F and 54°F.

516-6.4.2.3.2.2 The thermistor supplies the TCM with a resistance that is inversely proportional to the leaving chilled water temperature. When the prerotation vanes switch on the module is in the "AUTO" position, the TCM pulses the electric actuator to control the PRV position. Approximately once every 18 seconds a decision is made whether to adjust the PRV. The pulse duration or length of time that the PRV are moved, is proportional to the sum of the temperature error and the rate of change of this error. No pulses are sent until this sum exceeds 0.5°F. The maximum pulse duration is approximately 1 second.

516-6.4.2.3.2.3 Since it is necessary to have the PRV close on plant shutdown, the TCM will send a "close" signal after a routine shutdown. If all power is lost, the PRV will remain at its existing position, but will close eventually when power is restored. The green "close" light stays on while the plant is shut down.

516-6.4.2.3.3 TCM Load Limiting. Motor current is sensed by a current transformer in the compressor motor starter. A nominal signal of 2.9 - 6 VAC at full load motor current is then developed across a burden resistor located in the compressor motor starter (See plant technical manual for exact voltage). The TCM uses this signal to perform the current limiting function. With the "% CURRENT" adjustment on the TCM set to "100", the current limit circuit prevents the vanes from opening if the motor current exceeds the full load rating. If the motor current reaches 104% of the full load rating, "close" pulses are sent to the actuator at 16 second intervals. Maximum pulse duration is 1 second. When the motor current drops to 98% of the full load value, normal temperature control resumes. The point at which current limiting occurs can be adjusted to as low as 40% of the full load motor current rating with the % current adjustment on the module. A yellow "CURR LIMIT" LED on the module lights to indicate when the current limit circuit is in operation. Open signals are ignored during load limiting.

516-6.4.2.3.4 TCM Power. The TCM is powered by 15 VDC from the DC power supply. 115 VAC is applied to the DC power supply from the control panel via P1 and P2 on the TCM. A 3 amp fuse protects the components and wiring associated with the TCM. Control of electromagnetic interference is accomplished by the EMI filter and a Transient Voltage Suppressor.

516-6.4.2.3.5 Temperature/Current Module (TCM) Adjustment.

516-6.4.2.3.5.1 CURRENT CALIBRATION sets the cut in point for the TCM Load Limiter.

- a. Ensure the air conditioning plant is operating.
- b. Set % current at 100%. (This adjustment may be made at a lower plant load if more convenient (i.e., % current control at 50%). Readjust later when 100% load is available from the chilled water system.)
- c. Adjust the Chilled Water Temperature Control to increase the drive motor current to 104% of full load as indicated by the plant control panel ammeter or an accurate portable meter.
- d. Adjust "CURRENT CALIB" until the yellow "CURR LIMIT" light comes on. Clockwise increases the set point.

516-6.4.3 MAINTENANCE

- a. Ensure that the actuator bolts are tight and the PRV actuator shaft attachment is secure.
- b. Ensure that the thermistor did not back out of its well.
- c. Observe plant operation to verify that the sequence of control operations is correct.

516-6.4.4 TROUBLESHOOTING

516-6.4.4.1 There is only one electrical calibration (the Load Limiter). The only mechanical adjustments are the switch actuating cams in the actuator, and these will not become incorrectly set by themselves.

516-6.4.4.2 On normal plant startup, it takes up to two minutes for the electronic controls to pulse up to full load. This lengthy startup was a design trade off for more accurate steady state temperature control.

516-6.4.4.3 The actuator can be easily checked by varying the Temperature Control Point on the TCM. If the PRV will smoothly open and close, then no problem exists. If there is binding, disconnect the PRV linkage to decide which component is faulty.

516-6.4.4.4 The thermistor can be checked by disconnecting the leads and measuring resistance. Normal resistance is about 2000 - 3000 ohms at room temperature.

516-6.4.4.5 Troubleshooting the TCM consists of checking for the occasional "open" or "close" pulse at an 18 second interval during steady state operation. For transient conditions, such as rapidly increasing load, the load limiting function can be observed. During a large load increase, the TCM stops sending "open" signals when the load reaches 104%, and the yellow "CURR LIMIT" light comes on.

516-6.4.5 TCM TEST POINTS (TP)

516-6.4.5.1 The TCM circuit board Test Points are visible from the left side of the TCM. Test voltages are given below. It is not necessary to check these as a routine.

TCM Power	Red TP-1 to Black TP-2	15 VDC
Chilled Water	Brown TP-3 to White TP-5	0 +/- 0.5 VDC
Temp Set Point (adjustable)		
Current Limit Cut-In Point (adjustable)	Black TP-2 to Blue TP-6	7.96 VDC
Reference Voltage	Black TP-2 to Yellow TP-4	7 VDC

516-6.4.5.2 Drive motor current signal to the load limiter is 2.9 to 6 VAC at full load, measured on the terminal strip inside the A/C plant control panel. See equipment technical manual for terminal numbers.

NOTE

Technical manual changes were provided to each ship when MachAlt ECP 360 was installed. If your technical manual does not have this information, take action to have it brought up to date.

516-6.5 CENTRIFUGAL COMPRESSOR SAFETY CONTROLS

516-6.5.1 GENERAL. Safety controls protect the centrifugal compressor and compressor motor. The safety controls are electrical devices that shut down the air-conditioning plant when an abnormal condition is detected. Abnormal conditions include a motor overload, high refrigerant pressure, or low chilled water temperature. [Table 516-6-1](#) lists safety devices, and their settings, located on each centrifugal air-conditioning plant.

516-6.5.2 CENTRIFUGAL COMPRESSOR OIL QUALITY. To ensure the quality of the compressor oil, both a visual inspection and spectrographic analysis should be performed. The visual inspection, which consists of

carefully noting the color of the oil, should be performed whenever the oil level is checked. New oil is clear; when it begins to turn muddy brown or black, renew it. Discolored oil indicates adverse conditions inside the system and is generally caused by excessive heat, dirt or moisture. This foreign material might have been in the system at the time of installation and might never have been properly removed when the system was first started, or might have entered the system during a service operation. If the condition is not corrected, some part of the system (usually compressor parts) may eventually fail. If the compressor bearings or gears show a decided copper-colored surface (commonly known as copper-plating), an excessive moisture condition is indicated.

516-6.5.2.1 If the results of spectrographic oil analysis reveal high levels of copper, aluminum, or iron, determine the cause as this is unusual in refrigeration compressor oil. Wear in the aluminum journal bearings can contribute to high aluminum levels. Wear on the speed increasing gears can contribute to high iron levels. High iron and copper levels can also result from high acid levels. High acid levels are normally associated with moisture contamination of the refrigeration system. High operating temperatures can accelerate the increase in acid number. High acid levels can also result from inadequate refrigerant circuit cleaning or evacuation (dehydration) after fabrication, or after repairs or piping modifications. With an otherwise healthy system (leak-free and moisture-free), the trends in the oil analysis data are more important than the absolute values of the analysis results.

516-6.5.2.2 Navy experience with similar equipment has established threshold limits for metal content in oil. Use the data given below to alert the cognizant engineer of the need to investigate further for possible problems (such as, the presence of water or other chemical catalysts) causing abnormal material wear. Exceeding these limits is in no way intended to restrict plant operation nor does it inhibit plant performance. The threshold limits are listed in parts per million (ppm) in [Table 516-6-4](#).

Table 516-6-4. METAL CONTENT IN OIL LIMITS

Element	Limit (ppm)	Element	Limit (ppm)
Ag	2	Ni	4
Al	3	Pb	5
Cr	3	Si	3
Cu	24	Sn	5
Fe	4	Ti	2
Mg	3		
Moisture content: 100 ppm (maximum) Acidity: 0.07 neutralization number (max)			

516-6.5.2.3 Whenever the acid neutralization number exceeds 0.07, or the metal content of the oil exceeds the threshold values, thoroughly leak-test the air-conditioning plant and repair all leaks. Then replace the compressor oil and dehydrator cartridges. After 50 or 75 hours of operation, resample the oil and replace the dehydrator cartridges again. If the oil test results are unsatisfactory, repeat the process, beginning with a more thorough leak-test. Lengthy intervals between oil and dehydrator cartridge changes will result in higher oil contamination levels. Persistent high aluminum levels indicate high wear rates of the compressor bearings, and the compressor should be opened and inspected.

SECTION 7.

OTHER TYPES OF REFRIGERATING PLANTS FOR AIR-CONDITIONING INSTALLED IN U.S. NAVY SHIPS

516-7.1 INTRODUCTION

516-7.1.1 Several other types of refrigerating plants are installed in Navy ships in addition to those already described. Navy personnel operating and maintaining refrigeration plants should also have knowledge of these

other plants in the event they are assigned to ships in which they are installed. Other plants installed in Navy ships are lithium-bromide absorption, helical rotary screw compressor, and steam jet. The lithium-bromide absorption plant is a steam-driven unit installed in several attack and strategic submarines. The helical rotary screw compressor plant is electric motor-driven, has a positive displacement compressor, and is installed in only one ship at this time. The steam-jet plant is also steam-driven and is installed in only one submarine. These plants are described herein so that refrigeration personnel will know something about their principles of operation. For specific details about operation and maintenance, the operator is referred to the applicable technical manuals.

516-7.2 REFRIGERATING PLANTS

516-7.2.1 LITHIUM-BROMIDE PLANTS. Absorption machines are heat-operated refrigeration machines based on one of the earliest known principles of refrigeration; that is, the absorption of heat by an evaporating liquid. In comparison, the vapor compression cycle uses a volatile refrigerant such as R-12 in conjunction with a compressor, condenser, and evaporator. The absorption cycle uses an absorber and a refrigerant, generator, evaporator, and condenser. In the absorption cycle the most commonly used refrigerant is water and the absorbent is a lithium-bromide solution. Lithium-bromide is a salt, similar to table salt, which has a strong affinity to absorb water vapor. Basically, in both the vapor compression and absorption cycles, the evaporator and condenser perform the same function. In the evaporator, liquid refrigerant under low pressure evaporates at a low temperature, absorbing heat from the medium to be cooled. In the condenser, refrigerant vapor under high pressure condenses at a high temperature, rejecting heat to the condensing medium.

516-7.2.2 OPERATING CYCLE. In a compression system, a compressor increases the refrigerant vapor from evaporator to condenser pressure. The compressor suction draws refrigerant vapor from the evaporator, and the discharge forces the compressed gas into the condenser. In the condenser, the refrigerant changes from a gas to a liquid and flows to the evaporator, where it flashes to a gas to repeat the cycle. In an absorption system, the increase in refrigerant pressure is produced by heat in the generator (rather than by mechanical compression). The heat is supplied by steam. The absorber and generator are analogous to a compressor in that the absorber acts the same as the suction stroke of the compressor and the generator the same as the compression stroke. The absorber draws refrigerant vapor from the evaporator. The generator increases the pressure of the refrigerant vapor and forces it into the condenser where it is changed back to a liquid. The liquid then flows to the evaporator where it vaporizes to repeat the cycle. The absorbent solution creates the pressure difference that draws the refrigerant vapor from the evaporator, absorbs the vapor, and carries it to the generator. The low-pressure area in the absorber is created by controlling the temperature and concentration of the lithium-bromide solution.

516-7.2.3 WATER AS A REFRIGERANT. The most commonly used refrigerant in lithium-bromide plants is water. When refrigeration is mentioned, most people think of reciprocating or centrifugal machines using a volatile refrigerant. Such refrigerants have low boiling points that can be raised by compression. For example, the commonly used R-12 boils at -21°F at atmospheric pressure. But if the pressure is increased to 117 psig, the boiling (or condensing) point is raised to 100°F . At such a temperature, R-12 can be readily condensed by rejecting heat to an available medium at a lower temperature such as seawater in a condenser. The liquid R-12 is then subjected to a lower pressure in the evaporator. If its pressure is lowered from condensing pressure to 37 psig, R-12 will boil at 40°F , absorbing heat from the air, water, or other medium to be cooled in the evaporator. The absorption machine uses water as the refrigerant. At first it may seem strange to think of water as a refrigerant. Water boils or evaporates at a rather high temperature. When boiling or evaporating water is considered, a pot of boiling water on a stove usually comes to mind. Boiling water may also be thought of, however, in connection with power generation where steam pressures and temperatures often range to much higher levels. Actually, the temperature at which water boils varies with pressure. At sea level with a standard barometer of 14.7 psia (29.92 inches of mercury absolute), water boils at 212°F . At an elevation of about 10,000 feet, barometric pressure is

substantially less (19.85 inches of mercury absolute), than at sea level; under this reduced pressure water boils at 192° F. Under higher pressure the boiling point is raised. For example, in a boiler operating at 50 psig, water will boil at 298° F. When using water as a refrigerant, the effect of low pressure on the boiling point of the water shall be considered. Water evaporates at a low pressure. The heat required to evaporate the water is taken from the water in the container which becomes cool. This phenomenon also explains why one feels cool on a hot day when emerging wet from swimming. The water on the skin evaporates, removing heat from the body and causing one to feel cool.

516-7.2.3.1 The effect of low pressure on the boiling point of water is shown in [Figure 516-7-1](#). For example, when the pressure is about 1 inch of mercury absolute, water will boil at 80° F. Water will boil at 80° F when the vacuum is about 29 inches of mercury below atmospheric pressure. As an extreme example, water can be made to boil at 32° F by maintaining the pressure over the water at 0.18 inch of mercury absolute. This is a lower temperature than needed. Normal air-conditioning can be provided readily with water at 40° F to 45° F. As shown in [Figure 516-7-1](#), to evaporate or flash-cool water at 40° F, it is necessary to maintain a pressure of 0.25 inch of mercury absolute. By maintaining the evaporator in the absorption cycle at such low pressure, water is made to vaporize at a correspondingly low temperature, removing heat from the medium to be cooled.

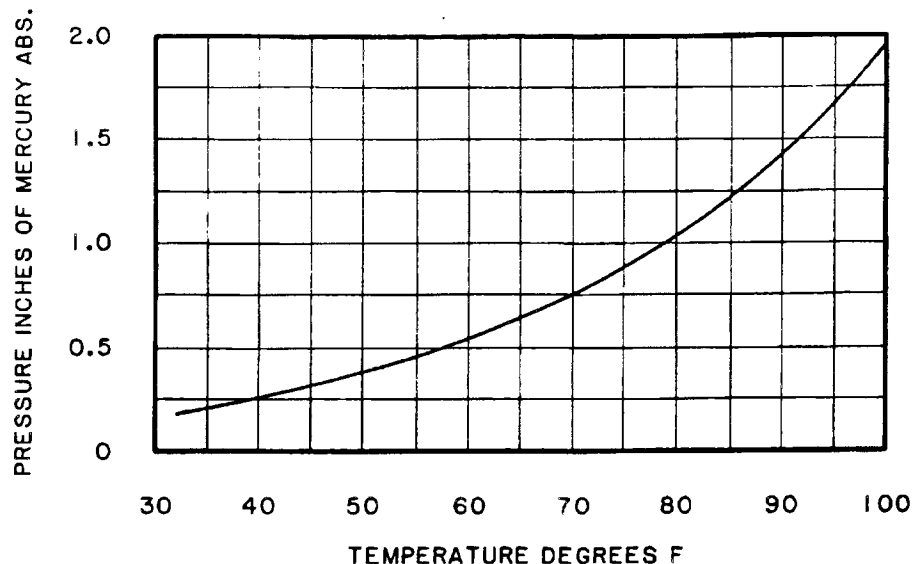


Figure 516-7-1. Pressure-Temperature Curve for Water

516-7.2.4 GAUGE VERSUS ABSOLUTE PRESSURE. Absorption refrigeration equipment is usually discussed in terms of absolute pressure rather than in terms of vacuum below atmospheric pressure. [Figure 516-7-2](#) shows the relationship of gauge pressure to absolute pressure. Barometric pressure indicates the weight of the atmosphere above the earth's surface. Standard barometer is the average pressure measured at sea level, corrected to 32° F. The established value for standard barometer is 29.92 inches of mercury absolute or 14.696 psig ([Figure 516-7-2](#)). As shown in [Figure 516-7-2](#), it is necessary to add atmospheric pressure (14.696 psia) to gauge pressure to obtain absolute pressure. Thus, a reading of 20 psig equals 34.696 psia. Because weather conditions and elevation influence the barometric pressure, where accuracy is important, use actual barometric pressure to determine absolute pressure. When dealing with high vacuums, that is, very low absolute pressures, the variation in barometric pressure may in fact be greater than the pressure to be measured. This is the case with absorption refrigeration machines. For this reason, an absolute pressure gauge should be used that can be read directly, without correction, in inches of mercury absolute rather than in inches of vacuum below atmospheric pressure. With a standard barometer, where a vacuum gauge might read 29.62 inches of mercury vacuum, an absolute pressure

gauge would read 0.3 inch of mercury absolute. The absorption refrigeration machine is equipped with an absolute pressure gauge that measures the pressure in the evaporator section of the absorber-evaporator shell in inches of mercury absolute.

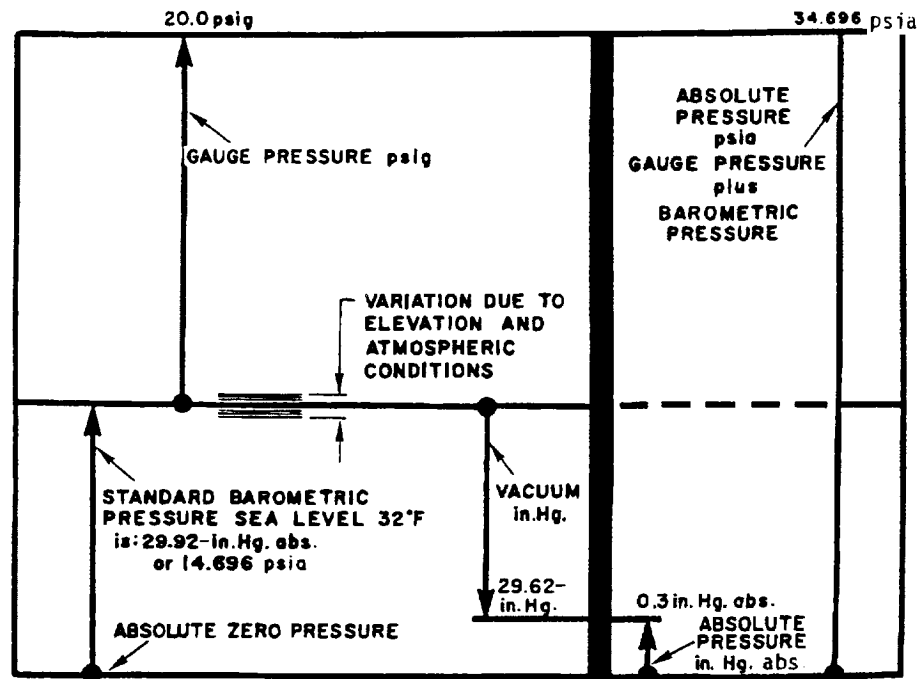


Figure 516-7-2. Gauge Versus Absolute Pressure Loss

516-7.2.5 USE OF ABSORBENTS. When using water as a refrigerant, the water can be made to boil in the temperature range of 40° F to 45° F by maintaining low pressures of 0.25 to 0.30 inch of mercury absolute with a mechanical vacuum pump or steam-jet exhauster. For each ton of refrigeration capacity produced by this flash cooling, about 400 cfm of low-pressure water vapor is generated. To handle 100 tons of refrigeration load, a mechanical compressor or pump would need a vapor pumping capacity of 100 tons by 400 cfm/ton or 40,000 cfm. The size and cost of such a mechanical device makes it impractical. The low-pressure necessary to produce cool water can be obtained more economically and in a smaller space by using an absorbent to absorb and remove the water vapors generated. Common table salt (sodium chloride) is an absorbent. During humid weather, for example, a salt shaker will clog because the salt has absorbed moisture from the air. As another example, calcium chloride is a salt spread on dirt roads to settle the dust. The calcium chloride absorbs moisture from the air, keeping the road surface moist. The absorbent most commonly used in absorption refrigeration machines is a lithium-bromide solution.

516-7.2.6 ABSORPTION REFRIGERATION PRINCIPLES. The absorption refrigeration machine uses a lithium-bromide solution as the absorbent and water as the refrigerant. The absorption machine obtains refrigeration by spraying refrigerant water in a shell maintained at a low absolute pressure over a tube bundle through which the chilled water flows. A portion of the refrigerant water flashes into vapor (boils) as it absorbs heat from the chilled water. The resulting water vapor is absorbed by the lithium-bromide solution. The absorption machine cycle is based on these two principles:

- Lithium-bromide solution has the ability to absorb water vapor.
- Water absorbs heat and boils at low temperatures when it is subjected to a low absolute pressure (a high vacuum).

516-7.2.7 ABSORPTION REFRIGERATION CYCLES. To explain the absorption refrigeration cycle, it will be broken down into its simplest components. Consider a shell partly filled with refrigerant water, the evaporator ([Figure 516-7-3](#)), and a shell partly filled with lithium-bromide solution, the absorber. The shells are connected by a pipe and air is evacuated from the shells so that only water vapor is present. (By removing the air, the boiling point of the water is reduced. If the shells are evacuated to a pressure of 0.25 inch of mercury absolute, the boiling point of the water will be 40° F. Any heat above this point is used to evaporate the water.) The lithium-bromide solution begins to absorb the water vapor. As the vapor is absorbed, more water evaporates causing the rest of the water to be cooled (that is, the evaporating water takes the heat it requires to turn into vapor from the rest of the water). The process will continue until the lithium-bromide solution becomes saturated at 50-percent concentrate, then it will stop. Lower vapor pressure of the lithium-bromide solution causes the water vapor to flow from the evaporator to the absorber. At 50-percent concentration, the pressures in the two vessels equalize.

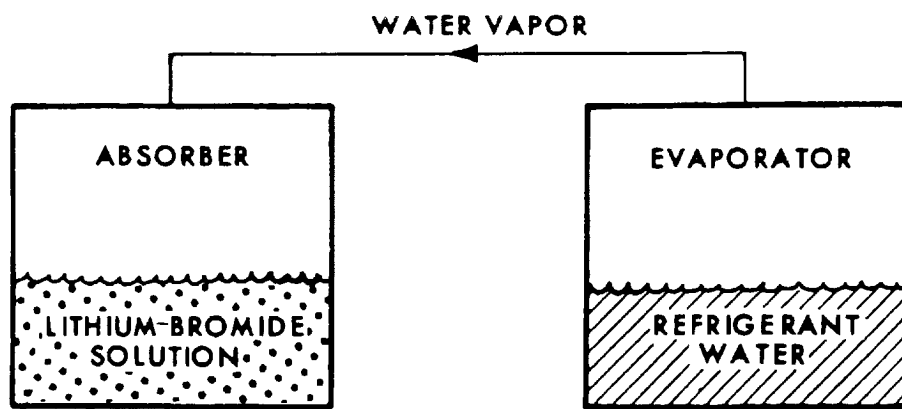


Figure 516-7-3. Absorption Effect

516-7.2.7.1 Chilled Water Coil. To improve the efficiency of the evaporator and absorber, pumps and spray headers are added ([Figure 516-7-4](#)). Since water vaporizes more readily if it is broken up into small particles, a pump is used to circulate water from the bottom of the evaporator to a spray header at the top of the evaporator. Since lithium-bromide can absorb water vapor more easily if its surface area is increased, a pump is also used to circulate solution from the bottom of the absorber to spray at the top of the absorber. A chilled water coil is added under the evaporator sprays ([Figure 516-7-4](#)). Returned chilled water from the air-conditioning cooling coils, or other loads, circulates through this coil and is cooled by the evaporation of the refrigerant water around it. Heat transfer is established because the chilled water circulated through the coil is at a higher temperature than the refrigerant water sprayed over the coil. The chilled water coil, in effect, provides more heat for further evaporation of the refrigerant vapor.

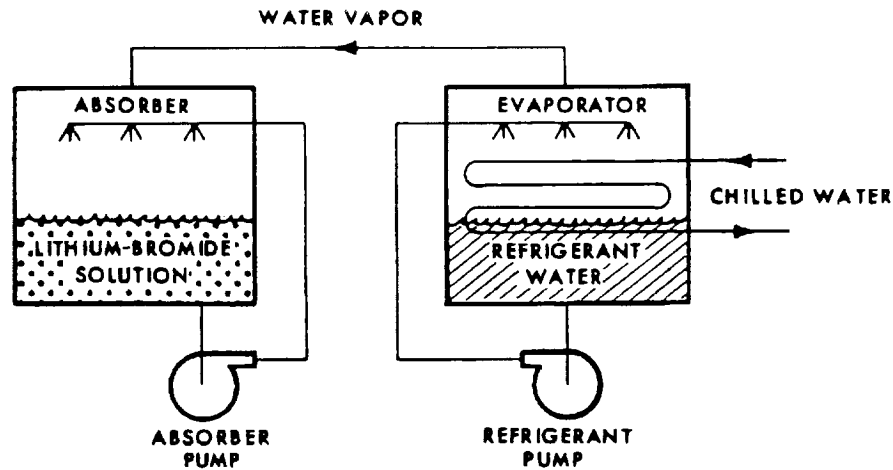


Figure 516-7-4. Absorber and Evaporator Cycle

516-7.2.7.2 Generator and Heat Exchanger. As the lithium-bromide solution continues to absorb water vapor, it becomes diluted (weak) and its ability to absorb decreases. Eventually, the process will stop. To prevent this and keep the cycle going, another shell called the generator (Figure 516-7-5) is added to reconcentrate the solution. Part of the weak solution is pumped from the bottom of the absorber to the generator where it is sprayed over a steam coil. Heat from the steam coil boils off refrigerant water from the lithium-bromide and reconcentrates the solution. The reconcentrated (strong) solution returns to the absorber by gravity to maintain the required solution concentration. Since the cycle requires heating of the weak solution in the generator and cooling of the strong solution in the absorber, a heat exchanger is added in the solution circuit (Figure 516-7-5) between the absorber and generator. In the heat exchanger, hot strong solution returning to the absorber preheats the weak solution being pumped to the generator, improving the efficiency of the cycle.

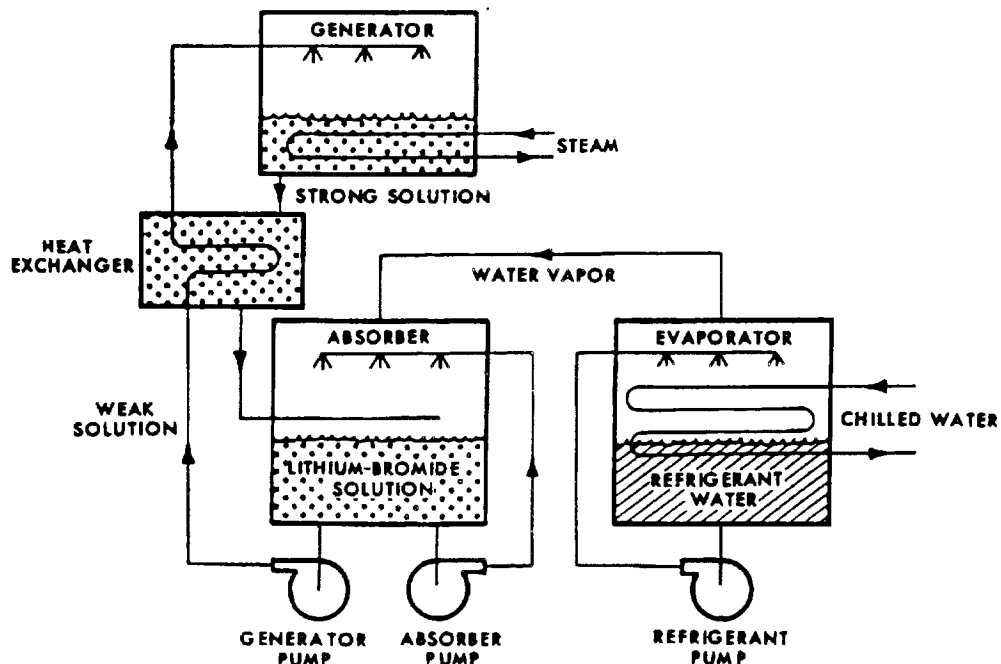


Figure 516-7-5. Absorber, Evaporator, Generator, and Heat Exchanger Cycle

516-7.2.7.3 Condenser. The refrigerant water vapors boiled out of the solution in the generator shall be changed back to a liquid to repeat the cycle in the evaporator. To accomplish this a condenser connected to the generator is added (Figure 516-7-6). The refrigerant vapors rise in the generator and pass to the condenser where they come into contact with the relatively cool condenser water coil and condense. The vapor condensate flows back to the evaporator by gravity, completing the cycle. Seawater circulated through the condenser coil removes the heat of condensation. This condensing seawater is first circulated through a coil in the absorber (Figure 516-7-6). This heat is the heat of condensation of the absorbed water vapor plus reaction heat (or heat of dilution) between the lithium-bromide and water. The condensing water circuit in the absorber removes the heat generated there and maintains the solution temperature at a level which allows the absorption process to be continuous.

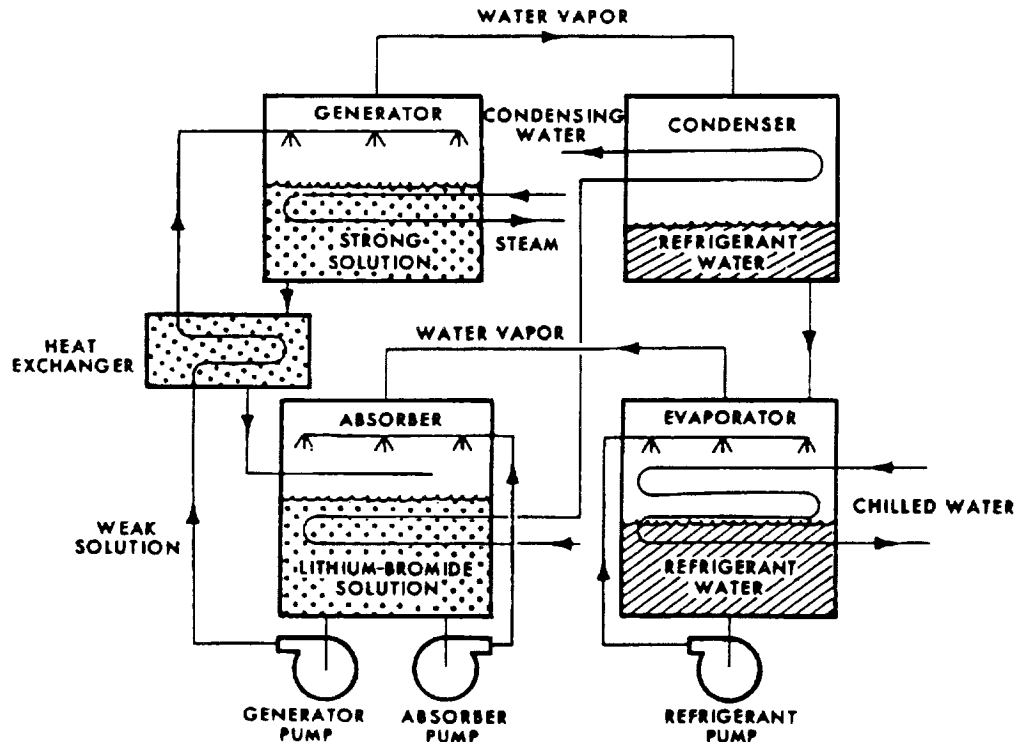


Figure 516-7-6. Complete Basic Cycle

516-7.2.8 ARRANGEMENT OF CYCLE COMPONENTS. The absorption-refrigeration cycle components may be combined in a machine in a number of ways. The basic configuration used on submarines is the three-shell configuration as shown in Figure 516-7-7. The absorber and evaporator are combined in the lower shell since they operate at nearly the same pressures and temperatures. The generator and condenser are kept separate to prevent splash-over of solution into the refrigerant during extreme roll or pitch conditions and to reduce the overall height of the machine to meet space limitations. The heat exchanger is a separate unit from the main shells. The evaporator is located in the upper part of the lower shell (see Figure 516-7-7). The chilled water coil or, more accurately, tube bundle is surrounded by a pan. Refrigerant water flows from the bottom of the pan to the refrigerant pump. This water is then pumped to the spray header above the water pan and sprayed over the tube bundle. Part of the refrigerant water flashes into vapor as it absorbs heat from the chilled water in the tube bundle.

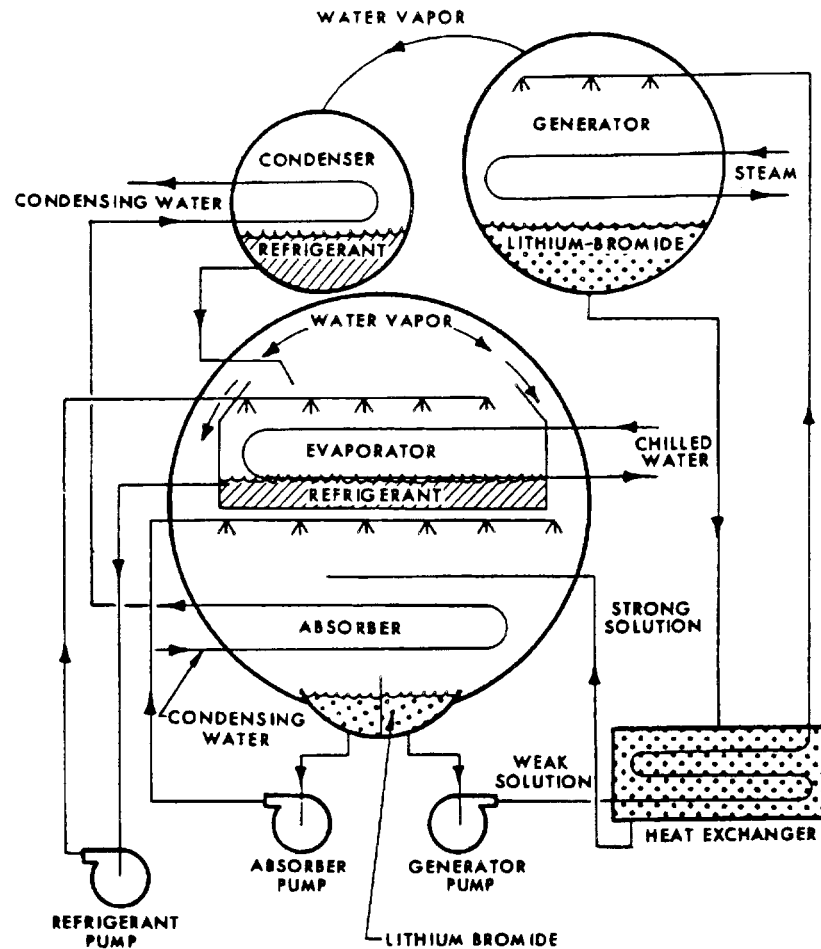


Figure 516-7-7. Arrangement of Cycle Components

516-7.2.8.1 The lower part of the lower shell is the absorber. Lithium-bromide solution is withdrawn from the bottom of the absorber by the absorber pump and circulated to the spray header above the absorber tube bundle. The lithium-bromide solution in the absorber has a lower partial pressure than the water vapor in the evaporator. Water vapor is drawn over the edges of the evaporator water pan and is absorbed by the sprayed solution in the absorber. Seawater circulated through the absorber tube bundle removes the heat of absorption. Part of the solution is withdrawn from the bottom of the absorber and pumped through the heat exchanger to the generator spray header by the generator pump. Steam supplied to the generator tube bundle drives water out of the solution sprayed over the tube bundle. This reconcentrates the solution, which flows back by gravity through the heat exchanger to the absorber to maintain the required solution concentration. The vapor released in the generator passes to the condenser through a connecting vapor duct and condenses on the condenser tube bundle. Seawater leaving the absorber water circuit circulates through the condenser tube bundle and removes the heat of condensation. The vapor condensate collects at the bottom of the condenser and returns by gravity to the evaporator water pan in the lower shell to complete the cycle. An essential component not shown in [Figure 516-7-7](#) is the purge unit. The purge unit is required to remove air and other noncondensables from the machine and maintain a low absolute pressure within the shells.

NOTE

An airtight machine maintained at a low absolute pressure is essential for satisfactory performance

516-7.2.9 SUMMARY OF PLANT FUNCTIONS. The previous paragraphs describe basically how a lithium-bromide plant functions. The number of shells indicated is that for the plant installation in submarines. The number of shells can vary, however, and all the functions indicated can be designed in one shell. Operating and safety controls are provided for automatic operation. The capacity of the unit in submarines is controlled by modulating the inlet steam flow through a control actuated by the chilled water temperature. Modulating the steam flow controls the lithium-bromide concentration and hence the capacity. For details of operating and maintenance procedures, personnel shall consult the specific technical manual that covers the equipment.

516-7.2.10 HELICAL SCREW COMPRESSOR PLANT. The helical screw air-conditioning plant installed in CGN 25 is an R-22, electric motor-driven, hermetic compressor ([Figure 516-7-8](#)). The high-pressure R-22 does not require a purge system. The plant components, other than the compressor, should be familiar to personnel, as they are similar to those used with reciprocating compressors. The helical rotary compressor, or screw compressor, belongs to the broad class of positive displacement compressors. The compressor consists essentially of two mating helically grooved rotors, a male (lobes) and a female (gullies), in a stationary housing with suitable inlet and outlet gas ports ([Figure 516-7-9](#)).

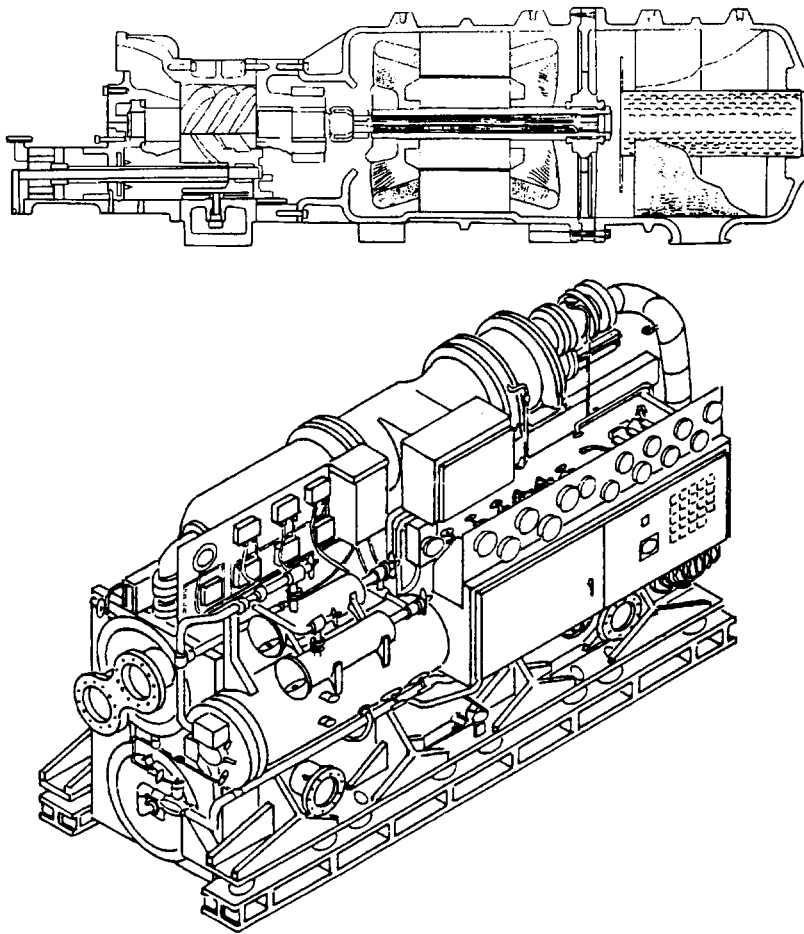


Figure 516-7-8. 125-Ton Helical Screw Air-Conditioning Unit Assembly

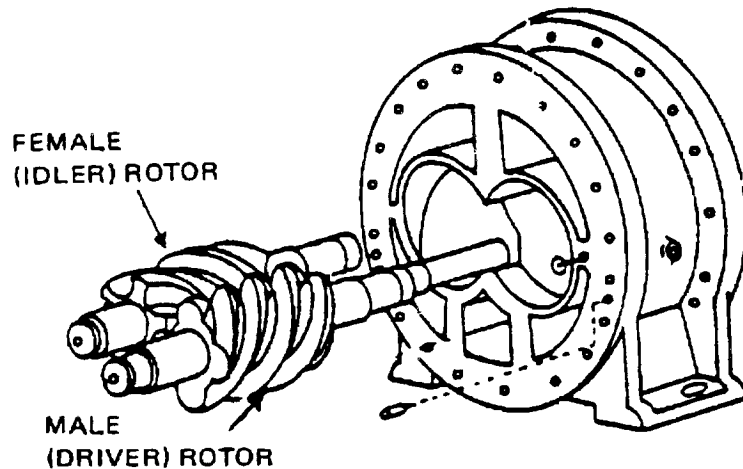


Figure 516-7-9. Rotor Housing Disassembly

516-7.2.10.1 The flow of gas in the rotors is both radial and axial. The female rotor is driven through synchronized timing gears or, in an oil-flooded machine, is directly driven by the male rotor. Compression is obtained by direct volume reduction with pure rotary motion. The helical rotary screw compressor has a number of advantages over other compressors. It has a maintenance advantage in that it has fewer moving parts as compared to centrifugal compressors. Also, this compressor is an oil-flooded type. The oil injection increases the compression efficiency, reduces discharge temperature and noise, and permits operation at high loads and higher compression ratios. The ability to tolerate oil also permits the compressor to handle occasional liquid refrigerant slugs and floodback, which is a desirable feature for a refrigeration compressor. An oil separator is also an essential component of these units.

516-7.2.10.2 [Figure 516-7-10](#) shows the capacity control slide valve within the rotor housing. Axial movement of this valve is programmed by a solid-state, temperature-initiated, hydraulically-actuated control arrangement. When the compressor is fully loaded, the slide valve is in the closed position and the flow of all the gas through the rotor housing is as previously described. Unloading starts when the slide valve is moved back away from the valve stop. Movement of the valve creates an opening in the bottom of the rotor housing through which suction gas can pass back from the rotor housing to the inlet port area before it has been compressed. Since no significant work has been done on this return gas, no appreciable losses are incurred. Reduced compressor capacity is obtained from the gas inside the inner part of the rotors and is compressed in the ordinary manner. Reduced capacity to 10 percent of full load is realized by progressive, backward movement of the slide valve away from the valve stop. In principle, enlarging the opening in the rotor housing effectively reduces compressor displacement.

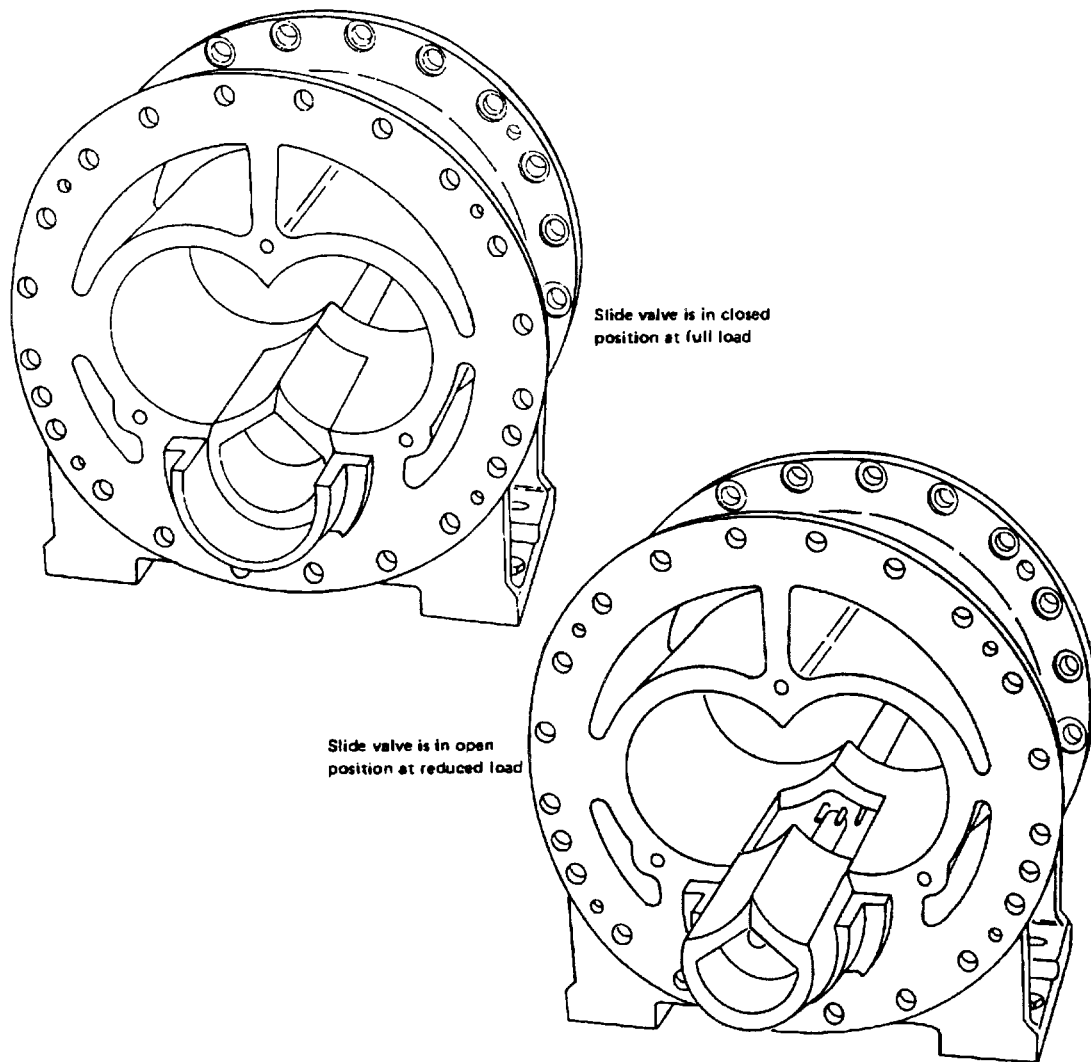


Figure 516-7-10. Helical Rotary Screw Compressor

516-7.2.11 STEAM-JET REFRIGERATING PLANT. The steam-jet system has limited use in Navy shipboard air-conditioning applications. While the steam-jet system cycle is simple, each unit is specially designed for each application as there are no off-the-shelf plants. This results in a considerable increase in the cost-per-ton of air-conditioning. Additionally, the units are large and bulky as compared to electric motor-driven units. The steam-jet refrigeration cycle is quite similar to other refrigeration cycles with an evaporator. The basic system components are a compression device, a condenser, an evaporator, and a refrigerant; [Figure 516-7-11](#) illustrates a simple steam-jet system. Instead of a mechanical compression device, a steam ejector or booster is used to compress the refrigerant to the condenser level. Water is used as the refrigerant. The cooling effect in the steam-jet refrigeration cycle is produced by continuous vaporization of some of the water in the evaporator at a low absolute pressure level. The function of the refrigerant or water is the same as that described for the lithium-bromide plant. The steam-jet refrigeration system consists of an evaporator (or flash tank), a steam-jet ejector (or booster ejector), a condenser, a two-stage air ejector, a cooling water circulating pump, and necessary valves and controls. High-pressure steam is delivered to the nozzle (see [Figure 516-7-11](#)) and flows at high velocity into the primary ejectors. The high-pressure steam issuing from the nozzle entrains water vapor and any entrained air from the evaporator or flash tank. The steam and water vapor mix in the diffuser and enter the condenser where the mixture is condensed and returns to the boiler by way of a condensate pump. Makeup water for the evaporator is

taken from the condensate (not shown in the illustration) and returned to the evaporator. Two-stage steam-air ejectors are usually used to maintain condenser vacuum and a back-pressure valve is added in the return chilled water at the evaporator to maintain a positive pressure in the chilled water system. Figure 516-7-11 shows an open system; that is, the chilled water in the evaporator is used directly in the cooling coils. In an indirect or closed system, the chilled water is circulated inside a heat exchanger or tubes inserted in the cool evaporator water.

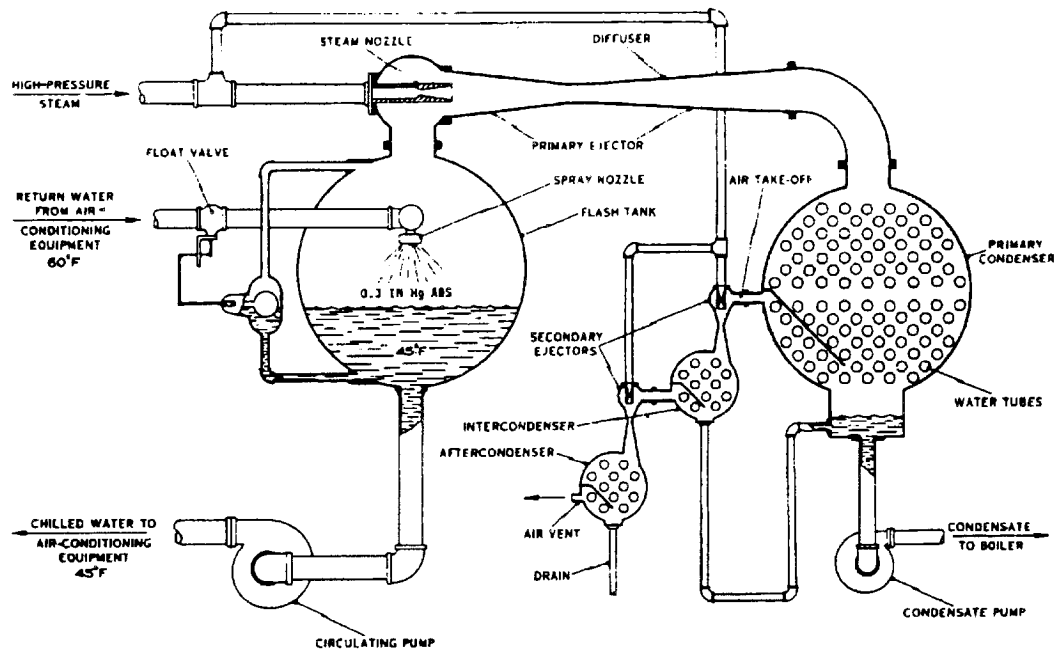


Figure 516-7-11. Steam-Jet Refrigeration Unit

SECTION 8.

REFRIGERATING SYSTEM MAINTENANCE AND REPAIR

516-8.1 GENERAL PRECAUTIONS

516-8.1.1 A number of precautions shall be observed when a system is to be opened for maintenance or repair. Refrigerant systems are seriously affected by air and moisture. Since refrigerants have a scouring or cleaning action, metallic surfaces are unprotected when exposed to atmospheric air and moisture. It is very important when performing maintenance or repair with the refrigerant removed from the system that a neutral atmosphere of nitrogen be maintained in the refrigerant system. This is particularly applicable to centrifugal plants where the refrigerant is removed generally to perform any maintenance. When it is necessary to remove the refrigerant and the system is to be opened for maintenance or repair, remove the refrigerant to the receivers and place the plant under a holding charge of dry nitrogen. Before the system is opened connect a cylinder of dry nitrogen with a pressure regulator to the refrigerant charging valve. Open the charging valve and cylinder valve and pressurize plant to 1 or 2 psig. Set the pressure regulator on the cylinder at 1 psig and keep valves open to constantly bleed nitrogen into the plant when it is opened.

516-8.2 MAINTENANCE AND REPAIR

516-8.2.1 OPENING SYSTEM FOR REPAIR. When it is necessary to open a part of a charged or functioning system for repairs, replacements, or to clean strainers, pump down the refrigerant pressure within the part of

the system to be opened to a pressure slightly above atmospheric (1/2 to 2 psig). Do this before any connections are broken or any covers are removed. If the repair is to a major part of the plant that requires securing the plant, pump down the complete system. For repairs to parts of the system that can be segregated, particularly in reciprocating plants, pump out the liquid and vapor refrigerant by closing shutoff valves in the piping feeding refrigerant to that part of the system.

516-8.2.1.1 As the part of the system containing liquid refrigerant is pumped down, its normally warm temperature decreases due to evaporation of the refrigerant liquid. When the temperature of the part begins to rise to normal again, with the low pressure in the part maintained, it is reasonably certain that all the contained liquid refrigerant has been evaporated. If possible, open the system at bolted or other mechanical connections. Cover openings to prevent dirt from entering the system. It is generally possible to pump down any part of a reciprocating system by appropriate manipulation of cutout valves (except the condenser, liquid receiver, and compressor discharge line). For that portion of a system that cannot be pumped down, recover the liquid refrigerant into a service cylinder. In the case of centrifugal plants, the refrigerant may be transferred to receivers. If the pressure goes lower than zero pounds (gauge) during the pumping down process, immediately bleed sufficient refrigerant into the evacuated part of the system to raise the pressure to between 1/2 and 2 psig. After the refrigerant has been pumped from the part of the system requiring repairs or maintenance, close the shutoff valve in the outlet piping of that part of the system, isolating it from the rest of the piping system. Connections to the isolated equipment may then be opened, and repairs, replacement of parts, or other necessary service operations completed. If brazed connections are opened or repaired, temporarily plug or cap the free ends of the refrigerant lines to prevent the entry of air and dirt. When brazed connections are remade, make one connection tight so gases can be purged out through the free end. A brazed joint can only be made when there is zero pounds (gauge) pressure in that section of the system. When the last joint is to be brazed, loosen a bolted or mechanical fitting, such as a dehydrator or strainer cover, compressor shutoff valve, or flanged union, to permit any pressure to escape. Air can also be purged from this loosened fitting. Purging may be done by admitting refrigerant to the repaired piping segment from either or both ends of that part of the system. When purging is completed, tighten the bolted (mechanical) cover or fitting and open all valves required to put this part of the system back in operation. ALWAYS LEAK-TEST any repaired or opened joint, connection, or fitting. Purge gauge and control lines, which are generally small and short, with refrigerant gas whenever they are opened to the atmosphere. Where connecting lines are removed and will be reconnected, cap the ends of the lines to protect the connecting fitting and to prevent entry of air, moisture, or dirt.

516-8.2.2 EFFECTS OF MOISTURE. Moisture in the refrigerant, even in very small quantities, is harmful to the refrigerant system. The moisture content in the refrigerant is measured in parts per million (ppm). Ice formation or separation of water from the refrigerant will occur if the concentration of water is sufficiently high and the temperature sufficiently low. For example, at 80°F, R-12 can hold 98 ppm; at 0°F, only 8.3 ppm of water can be dissolved in R-12. If the R-12 goes from 80° to 0° F, the difference in the amount of water that can be held will come out of solution and act as free water. Complete elimination of water in the refrigerant is therefore desirable; however, this may not be possible. Maintain a moisture content below these saturation points to minimize the harmful affects of moisture on the refrigerant system. Moisture in the refrigerant system can cause the following undesirable effects:

- a. Freezing at expansion valves or capillary tube refrigerant controls
- b. Formation of ice or free water in the evaporator
- c. Formation of acids and corrosion of metals
- d. Copper plating of machined surfaces
- e. Chemical damage to hermetically sealed motors

f. Emulsification and formation of sludge in the lubricating oil.

516-8.2.2.1 The moisture at the expansion valve or capillary tube can freeze when the evaporating temperature is 32°F or below. Ice formations at these locations block the flow of refrigerant, which results in intermittent frosting and thawing of the evaporator and erratic compressor operation. Ice can also form in the evaporator, or if the evaporating temperature is above 32°F, free water will separate from the refrigerant. Ice or water in the evaporator will affect the refrigerant flow and the rate of cooling (heat transfer characteristics) of the evaporator. The refrigerant forms hydrochloric and hydrofluoric acids when water is present in the system. These acids corrode metal parts, adversely affect gasket materials, and contribute to the formation of sludge in the oil. The formation of a film of copper on metal surfaces in the compressor, known as copper plating, results from complex chemical reactions. Moisture in the refrigerant generally increases the rate of copper plating. This moisture also attacks motor winding insulation materials in hermetic compressors causing shorts, grounds, and burnout.

516-8.2.3 MAINTENANCE SCHEDULE. Regularly check the operation and condition of each refrigerating and air-conditioning plant. Follow the shipboard Planned Maintenance System (PMS) which provides detailed procedures and instructions as well as the skill level and periodicity required for preventative maintenance of each refrigerating system component. The following maintenance schedule is recommended if a detailed PMS system has not been established or is not currently in use:

- a. Every 2 Hours: Log all operating temperatures and pressures ([Figure 516-4-1](#)).
- b. Daily:
 - 1 Check oil level in crankcase sight glass.
 - 2 Get accustomed to the temperature of the motors by the way they feel to the hand. Do this every day so that any temperature rise is noticed and reported.
- c. Weekly:
 - 1 Inspect moisture indicator.
 - 2 Vent any air that may be trapped in the condenser water heads.
 - 3 Check pump glands or shaft seals for excessive leakage.
 - 4 Clean the seawater strainer.
- d. Monthly:
 - 1 Lubricate motor bearings (where cups or grease caps are provided).
 - 2 Clean dust from motors.
 - 3 Clean contact points in controller.
 - 4 Inspect condition of compressor oil.
 - 5 Check water-regulating valve for current operation. Clean internal strainers where installed.
 - 6 Flush fresh water system and ice-forming areas of automatic type icemakers with fresh water.
- e. Quarterly:
 - 1 Inspect refrigerated compartment door gaskets and cooling coils.
 - 2 Inspect, lubricate, and test refrigerator door safety devices.
 - 3 Examine the zincs for erosion.
- f. Semiannually:
 - 1 Inspect flexible couplings.
 - 2 Inspect belt drive belts.

3 Check the alignment of the compressor and motor.

g. Annually:

- 1 Check the gaskets in all seal-capped valves and the packing in all water line valves.
- 2 Clean and inspect seawater condenser tubes.
- 3 Check settings and operation of switches and safety devices including high-pressure control switch, oil failure switch, and chilled water low temperature switch.
- 4 Inspect foundation fasteners and equipment bolts for condition and tightness.
- 5 Test compressor suction and discharge valves.
- 6 Visually inspect vibration isolators in the refrigerant piping system for damage and misalignment.
- 7 Test operation of capacity control (if installed).

h. As required:

- 1 Renew or reactivate dehydrator cartridge(s).
- 2 Clean compressor lubricating oil strainer; renew oil.
- 3 Test for leaks at all joints in the refrigerant piping, all gaskets at compressor, all valves, and condenser tubes, using a leak detector.

i. During overhaul or system shutdown: Clean the refrigerant liquid line and suction line strainers.

516-8.2.4 WATER FLOODING OR CONTAMINATION OF REFRIGERATING SYSTEM. If excessive water is found upon opening a system, check the water to determine if it is salt or fresh. Salt water usually indicates condenser leakage. Where salt water has been admitted to the refrigerant system, find and correct the source of the leak, and take the following additional steps to put the system back into operation:

1. Flush the condenser, receiver, refrigerant piping, and cooling coils or water chiller with fresh water.
2. Disassemble and clean automatic control valves, strainers, and compressors, including all internal parts, with an approved Navy solvent to remove all traces of salt water. Follow safety precautions in paragraph [516-1.10](#).
3. Evacuate and dehydrate the system in accordance with paragraphs [516-8.2.16](#) and [516-8.2.17](#). Recharge the compressor with new oil and the refrigerant system with clean dry refrigerant.
4. Place system in operation.
5. If excessive fresh water is found in a system, find and correct the source of the leak. In an air-conditioning or water-chilling system, fresh water usually indicates water chiller leakage. To put the system back in operation, follow the steps outlined below:
 - a Disassemble and clean automatic control valves, strainers, and compressor, including all internal parts, with one of the Navy solvents named in step 2.
 - b Evacuate and dehydrate the system in accordance with paragraphs [516-8.2.16](#) and [516-8.2.17](#).
 - c Recharge the compressor with new oil and the refrigerant system with clean dry refrigerant.
 - d Place the system in operation.

516-8.2.5 INSTALLATION OF REFRIGERANT PIPING. Preparation of pipe and fittings for installation and repair is of utmost importance. Exercise care in cutting copper tubing or piping to prevent the filings or cuttings from entering the pipe. Completely remove the small particles of copper, since the finely divided copper may pass through the suction strainer. Cut the tube square and remove all burrs and dents so that no internal restrictions

are introduced and to permit proper fit with companion fittings. The use of a tube cutter is preferred. If cutting is done using a hacksaw, use a fine-tooth blade, preferably with 32 teeth per inch.

516-8.2.6 SOLDERING AND BRAZING. When soldering and brazing joints, brighten up the ends of the tubing or pipe with a wire brush or crocus cloth to make a good bond. Do not use sandpaper, emery cloth, or steel wool for this purpose as those abrasives will get into the system and may cause derangement. Under no circumstances shall acid be used for soldering; the flux used shall be such that its residual substance will not form an acid. Use flux sparingly so that no residue will get inside the system and eventually be washed back to the compressor crankcase. Any of the compounds used to form soldering or brazing fluxes are potentially harmful to a refrigeration system. The primary purpose of a soldering or brazing flux is to protect the base metal from oxidation during the heating cycle of the soldering or brazing process. The flux also breaks up oxides that form on the surface of the joint and floats these contaminants out of the joint area. Apply flux in a thin, even layer on both surfaces of the joint. Excess flux may not only get into the refrigerant system, but may also impede the flow of the filler metal in the joint area, and cause an unsatisfactory joint. The temperature required for soldered or brazed joints will cause oxidation within the tubing. The scale or other products of this oxidation will be removed by the refrigerant flow after the system is in operation. The oxide will break up into a fine powder to contaminate the lubricant in the compressor and to plug the strainer and driers. To prevent this, provide a neutral atmosphere within the tube being soldered or brazed. This can be done by bleeding dry nitrogen gas through the tubing during the soldering or brazing operation and for a sufficient time after the bond is made, until the heat of the copper has been reduced below the temperature of oxidation.

516-8.2.7 BENDING. When bending pipe or tubing, use the special tools designed for this type of work. Never use Rosin, sand, or any other types of filler inside of the tubing to make a bend. Avoid taper pipe thread joints; if used, they shall be seal-welded or silver-soldered. Where it is necessary, as an emergency measure, use a thread compound for making up a joint, keeping in mind that refrigerants are hydrocarbons that will dissolve any compounds containing oil. Do not use a compound containing an acid or one whose residual substance will form an acid. The use of a thin paste made of fresh litharge and glycerin will make a satisfactory joint compound; however, thoroughly clean the joint with a solvent to eliminate any oil or grease. A commercial thread-sealing compound, Leak-Lock, is also suitable for refrigerant systems. Apply thread compound to the male part of the thread after the make-piece has entered 1/2 to 2 threads. This prevents any excess compound from entering the system.

516-8.2.8 SECURING REFRIGERANT LINES. When securing, anchoring, or hanging the refrigerant lines, exercise care to permit sufficient flexibility between the compressor and other components and the first set of hangers or points at which the lines are secured and to permit a certain amount of freedom and relieve any possible strain in the joints of these lines at the compressor and other components. Future reciprocating plants will be installed with flexible corrugated metal connectors at the compressor suction and discharge.

516-8.2.9 FLARE CONNECTIONS. SAE flare connections are not used on newer systems. On older systems, where it may be necessary to remake a flare connection, take care in making the joint. The flare shall be of uniform thickness with smooth, accurate surface free from tool marks, splits, or scratches. Cut the tubing square, provide with a full flare, remove any burrs, and saw filings. The flare seat of the fitting connector shall be free from dents or scratches. The flare can best be made using a special swivel head flaring tool that remains stationary and does not tear or scar the face of the flare in the tubing. Do not use oil on the face of the flare since the oil will eventually be dissolved by the refrigerant in the system, causing a leak through the displacement of the oil. Always tighten the flare joint using two wrenches; one to turn the nut and the other to hold the connecting piece to prevent applying strain on the connection, which may result in a leak.

516-8.2.10 VALVE AND CONTROL INSTALLATION. Most valves are marked with an arrow to indicate the proper direction of flow through the valve. Ensure that valves are installed in the system in the proper manner. Shutoff and control valves as well as other system components are normally brazed into the refrigerant piping systems. Excessive heat can easily damage these valves and components. Precautions should be taken to prevent overheating of these items during brazing operations.

516-8.2.11 DIAPHRAGM PACKLESS VALVE. Exercise particular care in installing these valves as they have a fiber or nylon disc that may char or burn and prevent proper sealing. Braze diaphragm packless hand valves as follows:

1. Open valve wide. Turn handwheel counterclockwise until stem backseats.
2. Turn handwheel back about 1/4 turn. This will move lower stem holding seat disc to the position shown in [Figure 516-8-1](#). This minimizes the danger of heat being transferred to the valve seat.

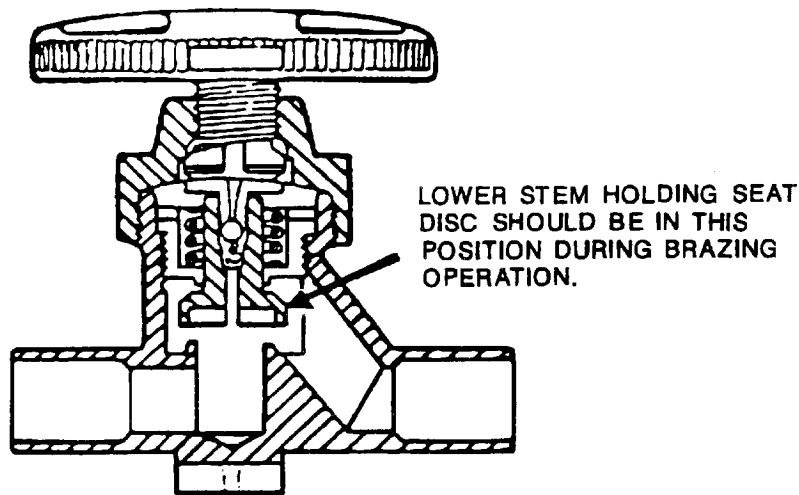


Figure 516-8-1. Packless Valve Stem Position

3. Thoroughly clean the end of the tubing and socket connection on the valve body.
4. Apply a thin coat of properly mixed, high-quality, noncorrosive flux to end of tubing and valve body socket.
5. Insert tubing into valve socket until it is tightly sealed against shoulder.
6. Wrap a wet, 1/4-inch-diameter Fiberfrax rope around the valve body and bonnet but away from the socket to be brazed.

NOTE

Fiberfrax is a trademark of the Carborundum Company. It is a ceramic fiber made of alumina-silica. Fiberfrax contains no asbestos.

7. With the torch adjusted to a reducing flame, apply heat to the entire circumference of the tube over a distance of approximately 1/2 inch to 2 inches from the valve socket to expand the tube and carry the heat down inside the socket ([Figure 516-8-2](#)). It is extremely important that the valve be wet packed and that the proper size brazing tip be used to prevent excessive heat from reaching the valve internals.

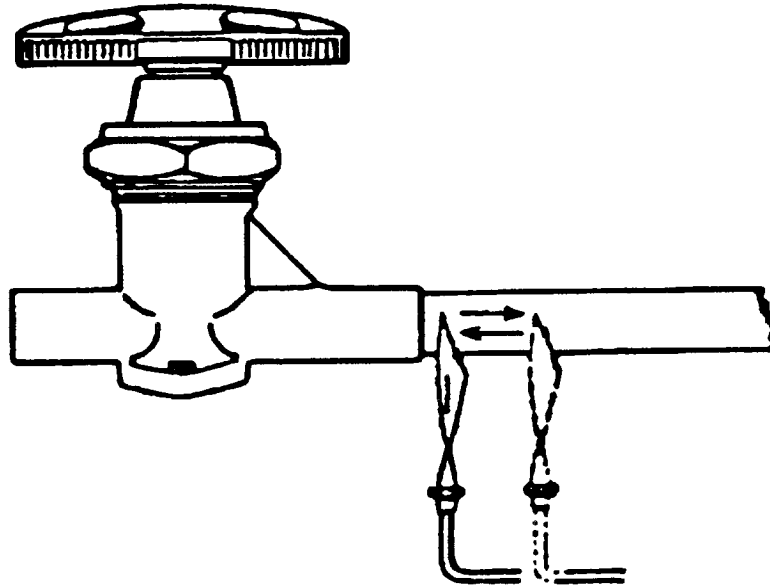


Figure 516-8-2. Packless Valve Installation - Preheating for Brazing

8. Continue heating until the flux on the tube becomes liquid, then direct the flame on the valve socket and the tube, but away from the valve body (Figure 516-8-3).

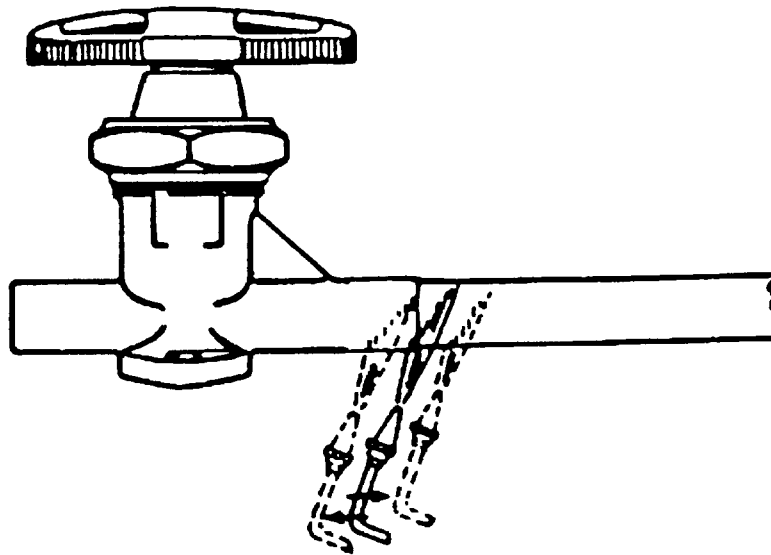


Figure 516-8-3. Packless Valve Installation - Heating for Brazing

9. When the flux has become very fluid and watery, apply the brazing alloy against the heated tube starting at the bottom of the junction of the tube and valve socket. If the joint is at the proper temperature, the brazing alloy will flow quickly around the tube and into the socket. If the alloy does not flow readily, continue heating until the proper temperature is reached (Figure 516-8-4).

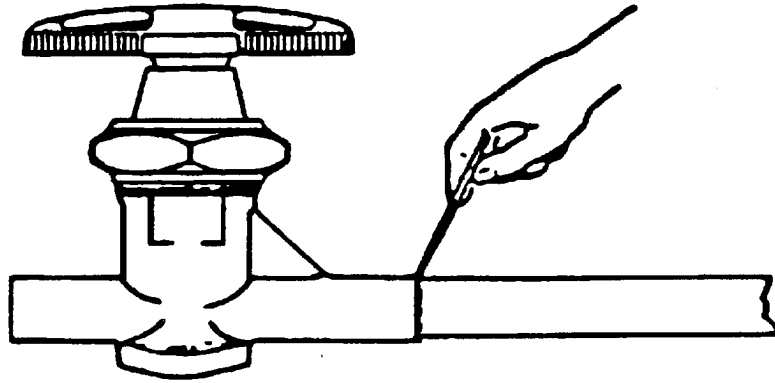


Figure 516-8-4. Packless Valve Installation - Brazing

10. After the valve assembly has cooled, clean the external surface of the brazed joint using a wire brush dampened in warm water. Then remove the residue of flux and scale with a damp rag.

516-8.2.12 LEAK-TESTING. After a new refrigerant piping system has been installed, extensively modified, or overhauled, pressure test and clean the system if required (paragraph [516-8.2.29](#)). Before insulation has been applied to any piping and prior to charging with refrigerant, completely leak-test the system. Compressors or other components and prefabricated packaged systems that have been cleaned, dehydrated, and sealed with a holding charge of refrigerant or inert gas, and have remained sealed during installation, do not require leak-testing. If the factory-sealed equipment has been damaged or there is evidence of leakage in a brazed or mechanical joint, leak-testing shall be done in those areas after repairs have been made. For existing plants that have been out of service for a long period of time or in which the refrigerant charge has been completely removed and air allowed to enter the system; clean the refrigerant system, remove all oil, test the entire system for leakage, and dehydrate the system before placing it back in service. Refrigeration systems shall be absolutely gas pressure-tight and vacuum-tight for two reasons. First, any leakage will result in loss of the refrigerant charge. Second, leaks allow air and moisture to enter the system. Leaks can occur not only from new joints or fittings, but from joints that were previously tested as tight, and from line breakage due to vibration, gasket failure, or other operating malfunctions. Thus, leak-testing is done not only before startup of a new system but as a necessary maintenance function throughout the life of the equipment. The following five procedures are used to ensure that a new or extensively modified system is leak- and vacuum-tight:

- a. Pressurizing system
- b. Soap suds test
- c. Use of a halogen leak detector
- d. Pressure tightness test
- e. Vacuum tightness test.

NOTE

Follow the safety precautions in paragraph [516-1.10](#)

516-8.2.13 LEAK-TESTING PROCEDURE. Depending on the refrigerating plant involved, one of the procedures or a combination of the procedures noted above is used to ensure a tight system. When leak-testing an operating system, the plant may be secured and the refrigerant system pressure used if it is a system with a posi-

tive pressure. For a new, extensively modified or overhauled system, or one that has been out of service a long time and the refrigerant removed or lost, all the procedures noted above can be used to ensure system integrity. For periodic leak testing or after minor repair or maintenance, conduct the leak test specified in the Planned Maintenance Subsystem (PMS) for the equipment. The pressures in the following leak-test procedure apply to R-12 and R-134a systems. For other plants with different refrigerants, use the test pressures indicated in the applicable technical manual. DO NOT exceed the design pressures indicated in the technical manual. The leak-test procedure for R-12 and R-134a is as follows:

1. Open all refrigerant line shutoff valves including solenoid and bypass valves in the system to be tested, except those communicating with the atmosphere such as purge and drain. Tighten valve caps securely. Isolate any control or gauge that may be damaged by the test pressure. If the system is not equipped with pressure gauges, install a pressure gauge at the charging connections to indicate the test pressure in the system. Isolate the compressor from the system.

CAUTION

Do not pressurize a refrigerant system with air. At pressures above atmospheric and with air concentrations greater than 60 percent by volume, refrigerants HCFC-22 (R-22) and HFC-134a can form combustible mixtures.

NOTE

The first consideration in a new or modified system is to use nitrogen pressure to verify that all joints have been made up and no large leaks are present. Using nitrogen initially prevents contamination of the atmosphere with large quantities of refrigerant vapor.

2. Connect a service cylinder of dry nitrogen to the charging connection and introduce sufficient nitrogen to create a pressure of 15 psig. Observe the pressure gauge. If the system loses pressure, there are leaks in the system. It is possible that there will be fairly large leaks; these may be located by listening for escaping gas. Repair any leaks located in this manner before checking for small leaks. When the system holds the test pressure satisfactorily, use soap bubble solution to check all piping joints and connections for the presence of small leaks. Repair any leaks found.
3. After all leaks have been repaired, release the nitrogen from the system to the outside or ventilate while releasing the nitrogen.

CAUTION

Do not pressurize a refrigerant system with air. At pressures above atmospheric and with air concentrations greater than 60 percent by volume, refrigerants HCFC-22 (R-22) and HFC-134a can form combustible mixtures.

4. Connect a service cylinder of refrigerant to the charging connection and open the system charging valve. Then slightly open the valve on the refrigeration cylinder, introducing enough of the refrigerant gas into the system to raise the pressure to about 10 psig or 10 pounds by weight, whichever comes first. Close the refrigerant cylinder valve, allowing a few minutes for any liquid that may have condensed in the charging line to be

evaporated; then close the system charging valve. Disconnect the cylinder from the system. Observe the safety precautions previously outlined. Reconnect the nitrogen cylinder and introduce sufficient dry nitrogen to raise the system pressure to 30 psig.

5. Check the system for leaks using an electronic halogen leak detector or a halide torch. Mark and repair all leaks.
6. When the refrigerant system is tight with a 30-pound pressure, proceed to close line valves in the system piping back to the charging connection. Open the charging valve and raise pressure to 225 pounds in the section of piping to the first shutoff valve. If this first section of piping will not hold the pressure, or leaks are noticed, repair the leaks and repeat the pressure test. When this piping segment has tested satisfactorily, open the system and charging valves and raise the pressure in next piping section to 225 pounds for testing. Repeat this procedure on each piping section until the complete refrigerating system and valves have been pressure-tested and are satisfactory. This procedure not only tests for piping leaks but also for leaks across system valve seats.

516-8.2.13.1 Leak-Testing R-114 and R-236fa Systems. Leak-test the R-114 and R-236fa systems as follows:

1. Deenergize air-conditioning plant according to ship procedures.
2. Close chilled water valves to chiller and seawater valves to condenser and tag Out of Service in accordance with ship procedures.
3. Set electronic leak detector for high sensitivity.
4. Measure and record idle main compressor suction pressure as indicated on low pressure gauge.
5. If suction pressure is less than 7 psig, proceed to step 6. If suction pressure is more than 7 psig, perform the following leak-test:
 - a Ensure that valves between remote receiver and purge and pump-out unit are closed. It may be necessary to test the pump-out unit for leaks. Valves between the air-conditioning plant and pump-out unit can be on-line or secured as necessary during this test.
 - b Open, but do not backseat, refrigerant and oil valves that do not vent to atmosphere.
 - c Ensure that remote receiver vent and drain valves are closed.
 - d Open the vent and drains on the condenser and chiller. Remove some water from the condenser and chiller to provide an air pocket. Close the vent and drains. Wait 1 hour and open the chiller and condenser water-side vents from top ends of each unit. Test vents with leak detector for presence of refrigerant. Close vents.
 - e Inspect fittings, joints, valve caps, flanges, and piping for leaks. Mark leaks. Repair leaks that do not require refrigerant removal. If all leaks have been repaired, continue with steps f, g, and h. Otherwise, remove refrigerant and repair remaining leaks.
 - f Close refrigerant and oil valves.
 - g Remove **Out of Service** tags from chilled water valves in accordance with ship procedures. Open valves.
 - h Energize air-conditioning plant (follow ship procedures).
6. If suction pressure is less than 7 psig, perform the following tests:

CAUTION

To prevent equipment damage, ensure that valves are closed to any gauges where maximum pressure, as indicated on their dials, may be exceeded.

- a Close the valves that isolate the refrigerant remote receiver. Ensure that valves that open to the atmosphere, including gauge and oil line valves, are closed. Isolate gauges with maximum pressure readings of less than 50 psig. Open all remaining air-conditioning plant valves to pressure test main unit and pump-out unit (chilled water valves and seawater valves are to remain closed).

CAUTION

Close any valves to a gauge where the maximum pressure indicated on the dial will be exceeded during the test. To prevent equipment damage from overpressure, use a pressure regulator between the dry nitrogen bottle and equipment being tested.

- b Transfer R-114 or R-236fa to remote receiver. With no pressure in the system, charge 10 pounds (by weight) of R-22, R-114, or R-236fa gas into the system through the charging valve connection.
- c Build up the system pressure with dry nitrogen to approximately 50 psig, as indicated on suction and discharge pressure gauges. To be sure the concentration of refrigerant has reached all parts of the system, slightly open the oil-charging valve and test for the presence of refrigerant with a leak detector.
- d With an electronic leak detector (set for low sensitivity), test around each joint including factory welds.
- e Open the vent and drains on the condenser and chiller. Remove some water from the condenser and chiller to provide an air pocket. Close the vent and drains. To check for refrigerant leaks in the chiller and condenser, open the vents in the chiller and condenser heads and test for refrigerant. If no refrigerant is present, the tubes and tube sheets may be considered tight. If refrigerant is found at the vents, remove the appropriate head, locate the leak by means of soap suds or an electronic leak detector, and repair it. See paragraph 516-8.2.23.
- f When the absolute tightness of the system has been established, discard the mixture of nitrogen and refrigerant using the following procedure:

CAUTION

Maintain adequate ventilation to minimize exposure to refrigerant vapor. Gas used for testing contains refrigerant vapor and will contaminate the ship atmosphere.

- (1) Close charging and vacuum indicator/pressure gauge valve. Disconnect dry nitrogen bottle and pressure regulator.
- (2) Connect lines, hose, or copper tubing to the charging and drain valves. Run the other ends of the lines to a ventilation exhaust that discharges overboard.
- (3) Open charging and drain valves to release mixture of nitrogen and refrigerant from the system to exhaust overboard.

CAUTION

To avoid system deterioration, immediately evacuate and charge the system to a positive pressure with dry nitrogen.

- (4) Evacuate the system and charge to a positive pressure with dry nitrogen or charge with refrigerant.

516-8.2.14 LEAK DETECTOR TESTING. After the refrigerant piping system has been pressurized, check each piping gasket, brazed or threaded joint, and other possible areas where leaks could occur, with an electronic leak detector set for a sensitivity of 1/2 ounce-per-year. The refrigerant charged into the system in the pressure testing procedure (paragraph 516-8.2.13) will act as a tracer, and if a leak is present, the leak detector will indicate so. After all leaks have been found and corrected, hold the pressure for 6 hours. No loss of pressure is permitted except as corrected for temperature. When the pressure test is completed, purge the system of test gases. Follow the safety precautions in paragraph 516-1.10.

516-8.2.15 SOAP BUBBLE TESTING. Despite its simplicity, the soap bubble test can be extremely helpful in finding a difficult-to-locate leak. There may be times when it is necessary or desirable to use soap suds for leak-testing. For example, soap suds would normally be used instead of other detectors in hazardous spaces. Also, in spaces where the atmosphere is contaminated with refrigerant or vapors from cleaning solvents, the halide torch or electronic leak detectors are ineffective. In this case soaps suds may also be used.

516-8.2.16 AIR DEHYDRATION OF SHELLS. Whenever a tube leak has been repaired or a refrigerant shell has been water flushed, the refrigerant system shall be thoroughly dehydrated and evacuated before being returned to service. To keep rusting to a minimum, there should be no lost time between completing leak repairs and the dehydration and evacuation processes. After pressure testing, dehydrate the system as follows:

1. Remove the compressor from the unit. Disassemble the compressor, and thoroughly clean all parts with an approved solvent if serious contamination or water leakage has occurred.
2. Install makeshift connections on the shell suction and discharge connections so a smaller size pipe or hose may be connected to these openings.
3. Isolate and drain seawater side of condenser.
4. Isolate and drain chilled water side of chiller. Do not conduct air dehydration unless chiller is drained of chilled water. Chilled water could cause moisture to condense out of the air supply. Open chiller vent and drain valves.

NOTE

When the temperature of the chiller tubes is low or the same as the temperature of the chilled water, the moisture in the drying air will condense on the chiller tubes and defeat the purpose of the compressed air dryout.

5. Remove both orifice chamber sight glass covers and sight glasses.
6. Remove the two cleanout covers.

NOTE

The internal path of the drying air shall be chosen on-site to suit the specific job. This procedure can only be used as a guide because of the many types of air-conditioning plants and the many possible stages of disassembly. The following is an example of successful air dehydration in a plant not equipped with a float chamber (R-114 plants). The dehydrated air typically enters the refrigeration plant through the chiller side of the hot gas bypass and leaves through the charging valve and the orifice chamber sight glass fitting.

7. Ensure that the ship's low-pressure air dehydrator is operating properly.

8. Connect an air filter-separator to the closest ship service air connection.
9. Connect an air pressure regulator to the air filter-separator and regulate air pressure to 20 psig.
10. Connect air hoses to air pressure regulator. Blow air through hoses for 15 minutes to ensure dry air.
11. Connect air hoses to the makeshift connections at the shell suction and discharge connections.
12. Initiate airflow.
 - a. Open charging valve.
 - b. Break the flange on the chiller side of the hot gas bypass solenoid valve or remove internals if welded. Blank-off side to condenser.
 - c. Using makeshift fittings and packing, connect air hose to the hot gas bypass. Air will flow into the chiller shell and exit through the cleanout openings.
13. Open refrigerant drain valve and cooler drain valves. Drain valves shall remain open for the first hour of air dehydration or until dripping stops.
14. Allow air purge to continue for 36 hours. Optimum air purge is 48 hours.
15. Secure airflow and disconnect air hoses. To limit reentry of moisture into the shell, quickly remove makeshift connections and reassemble the shell suction and discharge connections.
16. Remove makeshift connections installed on the shell suction and discharge connections.
17. Reinstall orifice chamber sight glasses and sight glass covers. Install new gaskets. Reinstall the cleanout covers using new gaskets.
18. Install the compressor on the unit.
19. Proceed with air-conditioning plant evacuation and vacuum dehydration (paragraph [516-8.2.17](#)).

516-8.2.17 EVACUATION AND VACUUM DEHYDRATION. Dehydration and evacuation with a vacuum pump is accomplished after pressure testing and leak repairs are complete. If the plant was flooded with water, it must also be air dried (see paragraph [516-8.2.16](#)) prior to dehydration and evacuation. The amount of time required to dehydrate will depend on the volume of the refrigerant circuit and the amount of moisture inside the plant. (Reciprocating plants have less refrigerant circuit volume than centrifugal plants.) During dehydration, the plant pressure will remain constant, and will correspond to the saturation temperature (or boiling point) of the water inside the plant. The boiling points of water at low pressures are shown in [Table 516-4-3](#). After dehydration is complete, the plant pressure will decrease until the target 5 mm Hg Abs is reached. While dehydration is taking place, the pressure inside the refrigerant circuit should correspond to the plant temperature. On a centrifugal A/C plant, the compressor suction and discharge thermometers are usually adequate for measuring internal plant temperature; but sometimes a judgment must be made, for instance, when chilled water is trickling through the chiller or when ambient conditions are colder than the compressor temperatures. Pressure drops, long lengths of hose or small line size, in the vacuum pump suction line greatly reduces pump capacity. Therefore, place the vacuum pump as close as possible to the plant and ensure the line size is equal to or larger than the pump suction fitting. Use a cold trap if the plant has been acid cleaned, or flooded with water. This will greatly reduce dehydration time. (see paragraph [516-8.2.17.2](#)) During a long dehydration of a wet plant, or if the vacuum pump suction line is accidentally disturbed, leaks can develop which result in lost time. For this reason, record plant pressure every fifteen minutes. This log will also be used to monitor progress.

CAUTION

Do not use a mercury column or manometer as a substitute for an absolute vacuum indicator. Even a very small amount of mercury entering the refrigerant system will cause a total system derangement.

NOTE

The only accurate measure of small vacuum changes would be with an electronic high vacuum gauge (see [Figure 516-8-5](#)).

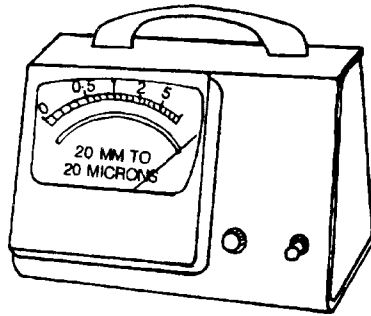


Figure 516-8-5. Electronic High Vacuum Gauge

Evacuate and dehydrate the system as follows:

1. Isolate the compressor, pressure gauges, and pressure switches from the system during vacuum testing.
2. Using a vacuum pump and an absolute pressure or vacuum gauge, evacuate the system to 200-mm hg and hold pressure for 1 hour. Any increase in pressure indicates that an air leak is present (moisture will not vaporize at 200-mm hg unless the system temperature is 151°F). This will potentially save time in the evacuation process. Leak-test the system and repair all leaks until no change in vacuum occurs at 200-mm hg.
3. To dehydrate the system, triple-evacuate the refrigerant circuit to 5-mm hg. Pull a vacuum of 5-mm hg ([Table 516-4-3](#)). (The amount of time required to obtain this pressure will depend on the volume of the refrigerant circuit and the amount of moisture inside the plant.) Then close the valve, secure the vacuum pump, and hold the vacuum for about 1 hour. After this period, charge the system with dry nitrogen to a pressure of about 2 psi. Wait for about 1/2 hour. Use the vacuum pump again to pull a vacuum of 5-mm hg, then close the valve, secure the vacuum pump, hold the vacuum for about 1 hour, and again pressurize with nitrogen. Repeat this process a third time, except this time hold the vacuum for 6 hours. Any increase in pressure (corrected for ambient temperature changes) greater than 3-mm hg shall be cause for rejection as there probably is moisture still in the system.

NOTE

To check progress, carefully record the pressure and then isolate and shut off the vacuum pump. If the pressure rises within minutes to where it corresponds to the plant temperature, then the plant still contains water. Pressure increases resulting from small leaks will be much slower.

516-8.2.17.1 Final Step. This method will not pinpoint the exact location of any leaks but is one of the exact methods to determine if the system is absolutely free of leaks and moisture. At the conclusion of the vacuum test, break the vacuum with dry nitrogen (if the plant will be layed up) or with refrigerant gas (if the plant is to be placed in operation). Do not charge liquid refrigerant into a system that has been evacuated until the system refrigerant pressure is 1 to 2 psig. If the system requires cleaning, use the cleaning procedure indicated in paragraph [516-8.2.29](#).

516-8.2.17.2 Cold Traps. The cold trap is a water vapor condensing device, installed in the suction line of the vacuum pump. Its action is to condense a large portion of the water vapor flowing toward the vacuum pump suction. This greatly increases the water removal rate. The use of a cold trap is generally not necessary for a routine post repair dehydration and evacuation of a relatively moisture-free refrigerant plant. For a wet plant, however, the cold trap will greatly reduce the time for dehydration, and also reduce, or eliminate, the need for vacuum pump oil changes. Many shore activities and private contractors use mechanically cooled cold traps. These are local designs, and all incorporate a small refrigeration system. These are very effective, and are used routinely for in-port work. There are no off-shelf non-mechanical cold traps, since these are manufactured locally when needed. Deployed ships can make a cold trap, when needed, from on-board parts. The design considerations are large heat transfer area, low pressure drop, and adequate capacity to store the condensed vapor (water) until the trap is drained. A suggested makeshift design is a 16 inch length of 6 inch diameter pipe, capped at both ends by welded 1/4 inch plates. This would lie horizontally in a mixture of ice cubes and water, such as in a trash can. Inlet and outlet penetrations would be located at the high points, on both ends, while in the operating position. The cold trap would be incorporated into a short, plant-to-pump suction line. The plant charging valve would be used for isolation, and no other valves are needed. The cold trap must be leak tight. During the dehydration process, the cold trap must be disconnected and drained after the first hour, and as required after that. The cold trap must be drained just before the final evacuation. (If the cold trap is allowed to warm up, the water inside would be boiled off by the vacuum pump, thus extending time to evacuate.)

516-8.2.18 TESTING AN OPERATING SYSTEM. Where a plant has been repaired, leak-test the section or part repaired and evacuate using all or some portion of the methods previously described, where possible. If a repair is minor such as a joint, the section isolated can be purged of air by blowing some refrigerant gas through it. The halogen leak detector can be used to leak-test an operating system. It is unnecessary to shut down the system to leak-test. Normal operating pressures are adequate for leak-testing, except where the low side (suction side) of a system operates at a negative pressure (vacuum). If it is necessary or desirable to leak-test the low side of an operating system which operates in a vacuum, the system can be shut down for an hour or so. With the plant shut down, the low side pressure will quickly rise to a positive pressure (above 0 psig) and leak-testing can be done. Where an operating plant such as an R-11 plant may be located in a cool machinery space, the resulting refrigerant pressure may be too low for a satisfactory pressure test because of the low ambient. The plant will have to be stopped, the chiller isolated, and warm water circulated through the chiller to increase the refrigerant pressure for leak-testing.

516-8.2.19 EVACUATION BY COMPRESSOR. In an emergency situation where air shall be removed from a reciprocating plant, the plant compressor may be used to evacuate the system. The average compressor will only pull a vacuum of 27 or 28 inches of mercury. Considering this limitation, no water will be evaporated from the system unless the ambient temperature is above 100°F. However, the compressor will remove sufficient air from the system so that it can be charged with refrigerant as long as no moisture or water is in the system. If the applicable technical manual indicates that the compressor can be used for this purpose, follow the procedure indicated. If the compressor manufacturer states that the compressor shall not be used for evacuation, use another means to do so.

516-8.2.20 CONDENSER MAINTENANCE. Periodic condenser maintenance is most important for reliable, proper functioning of refrigerating plants. This involves condenser cleaning, leak-testing, retubing or tube plugging, zinc replacement, and air purging.

516-8.2.21 CONDENSER CLEANING. The PMS requires that condenser tubes be cleaned at least yearly. To clean condenser tubes, it is necessary first to drain the cooling water from the condenser and then remove the water connections and water heads. When the water heads are removed, be careful not to damage the gaskets between the tube sheet and the water heads. Inspect condenser tubes as often as possible and clean when necessary using an approved steam condenser tube cleaning method. Refer to **NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors**. Employ rubber plugs and an air or water lance when necessary to remove foreign deposits. Only nylon or other fiber bristle brushes shall be used. Take care that the thin, green oxide corrosion-inhibiting coating on the inner surfaces of the tubes is not destroyed during the cleaning process. It is not necessary to clean the metal to a bright finish but it is essential that the tube surface be kept clear of foreign matter such as barnacles and pieces of loose scale. If the tubes become badly corroded or eroded, replace them to avoid losing the refrigerant charge and admitting salt water into the refrigerant system. The seawater side of refrigerant condensers should not require acid cleaning. Acid cleaning is not recommended because it will remove the protective oxide coating from the bore of the tubes. However, if acid cleaning is desired, follow one of the methods outlined in Appendix D of **NSTM Chapter 531, Volume I, Desalination Low-Pressure Distilling Plants**. If the seawater side of the condenser is acid cleaned and condenser tubes include nylon tube inserts, remove the inserts and replace after acid cleaning.

516-8.2.21.1 Condenser Gaskets

516-8.2.21.1.1 Centrifugal Plant Condensers. Centrifugal plant condenser heads use a bulb type gasket. The bulb gasket is actually an extruded neoprene seal, with a solid D-shaped cross section. It fits into a groove, round side out, much like an O-ring. The divider baffle may use a bulb gasket or, on some condensers, use a channel gasket, which has a U-shaped cross section, and fits on the mating end of the baffle. All joints must be tight and have no gaps.

516-8.2.21.1.1.1 The bulb gasket used for the condenser head flange is 25/64 x 9/16 inch. The most important consideration of the bulb gasket installation is that the ends must be cut square, and the ends must fit tight against each other with no gap. To install, cut the flange gasket with extra length, which will be trimmed later. Then tap the gasket into the flange groove, round side out. When approaching the end, plan the cutoff of the excess material. It is best to first make a trial cut, with the material about 1/8 inch too long and then make the final cut and complete the installation.

516-8.2.21.1.1.2 The baffle gasket uses either a 1/4 x 7/16 inch bulb gasket, or a channel gasket. Installation of the baffle gasket is similar to that of the flange gasket.

516-8.2.21.1.1.3 Unlike the O-ring, the bulb gasket design does not require metal to metal contact between the condenser head flange and the tube sheet. Instead, the bulb gasket is only partially compressed, and clearance between the tube sheet and condenser flange must be maintained within limits by adjusting the flange bolts. Use standard mechanical practices in installing the heads. Ensure that the clearance around the studs is uniform. Tighten the nuts evenly in gradual increments, diametrically by quadrants. Great care must be taken to keep the head flange parallel to the tube sheet, so that the bulb gasket is compressed evenly. The final clearance between the head flange and the tube sheet, at the outer edge of the gasket joint, is 5/32 inch minimum and 9/32 inch maximum. This clearance may be checked with drill bits or a feeler gauge.

516-8.2.21.1.2 Reciprocating Plant Condensers. Reciprocating plant condensers all use flat neoprene gaskets. This two pass condenser has a divider baffle, and problems at the baffle frequently occur if the gasket is not properly installed. If a replacement gasket is manufactured on the job, and the section under the divider plate has been cut too wide, the tube sheet will corrode underneath the excess gasket material. The term for this condition is crevice corrosion. Another problem is that the gasket can slip out from under the divider plate during or after installation.

516-8.2.21.1.2.1 Use pre-cut gaskets from the supply system or vendor if possible. If it is necessary to make a new gasket from sheet stock, do not make the gasket too wide, especially on the divider baffle. Maximum material excess at all mating surfaces is 1/16 inch. For installation, first glue the gasket to the condenser head using quick drying adhesive. Do not use grease or permatex since narrow cut gaskets can slip out when the head is bolted on. Use quick drying adhesive, MIL-MMM-A-121, **Standard PMS Materials Identification Guide (SPMIG) 2287**, to attach the gasket to the condenser head for installation. It will be found that after a hand made gasket is glued in place on the condenser head, the excess material can easily be trimmed off using a sharp knife.

516-8.2.22 AIR-COOLED CONDENSER CLEANING. When air-cooled condensers are installed, keep the exterior surface of the tubes free of dirt, lint, and all obstructions to heat flow and air circulation. Brush the finned surface clean with a stiff bristle brush as often as necessary to prevent accumulation of foreign matter. When installations are made in locations exposed or accessible to salt spray or rain, take care to minimize corrosion of exterior surface. The finned surface may be coated with solder or some other corrosion-inhibiting substance and should never be painted.

516-8.2.23 CONDENSER LEAK-TESTING. When a condenser tube is suspected of leakage, always conduct the leak-test on a condenser that has not been used for at least 12 hours. After this time there is usually a small air pocket at the top of the water head. To test, slowly open the water head vent valves, one at a time, and insert the exploring tube of the leak detector. If this test shows the presence of a refrigerant gas, determine the exact location of the leak or leaks as outlined below. Note that for R-11 plants the refrigerant pressure may be too low for a satisfactory test depending on the temperature in the machinery space. In that case circulate some warm water through the chiller to raise the refrigerant pressure.

1. To detect very small leaks, remove water heads and listen at each section of the tube bundle for a hissing sound that would indicate gas leakage.
2. Wash off tube sheets and clean and dry inside surfaces of all tubes. Then hold the exploring tube of the leak detector in one end of each condenser tube for about 10 to 20 seconds to draw in fresh air. As soon as fresh air is drawn through the tube, drive a cork into each end. Repeat this with all the other tubes in the suspected section or, if necessary, with all tubes in the condenser. Then let the condenser remain idle in this condition for about 48 hours before continuing the test. Do not use carbon tetrachloride for cleaning tube sheets or tubes, as its fumes give the same flame discoloration that refrigerant does and will only serve to confuse the investigation.
3. After the tubes have been corked for 48 hours, three people are required to complete the remainder of the test; one to remove the corks at one end of the tubes, one to remove corks at the other end and handle the halide torch exploring tube, and a third to watch the detector. Start with the top row of tubes in the section being investigated. Remove corks simultaneously at each end of one tube and insert the exploring tube for about 5 seconds. This will be long enough to draw into the detector only refrigerant gas that may be bottled up in a leaking tube.
4. Mark any leaking tubes found for later identification for plugging or replacing.
5. If any tube joints are leaking, there will be oil at the tube joint after the 48-hour period. Reroll or replace if

required. If a tube of the right length is not available, a blind tube piece may be rolled in the tube sheet in an emergency. Note that a leaking, rolled condenser tube may be sealed by rerolling. However, if the tube was originally rolled with a material such as Loctite to seal the tube joint, it is difficult or virtually impossible to seal a leak by rerolling. When retubing a condenser a tube joint sealant should not be used at the tube and tube sheet joint.

6. If the condenser is to be completely retubed, follow the procedures for retubing in paragraph 516-8.2.24, the equipment technical manual, or **NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors**.

NOTE

The above procedure is a laborious one but it is the only practical method that will offer conclusive evidence of small leaks.

516-8.2.24 TUBE REPLACEMENT AND PLUGGING.

516-8.2.24.1 Condenser and Chiller Tubes. The standard tube for refrigerant condensers and chillers is copper or copper alloy extruded fin tubes, .049" minimum wall thickness under the fin and .065" minimum wall in the bare section.

516-8.2.24.2 Condenser and Chiller Tube Removal. The following procedures are for single and double tube sheet heat exchangers used on air-conditioning plants. Most applications will be for condensers; therefore, the procedures cite condenser examples. Applicable air-conditioning plant technical manuals should be consulted for tube and tube sheet dimensions. If a tube or tube stub cannot be removed, plug the tube.

NOTE

Special tools are needed to remove tubes because tubes are expanded into tube sheet holes. One special tool uses hydraulic pressure to pull 5/8 - inch, 3/4 - inch, and 1- inch outside diameter (OD) tubes. Another special tool uses an air - or electric - driven impact wrench to pull tubes.

1. Use the following tools to remove condenser and chiller tubes.
 - a Internal tube cutter, adjustable from 1/2- to 2-1/2 inch diameter, from the Thomas Wilson Co., Long Island City, NY, 11101-3559 (or equivalent). **NSTM Chapter 254** provides exact dimensions for the internal tube cutter if it is necessary to fabricate this tool.
 - b Jenny hydraulic tube pulling unit, electric motor-driven, model 80, Pr 36111, from United Technology, Elliott Division, 1760 Tuttle Ave., Dayton, Ohio, 45401-1165 (or equal). Alternate: air motor-driven model 80, Pr 36120 (or equivalent); tube stub puller kit, 5/8- and 3/4-inch tube sizes, 16- to 19-gauge wall, Model #NJSPK-67(A), from Norfolk Industrial Supplies, Inc., 2705 Avenger Drive, Virginia Beach, VA, 23452, or equal; and 1/2-inch square drive air impact wrench.
 - c Standard puller spear for extracting 3/4-inch OD tube x 0.064-inch minimum wall thickness, PN 3055-00304/16 (or equivalent) standard puller spear for extracting 3/4-inch OD tube x 0.084-inch minimum wall thickness, PN 3055-00304/14 (or equivalent) spears, available locally or from Elliott Division, 1760 Tuttle Ave., Dayton, Ohio, 45401-1165.
2. Transfer the refrigerant to the receiver. Evacuate the refrigeration system and bring it to atmospheric pres-

sure using dry nitrogen. Drain the seawater side of the condenser and remove the condenser heads. Follow the applicable air-conditioning plant technical manual for these maintenance procedures.

3. Clean tube ends and tube sheet surface of all foreign material. Remove nylon tube inserts installed in any tube to be replaced.
4. Cut the tubes using the internal tube cutter at a point 1/2 to 1 inch beyond the inner tube sheet surface. **DO NOT** cut all the way through the tube wall.
 - a Set the tube cutter reach by adjusting the stop collar located on the shaft of the tube cutter. The tube is to be cut 1/2 to 1 inch beyond the inner tube sheet surface. For single tube sheet condensers (surface ships), this setting will be about 2 inches from cutter tip to edge of stop collar (Figure 516-8-6). For double tube sheet condensers (submarines), this setting will be about 5 inches from cutter tip to edge of stop collar (Figure 516-8-7), but could be as great as 7 inches for some condensers. Ensure that the tube is being cut in the bare tube section, not at the transition or in the finned section of the tube. The inside of the tube can be measured to determine the appropriate region to cut. The inside diameter of the bare section of tube is approximately 0.616 inch on single tube sheet condensers, and 0.582 inch on double tube sheet condensers.

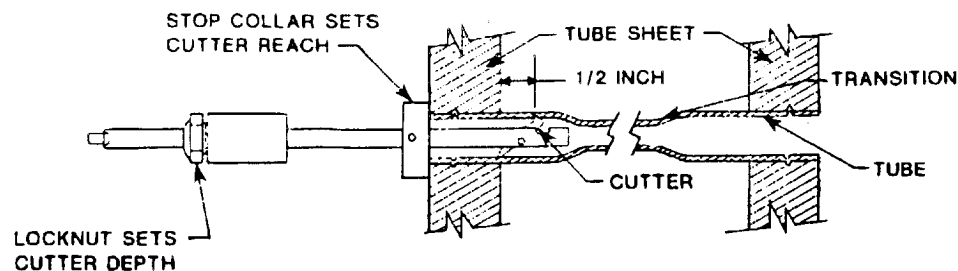


Figure 516-8-6. Cutting Tool, Single Tube Sheet Arrangement

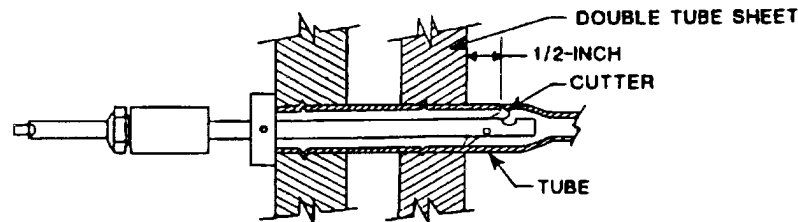


Figure 516-8-7. Cutting Tool, Double Tube Sheet Arrangement

- b Set the cutting depth approximately 70 to 90 percent of the tube wall thickness to prevent chips from entering the condenser shell. Practice on the same size tube held in a clamp or vise to ensure proper depth setting. Set the cutting depth by adjusting the lock nut on the internal tube cutter (Figure 516-8-6 or Figure 516-8-7).
 - c Attach an electric or air-driven motor to the tube cutter. Slowly rotate the cutter within the tube to circumferentially cut the inside of the tube. **DO NOT** use a high-speed drill. Maximum speed should be about 250 revolutions per minute (rpm).

CAUTION

Flying chips and debris can injure face and eyes of bystanders. All personnel should wear a face shield or goggles.

5. From the end opposite the cut, blow the cutting chips and other debris out of the tube using a compressed air jet (Figure 516-8-8). Catch the chips in a tarpaulin or canvas or heavy plastic. All personnel should wear a face shield or goggles while performing this procedure.
6. Screw the proper size spear into the end of the tube opposite the cut (Figure 516-8-9). The long end of the tube shall be withdrawn from the condenser first. When removing tubes, start near the center and work towards the outside of the tube sheet to avoid distorting the tube supports. The spear is similar to an easy out.
 - a Use 304/16 spear for 3/4-inch OD condenser tubes found on surface ships.
 - b Use 304/14 spear for 3/4-inch OD condenser tubes found on submarines.

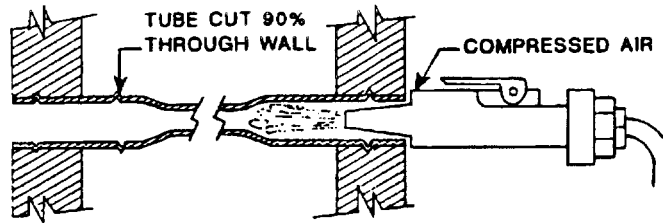


Figure 516-8-8. Blow Cutting Chips Out of Tube

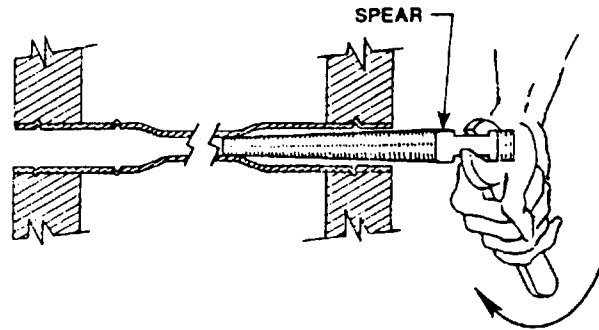


Figure 516-8-9. Insert Tube Pulling Spear

NOTE

A crescent wrench may not adequately tighten tube pulling spears in 5/8 - and 3/4 - inch tubes. This creates a risk of stripping the tube when the spear is pulled. Therefore, it may be necessary to use an impact wrench to tighten the spears into the tube.

7. First, use a crescent wrench to tighten the tube pulling spear into the tube. If the crescent wrench does not adequately tighten the spear in the tube, use an impact wrench to tighten the spear.

CAUTION

If a chiller tube cannot be extracted, it may have bulged because it froze. Plug the frozen tube by following the procedure for plugging leaking tubes in paragraph 516-8.2.24.4.

8. Extract the tube from the tube sheet. Attach the hydraulic ram or tube stub puller to the spear. If the hydrau-

lic ram is used (Figure 516-8-10), protect the tube sheet by placing rubber blocking between it and the ram cylinder. To attach the hydraulic ram to the cylinder, use an appropriate adapter, horseshoe lock, and nut. Apply hydraulic pressure to withdraw the long end of the tube. If the tube stub puller is used, screw the puller onto the spear and bring it up tight against the tube sheet face. Withdraw the long end of the tube from the tube sheet using an air impact wrench attached to the tube puller. The tube will part at the cut made in step 4.c (Figure 516-8-11) while pulling the spear.

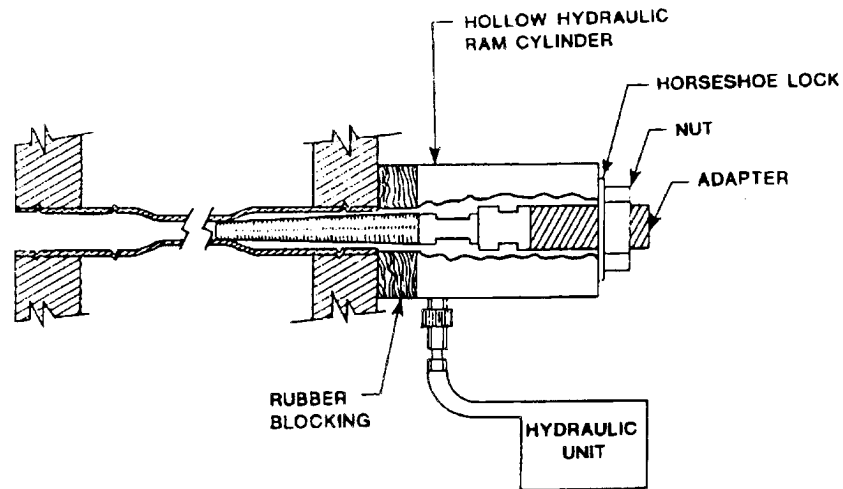


Figure 516-8-10. Extract Tube Using Hydraulic Ram Cylinder

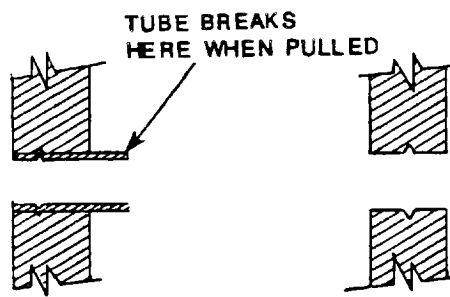


Figure 516-8-11. Tube Extracted

9. Screw the spear into the stub end of the tube (Figure 516-8-12). Repeat steps 6, 7, and 8 to remove the stub end of the tube.

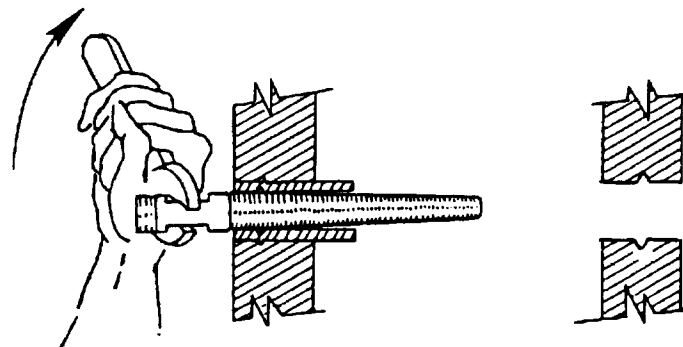
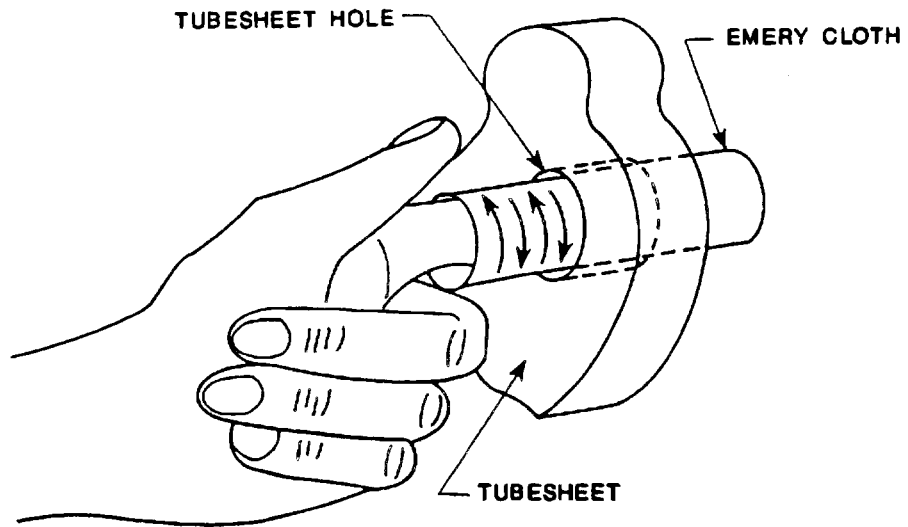
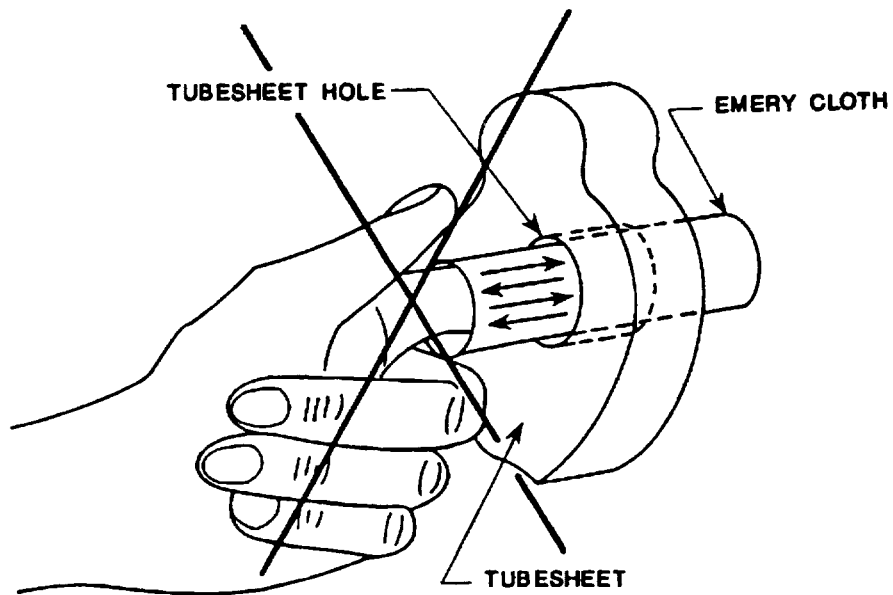


Figure 516-8-12. Spear Inserted to Remove Tube Stub

10. Clean the tube sheet holes. Polish the inner surfaces by hand with fine (180) or extra fine (220) emery cloth ([Figure 516-8-13](#)). **DO NOT** use a grinding wheel with medium or coarse grit. Clean the inner grooves of tube hole to remove foreign material with a dental pick or thin wire.



CORRECT POLISHING TECHNIQUE



WRONG POLISHING TECHNIQUE

Figure 516-8-13. Tube Sheet Polishing

516-8.2.24.3 Condenser and Chiller Tube Installation. In air-conditioning plant heat exchangers, the tubes are expanded (rolled) into the tube sheet holes. The following procedures are for single and double tube sheet heat exchangers. Most applications will be for condensers; therefore, the procedures cite condenser examples. The procedures will be the same for chillers. Applicable air-conditioning plant technical manuals should be consulted for tube and tube sheet dimensions.

1. Special tools are needed to install tubes because tubes are expanded into tube sheet holes. Use the following tools, or their equivalent, to install heat exchanger tubes. The tube expanding tool conforms to MIL-E-15809.
 - a Tube expanding tool (tube roller), PN 480504, for expanding 3/4-inch OD x 0.064-inch minimum wall tube, from Elliott Division, 1760 Tuttle Ave., Dayton, Ohio, 45401-1165.
 - b Torque control air motor (midi-torq control), uses 45-cfm, 90-psig air at 1,800 rpm, from Elliott Division.
 - c Alternate electric torque control with #440-KER-500 electric motor, from Elliott Division.
2. Ensure that the tube sheet holes are clean and free of burrs. Polish if necessary using the procedure described in paragraph [516-8.2.24.2](#).
3. Before installing new tubes, take the following measurements of the tube sheet and tubes:
 - a Measure inside diameter of tube sheet holes. Do not measure at the groove. Take several measurements to establish an average hole diameter. Record the average hole diameter.
 - b Measure the tube wall thickness of the new tubes. Take several measurements to establish an average tube wall thickness. Record the average tube wall thickness.
 - c Measure tube sheets (single and double) to determine the exact location and thickness of each tube sheet. Record these measurements.
4. Polish outside surface of tube about 3 inches on each end using 180- or 220-grit energy paper. The technique used is similar to that shown in [Figure 516-8-13](#).
5. Install the new tubes in the heat exchanger shell. All replacement tubes should be of 70:30 copper-nickel material and conform to MIL-T-22214 for integrally finned tubes. Where the original tubes were 90:10 copper-nickel, the 70:30 copper-nickel tubes selected as replacements shall have more fins per inch to achieve the same heat transfer as the 90:10 tubes. For example, 19 fin/inch 90:10 tubes shall be replaced with 26 fin/inch 70:30 tubes to maintain the original capacity. All surface ship tubes are Class B, Type II. All submarine tubes are Class A, Type II. Begin inserting tubes at the bottom of the tube bundle. In longer heat exchangers, guide the tubes by first inserting a wooden dowel or fiber rod that is 3/8 to 7/16 inch in diameter. A bull nose insert with a rounded or tapered end can also be fitted into the tube for guiding the tube through the intermediate tube sheets.

NOTE

During tube rolling, the tube wall material is first expanded then thinned by cold deformation. The tube sheet is also slightly enlarged. Total deformation is limited to 5 percent and is determined by measuring the inside diameter of the tubes during the rolling process.

6. Determine the amount of tube rolling necessary to properly expand and thin the tubes into the tube sheet holes. Use the measurements determined in step 3 and the following example to calculate the maximum allowable tube inside diameter.
7. Expand a scrap piece of same size tube to the maximum allowable tube ID using the rotary expanding tool ([Figure 516-8-13](#)). Use the proper tool for the particular tube size. Mark the location on the mandrel with

paint, ink, chalk, or other material. A piece of tape can be applied for better visibility. This marks the tube maximum thinning limit (inside diameter = 0.632 inch for surface ships; inside diameter = 0.595 inch for submarines).

8. Expand another scrap piece of same size tube to the ID of the tube after the tube is expanded into the tube sheet hole. Set the variable torque drive at a low value and expand the tube slowly. Two or three tries should be made to obtain this setting as accurately as possible. Mark the expander at this position. This marks the minimum (zero thinning) setting (inside diameter = 0.625 inch for surface ships; inside diameter = 0.587 inch for submarines).

Calculate Maximum Allowable Tube Inside Diameter (ID)	Surface Ships	Submarines
Tube sheet hole ID minus 2 x wall thickness =	0.755 inch - (2 x 0.065)	0.755 inch - (2 x 0.084)
ID of tube after tube is expanded into tube sheet hole	0.625 inch	0.587 inch
Plus 5% of wall thickness doubled (for tube thinning) =	+ (0.05 x 0.065) + (0.05 x 0.065)	+ (0.05 x 0.084) + (0.05 x 0.084)
Maximum allowable tube ID after thinning	0.632 inch	0.595 inch

CAUTION

If the roll is too deep, the tubes will be expanded beyond the tube sheet. This will make it difficult to remove the tubes later.

NOTE

Excessive wear on the tube sheet and tube can occur if a crevice is created between the tube and tube sheet during rolling.

9. Set the tube expander depth so that the tube is rolled as close as possible to the inner edge of the tube sheet without going beyond the tube sheet. The depth of the roll **shall not** exceed the thickness of the tube sheet minus 1/16 inch. For example, if the tube sheet is only 1-inch thick, the depth of the roll shall not exceed 15/16 inch. The depth of the original tube roll can be determined by checking the ID (Figure 516-8-14) to locate the depth at which it changes from thinned ID to original tube ID at end. To set the expander depth (depth of roll), refer to Figure 516-8-14 and Figure 516-8-15 and proceed as follows:

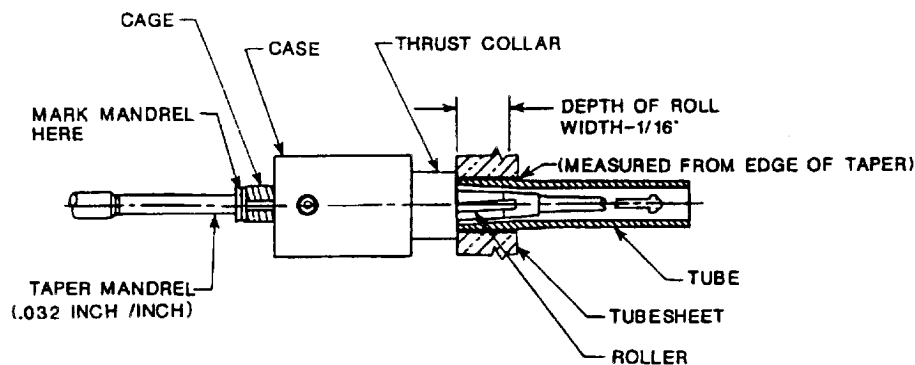
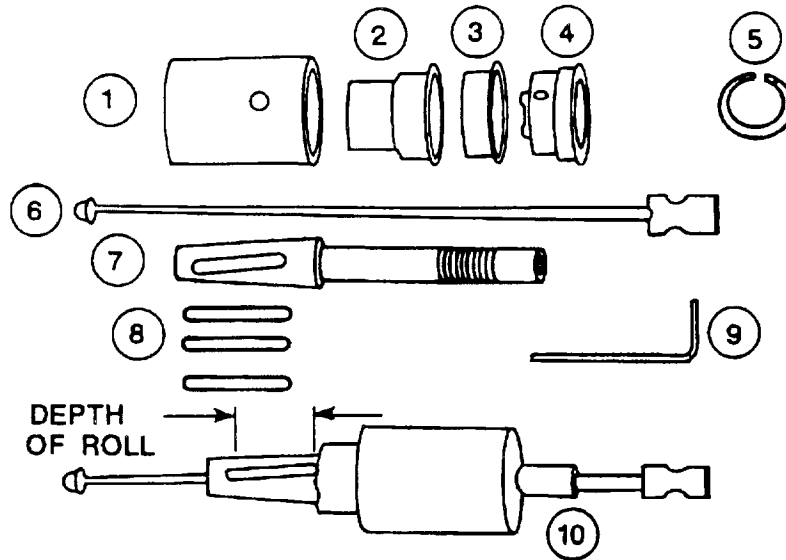


Figure 516-8-14. Dimensional Rolling



1. NONROTATING CASE	6. MANDREL
2. THRUST COLLAR	7. CAGE
3. BALL THRUST BEARING	8. ROLLERS
4. THRUST NUT	9. ALLEN WRENCH
5. SNAP RING	10. ASSEMBLED EXPANDER

Figure 516-8-15. Elliot Tube Expander for Rolling Tubes in Tube Sheets

- Through the hole in the case (1), loosen the setscrew in the thrust nut (4).
- Turn the cage (7) inside the thrust nut (4) until the distance from the face of the thrust collar (2) to the taper of the rolls (8) is equal to the required depth of the roll.
- Tighten the setscrew in the thrust nut (4) into the groove provided in the cage shaft (7).

CAUTION

DO NOT overroll the tubes. Excessive thinning of the tubes or distortion of the tube sheet may result.

- For single tube sheets, the initial rolling setting should be midway between the two marks established in steps 6 and 7. This setting corresponds to three-percent thinning. Roll the tubes to this setting and check for leaks. If any leaks exist, reroll the leaking tubes to the 5-percent (maximum) setting. Take care not to roll over the inside surface of the tube sheet. Use a lubricant between the expanding tool and inside surface of the tube while rolling joints.

CAUTION

DO NOT use joint sealants, such as Loctite, between the tube and the tube sheet when rolling joints. If a joint is rolled with a joint sealant and a leak develops at the joint, it will be impossible to seal the joint by rerolling.

CAUTION

DO NOT overroll the tubes. Excessive thinning of the tubes or distortion of the tube sheet may result. Take care not to roll over the gap between the tube sheets or roll over the inside surface of the innermost tube sheet. Removal of tubes incorrectly rolled is almost impossible and may damage the hole surface of the tube sheet.

11. For double tube sheets, first roll all joints of newly installed tubes on the innermost tube sheet. Determine the exact position of the tube rollers on the tube sheet surface by the measurements taken in step 3.c. The initial rolling setting should be midway between the two marks established in steps 6 and 7. This setting corresponds to 3-percent thinning. Roll the tubes to this setting and check for leaks. If any leaks exist, reroll the leaking tubes to the 5-percent (maximum) setting. Use a lubricant between the expanding tool and inside surface of tube while rolling tube joints.
12. Roll the joints of newly installed tubes on the outermost tube sheet and check for leaks. Accurately determine the exact position of the tube rollers on the tube sheet surface by the measurements taken in step 3.c. The initial rolling setting should be midway between the two marks established in steps 6 and 7. This setting corresponds to 3-percent thinning. Roll the tubes to this setting and check for leaks. If any leaks exist, reroll the leaking tubes to the 5-percent (maximum) setting.
13. Perform an accurate leak-test on newly installed tubes. Also leak-test originally installed tubes adjacent to new tubes to ensure that tube rolling did not disturb the tightness of the existing tube joints. In the event of a leak, carefully limited rerolling will probably correct the leak. If the leak cannot be corrected, the tube will have to be plugged or replaced. In some cases, the cause of a leak may be a tube sheet hole that is out-of-round. If this happens contact NAVSEA 03L22 or Naval Surface Warfare Center Ship System Engineering Station (NSWCSSS) 9213. If the tube sheet hole is out-of-round it may be virtually impossible to seal the leak.
14. Bell tube end in accordance with MIL-R-16743F.
15. Face tubes flush with tube sheet.
 - a Trim excess tube to within 1/4 inch of tube sheet.

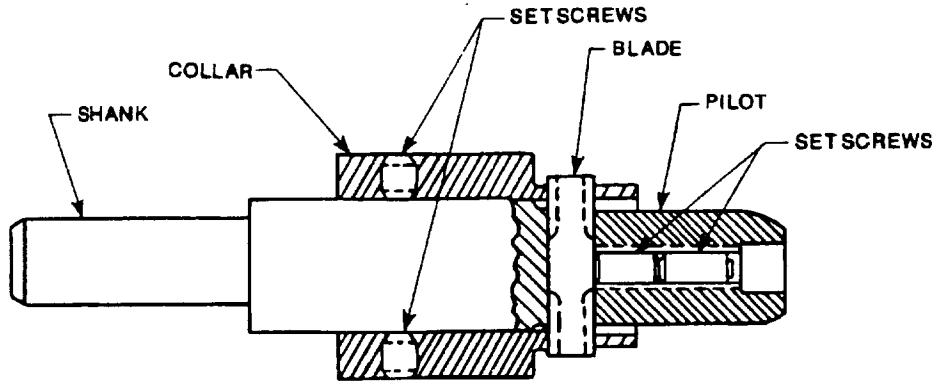
NOTE

The tube will first be faced to within 1/16 inch of tube sheet, then faced flush with tube sheet.

NOTE

Facing tool pilots are sized according to tube gauge (wall thickness). Be sure to select correct facing tool.

- b Select proper size facing tool.
- c Set collar (Figure 516-8-16) on facing tool to cut a 1/16-inch tube extension.



NOTE: SHANK AND PILOT ARE INTEGRAL

Figure 516-8-16. Facing Tool - Cutaway View

- d Hold the facing tool square with tube sheet.
- e Press facing tool against tube end with considerable force to prevent chatter.
- f If tool is too loose in tube, wrap Teflon tape a few times around the pilot to help prevent chatter.
- g Set collar on facing tool flush with blade to cut the 1/16-inch tube extension flush with the tube sheet. Take care to ensure that the blade does not extend past the collar.

CAUTION

Do not cut into face of the tube sheet.

- h Repeat steps d, e, and f to face the tube flush with the tube sheet. Ensure that the facing tool does not cut into the tube sheet.
16. Reinstall heads, dehydrate and evacuate the refrigeration system, transfer refrigerant from receiver to chiller, and return the plant to readiness condition by following the applicable air-conditioning plant technical manual procedures.

516-8.2.24.4 Condenser or Chiller Tube Plugging. If immediate tube replacement is impossible, leaking condenser or chiller tubes may be temporarily plugged with Elliott plugs using the following procedure:

NOTE

Tube plugging is not a permanent repair. If more than 10 percent of the condenser tubes in any pass are plugged, serious capacity reduction may result.

NOTE

The condenser or chiller should be retubed if over 10 percent of the tubes or 10 percent of the tubes in any one pass need to be plugged or replaced due to defects or thinning (paragraph 516-8.2.26, step 7).

1. Procure manufactured plugs (bushings with proper pins) using information shown in [Table 516-8-1](#) or make up the required number of copper-nickel plugs as shown in [Figure 516-8-17](#) (refer to note in [Table 516-8-1](#)).

Table 516-8-1. ELLIOT PLUGS FOR CHILLER AND CONDENSER TUBES

70:30 Copper-Nickel Bushing (Specify Soft Tempered) Elliott Part No. *		70:30 Copper-Nickel Pin (Specify Soft Tempered) Elliott Part No. *
874402-570	used with	874403-500
874402-590	used with	874403-500
874402-613	used with	874403-1
874402-631	used with	874403-1
874402-640	used with	874403-1
*The number following the dash (-) in the part no. for the busing represents the outside diameter of the plug in thousandths of an inch, that is, #853002-631 has an 0.631-inch outside diameter. The sizes are selected to fit the normal range of inside diameters found in air-conditioning plant tubing without machining.		

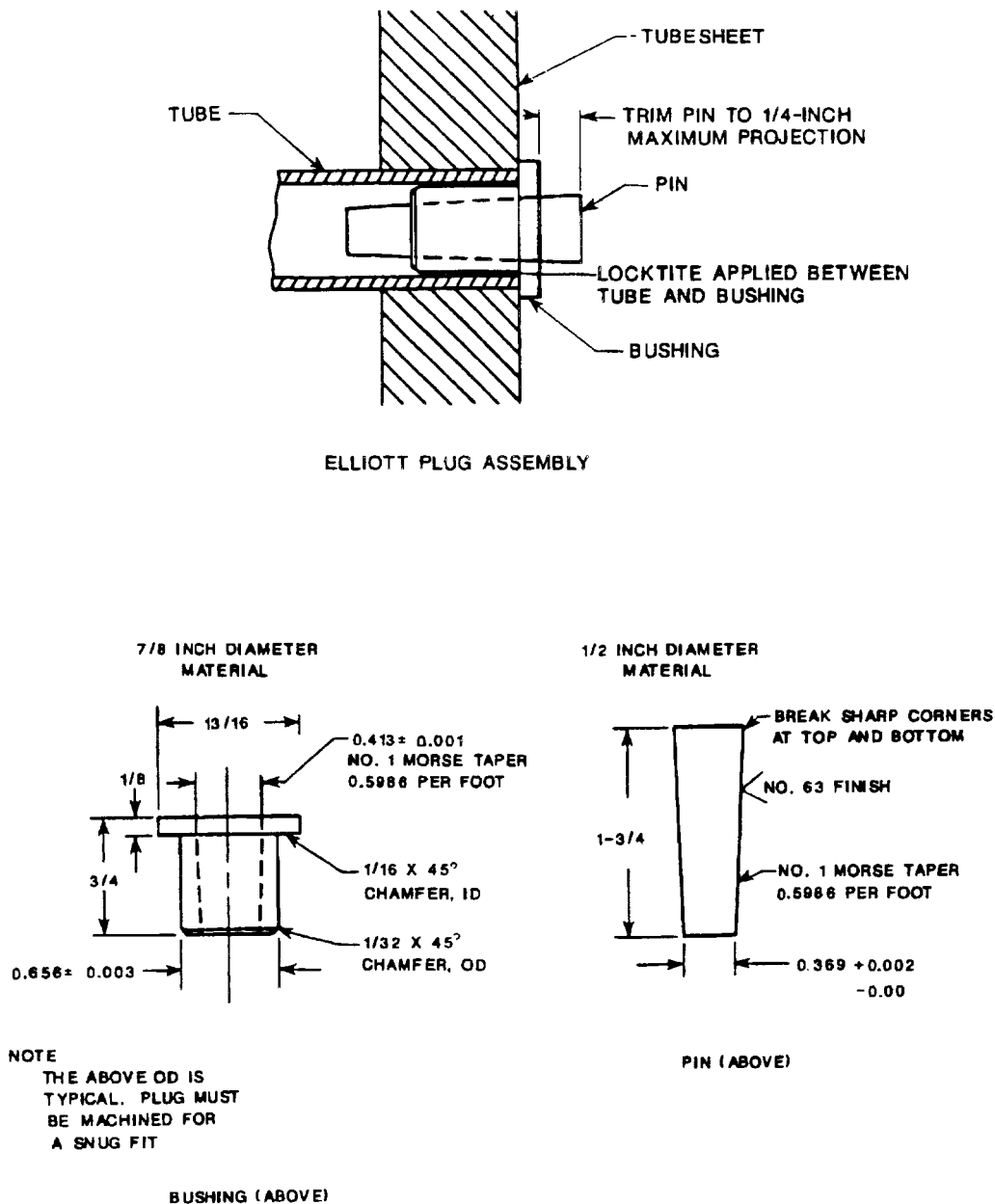


Figure 516-8-17. Fabrication Detail Tube Plug

2. Remove excess scale and other defects from the inside of the tubing to a depth of approximately 1 inch using fine grit sandpaper or emery cloth. Remove excess grit.
3. Degrease the outside of the bushing and inside the ends of the tube to be plugged. Apply anaerobic sealing compound, Grade AVV per MIL-S-22473 (Loctite), to these surfaces.
4. Insert bushing portion of plug into tube.
5. Insert pin portion of plug into bushing.
6. Drive pin into bushing until tight. Usually a ringing sound will be heard when the assembly is tight.
7. Check plug for refrigerant leakage in accordance with standard leak-testing procedures.

8. Thoroughly clean and dehydrate the system and return to service.

516-8.2.25 Waterbox and Tube Sheet Epoxy Repair. Epoxy coatings can be used to repair erosion and corrosion damage to tube sheets and waterboxes of refrigerant condensers in air conditioning and refrigeration plants. When authorized, the application of epoxy to tube sheets or waterboxes shall be in accordance with the following general guidance.

NOTE

Epoxy repairs to refrigerant condensers is not authorized to restore structural integrity.

NOTE

The requirements herein apply to epoxy repair technique for all shipboard air conditioning and refrigeration units. However, epoxy repairs are not considered to be permanent repairs for submarine air conditioning and refrigeration units.

516-8.2.25.1 Inspection. Inspect the areas to be repaired. If a defect causes the waterbox or tube sheet thickness to be less than 2/3 of the original thickness, the area(s) shall be repair welded or replaced to restore to original thickness.

516-8.2.25.2 Surface Preparation. The surface to be coated must be carefully prepared to provide a good anchor for the epoxy. Corrosion, salt deposits, dust, moisture, oil, and grease must be completely removed prior to epoxy application. Surface preparation applies to the area to be coated, plus a minimum of 1/2 inch beyond this area on all sides. The epoxy coating shall not extend onto unprepared surfaces.

- a. **Water Removal.** When repairing tube sheets, any standing water in the tubes should be blown out using an air line. The process should be continued until the tubes are dry. When repairing waterbox surfaces, all standing water should be removed and the surface blown dry using an air line.
- b. **System Protection.** When repairing tube sheets, the tubes require temporary plugging. Corks of maximum diameter slightly greater than the internal diameter of the tubes should be obtained. One cork should then be pushed into each tube of concern, and, when all tubes are plugged, a flat piece of wood, metal bar, etc. shall be used to level all the corks with the tube ends.
- c. **Grease and Oil Removal.** Thoroughly clean surfaces which are to come in contact with epoxy using a non-ionic, biodegradable, water-soluble detergent, degreaser or cleaner recommended by the epoxy manufacturer. Afterwards, surfaces shall be solvent cleaned prior to any preliminary surface conditioning.
- d. **Preliminary Surface Conditioning.** Prior to any surface conditioning, the surrounding areas that are not to be reconditioned shall be masked with a material which provides adequate protection. The surface to be prepared shall be conditioned to produce a 0.003" to 0.005" anchor tooth profile. Surface conditioning shall be accomplished by abrasive blasting, needle gun, or grinding. The use of a wire brush or sanding disk is to be avoided as the resultant "polishing" may leave the surface too smooth for proper adhesion of the epoxy.
- e. **Salt Removal.** Wait at least 24 hours following preliminary surface conditioning to allow ingrained salts to crystallize on the surface of the metal. Crystallized salt will be removed during oxide removal.
- f. **Oxide Removal.** A final abrasive cleaning shall be done to remove any surface oxides or contamination left

from previous cleaning procedures and to obtain a final surface profile that promotes adhesion of the epoxy coating. The same methods used for preliminary surface conditioning shall be used for this cleaning.

- g. **Final Cleaning.** Immediately following oxide removal, but prior to coating, the surface shall be cleaned with the same solvents used for oil and grease removal. The surface shall be cleaned until it is free of oil, grease, dirt, mill scale, rust, corrosion products, oxides, and other foreign matter.

NOTE

Avoid contacting surfaces to be coated with the bare hand or other sources of contamination.

CAUTION

The first coating of epoxy should be applied immediately following oxide removal and final cleaning to avoid oxide formation. If the epoxy is not applied within 4 hours, the oxide removal and final cleaning steps must be repeated.

NOTE

NAVSEA S9520-AA-MMA-01/VOL I, **Repair of Submarine Seawater Ball Valves (Non-Nuclear)** and NAVSEA Technical Publication 03Y3-100, **Pump Repairs Using Polymeric Compounds** provide acceptable alternate procedures to accomplish the required surface preparation.”

516-8.2.25.3 Application. Care must be exercised when selecting an epoxy to match the environment, operating fluid, and waterbox material of the condenser. NAVSEA Technical Publication 03Y3-100 contains a listing of various epoxies and associated physical properties. Epoxy Material Selection and Handling shall be in accordance with NAVSEA Technical Publication 03Y3-100. The mixing and application of the epoxy shall be in accordance with the manufacturer’s instructions and NAVSEA Technical Publication 03Y3-100.

516-8.2.25.4 Finish Machining. Careful application of the epoxy can often reduce or eliminate any required machining. Careful buildup and fairing of the material or the application of multiple layers slowly approaching the desired thickness is often much less labor intensive than machining or grinding off excess material. However, if machining is required it should be accomplished in accordance with the requirements of NAVSEA Technical Publication 03Y3-100 and the manufacturer’s instructions. Wet or dry grinding with aluminum oxide or silicon carbide grinding wheels can be used to remove excess material. Care must be taken during any machining operation to avoid damaging the coating.

516-8.2.25.5 Final Inspection. The coating shall be free from cracks, areas of separation, blisters, rough surfaces, areas of porosity or areas of discoloration. There should not be an excessive build-up of epoxy coating. Any discrepancies of the aforementioned types are cause for coating repair.

516-8.2.25.6 Coating Repair. Epoxy coating repair and the application of an epoxy coating over an existing one is to be accomplished in accordance with the requirements of NAVSEA Technical Publication 03Y3-100.

516-8.2.26 CONDENSER NYLON TUBE INSERTS. As previously stated, use of condenser tube inserts is desirable to prevent corrosion or erosion at tube inlets. The following procedure is a guide for the installation of nylon tube protectors (Crane drawing R-21375) in air-conditioning plant condensers.

1. Drain the condenser and attached piping. Tag out pumps and valves as required.
2. Remove the condenser vent and drain piping and instrumentation such as the thermostat sensing bulb and inlet and outlet thermometers.
3. Disconnect seawater inlet and outlet piping, as required, to remove condenser water heads. Support piping where required.
4. Attach a chain hoist (minimum 1-ton capacity) to condenser water heads, remove bolts, and while supporting the load, carefully remove heads and lower to a suitable location. Clean all nuts and bolts and ensure new gaskets are available for reassembly.
5. Clean the surface of the tube sheet and the interior of water heads, removing all foreign material, silt, and oil.
6. Clean the ID of all tubes using nonmetallic brushes designed for 1/2-inch ID copper-nickel tubing. Only nylon or other fiber bristle brushes shall be used. A high-pressure water jet or nozzle can be used as long as the spray is not concentrated on a local area for a long period of time. Do not remove the very thin, green oxide on the interior of the tubing. This oxide coating is essential to protect the metal. It is not necessary to clean the metal to a bright finish. Flush each tube individually to remove loose residue. If an oily film is present, remove it with a mild detergent. Do not use chemical or petroleum solvents for removal of grease or oil. Flush tubes to remove excess detergent if used.

NOTE

It is recommended that shore or tender personnel [such as Shore Intermediate Maintenance Activity (SIMA)] experienced in condenser cleaning perform this cleaning procedure.

7. Examine the interior surfaces of at least the first 8 inches of the individual tubes. Mark all tubes showing evidence of erosion or corrosion in the tubing metal. Replace or plug tubes having excessive pitting. The basic criterion for tube replacement or plugging of tubes is erosion or corrosion of the wall thickness of the tubing in excess of 50 percent of the base metal. Do not plug more than 10 percent of the total tubes in the condenser and not more than 10 percent of the tubes in any one pass. The wall thickness under the fin is specified as 0.049-inch minimum. Since no maximum thickness is stated in the specification and the exact point of perfect fin formation is difficult to determine, the following criteria are established. Beyond the tube sheet area (first 2 inches on surface ships), any pitted area in excess of 0.025-inch depth is cause for replacement or plugging. Within the tube sheet area (first 2 inches of length), the wall thickness is 0.064-inch minimum. Therefore, the normal maximum depth of defect of 0.032 inch (approximately 1/32 inch) applies. The 50 percent of base metal criterion may be extended to 70 percent (or 0.045 inch) under the following conditions:
 - a When the only defect in the tube is within the first 2 inches (tube sheet area)
 - b When the defect is less than 1/4 inch long in any direction
 - c Where the tube is properly expanded into the tube sheet
 - d When nylon inserts are properly installed with liberal amounts of adhesive covering the defect.
8. Test each condenser tube for refrigerant leaks. Use normal approved leak detection devices such as a halide torch or an electronic halide leak detector. Replace or plug leaking tubes with Elliott-type copper-nickel plugs.

9. Clean the first 6 to 8 inches of the inlet end of each tube of each pass with a dry, clean, lint-free cloth wrapped around a brush, drill rod, or dowel of proper OD. Discard dirty cloths. Check inserts to ensure that dust, dirt, oil, grease, or other foreign substances are not present.
10. Using a tubing micrometer or similar measuring device, measure the minimum ID of the tubing under the fin (at least 4 inches into the tube). The measured IDs shall be 0.505 inch minimum to 0.522 inch maximum. (Refer to paragraph 516-8.2.24.1 to determine MIL Spec tube.) Use tubing insert, Crane drawing R-21375, NSN 4730-01-181-9598 (6 inches long). Apply Pliobond 30 (1/2 pint, NSN 8040-01-205-3995) cement over entire outer surface of the insert except the 1/2 inch at the downstream end. Use small bristle brush (acid brush).
11. Place the insert into the tube, using a light steady rotating motion, until the flange is within 2 inches of the tube sheet. If required, apply additional adhesive in this area to ensure a perfect seal. Push the insert until the flange is in contact with the tube sheet. Remove excess adhesive.

CAUTION

Adhesive vapors are flammable. Provide adequate ventilation overboard. No smoking is permitted in the immediate area. Follow prescribed safety precautions when using adhesive.

516-8.2.26.1 At ambient conditions (60° F to 80° F) adhesive will dry in 48 to 72 hours. To reduce drying time, forced air drying is permitted. Use a Red Devil forced air fan unit, with flexible duct hose attached, to direct a flow of hot air onto the inserts to raise the air temperature to 150° F to 160° F. A 10-kilowatt (kW) to 12-kW tubeless fin duct heater is ideal for heating purposes. Mount thermometers in the airstream and attach them to the tube sheet metal to monitor the temperatures continuously during drying. Under these conditions drying can be completed in 10 to 12 hours.

NOTE

Do not allow air temperature to exceed 170°F under any conditions. Drying time depends on many factors. Drying is complete when inserts cannot easily be removed by hand and visible adhesive is reasonably firm and dry.

516-8.2.26.2 A watchstander shall be in attendance at all times during drying of adhesive. The recommended duties of the watchstander, to be done at least each 1/2 hour for the first 4 hours and each hour thereafter, are as follows:

1. Record air and metal temperature.
2. Ensure that temperature limits are not exceeded.
3. Make adjustments necessary to keep temperature within limits. Usually some throttling of airflow through the fan is required.
4. During the drying process, inserts sometimes back out of place due to solvent vapor buildup. Watchstander will reposition inserts by thumb pressure until adhesion takes place.
5. Ensure that adequate ventilation is maintained and safety procedures are followed at all times.

6. Reassemble condenser using new gaskets. Ensure that divider plate on inlet end is gasketed to prevent leakage between passes.
7. Reinstall piping and instrumentation.
8. Perform hydrostatic leak-test in accordance with established procedures.

516-8.2.27 CONDENSER ZINC ANODE REPLACEMENT. Where applicable, install and use zinc anodes in refrigeration condensers. Periodically check and replace the zinc anodes as follows:

1. Drain the condenser and remove the plugs holding the zinc anodes to examine the zinc fingers for deterioration.
2. Replace the fingers, when necessary, by unscrewing them from the tapped plugs. All zinc anodes are threaded on one end to screw into the plugs. Replacement anodes can be fabricated from zinc rod available in general stock for this purpose.
3. Before reinstalling the zinc anode retaining plugs, look through the plug holes with a light and examine the tube and tube sheet for debris and tube blockage. The condenser should be cleaned in accordance with paragraph [516-8.2.21](#).

516-8.2.28 CONDENSER SEAWATER FLOODING. Any seawater flooding of the refrigerant plant is a serious problem. The procedure for returning a plant to service after seawater flooding is in paragraph [516-4.1.16](#). This procedure is included in [Section 4](#) on operation because operating personnel who have the plant under surveillance will be the first to note a seawater leak and will take the necessary action to protect the plant against corrosion.

516-8.2.29 REFRIGERANT SYSTEM CLEANING.

516-8.2.29.1 General. This section presents cleaning methods for both centrifugal and reciprocating refrigeration systems. Since these systems are quite different, they are presented separately. Since each cleanup situation is unique, as much technical background as possible is included. This is to aid the user in making on-site decisions.

516-8.2.29.2 Centrifugal Air-Conditioning Plant Contamination. Minor internal rust and corrosion of centrifugal air-conditioning plant shells develops during the service life of fleet units despite maintenance practices designed to keep them corrosion-free. A small amount of rust on the interior surface of a plant is common and rarely causes operational problems. Surface rust that comes off when brushed with the hand is not a justification for system cleaning. A small amount of rust particles suspended in the lube oil will not accelerate bearing failure. Light rust will form on the interior of the plant after the refrigerant charge is removed and the plant is opened to the atmosphere. Oxygen in the air causes rust formation when the plant is left open for a day or two, especially since the refrigerant has degreased the steel. To minimize rust formation, cover plates should be installed and a nitrogen blanket maintained if a plant shall be open for more than a day. If heavy rust has formed while the plant was in operation, one of the following has probably occurred: a leak to the atmosphere (usually on the suction side) that allows air and moisture to enter the refrigerant side; seawater leakage through the condenser tubes or the tube-to-tube sheet joints; chilled water leakage in the chiller; or chilled water leakage through the oil cooler. These conditions are especially serious in R-11 plants, which often have an ample oxygen supply due to inward flowing air leaks during operation at negative pressure. A plant that is leak-free and dehydrated will not continue to rust. In those cases where there is an established history of compressor failure because of rust or other

contamination, acid cleaning may be necessary. Centrifugal units with a history of nuisance shutdowns, surging, or hunting probably fail for reasons other than dirt contamination. For more information on compressor surge, refer to paragraph [516-5.2.4](#).

516-8.2.29.2.1 Lube Oil Condition - Centrifugal. The condition of the lube oil cannot be a factor in deciding whether to flush the plant shell. This is because available parameters, including the Navy Oil Analysis Program, only describe the condition of the lube oil, and do not indicate whether there are sufficient dirt and corrosion products out in the system to justify acid cleaning. New lube oil has a light amber color, which in Navy systems typically darkens slowly at normal refrigerant system operating temperatures. Suspended rust particles also cause discoloration. Cloudiness of the oil is usually caused by excessive moisture content.

516-8.2.29.2.2 Centrifugal System Refrigerant Filtering. Fine dirt and rust particles, visible in the sight glass of centrifugal plants, can be routinely filtered from the refrigeration system without disturbing operation. This is accomplished by operating the refrigerant cleaning system. Routinely replacing the filter/dehydrator cartridge will aid in keeping the refrigeration system clean. In some systems, larger filters, dehydrators, and eductors have been installed to remove dirt and moisture. These systems are usually connected between the condenser and chiller.

516-8.2.29.3 Flushing Centrifugal Plants. R-113 flushing of centrifugal air-conditioning plants is no longer recommended. R-113 is an ozone-depleting substance and is harmful to the environment. R-113 flushing is thus not recommended for this reason and because of the high cost and time associated with required safety precautions. Furthermore, the solvent characteristics of R-113 are no better than for the other common Navy refrigerants. R-113 was used because it will not boil off at ambient conditions, which makes it easier to handle. Flushing of rust and other particulates requires a high fluid velocity inside the plant shell to remove particulate matter. Comparison of the plant shell dimensions relative to the flushing hoses shows that even with maximized velocities in the flushing hoses, the velocity of the fluid inside the plant shell will be too low to flush out the contamination. Experience has shown that the maintenance actions included as part of an R-113 flush are more beneficial than the actual flush. Leak repairs, restoration of adequate refrigerant charge, removal of excess oil from the refrigerant, evacuation and dehydration, and filter-dehydrator changes would improve plant operation and reliability independently of an R-113 flush job. R-113 flushing will not increase the capacity or efficiency of a system. It has been found to be more effective to clean only the problem areas. For instance, clogging of the oil return system (ORS) can be corrected by cleaning the associated piping. Excessive oil in the refrigerant can be corrected by operating the ORS, cleaning the ORS eductor, or replacing part or all of the refrigerant charge. The purge and pump-out unit and receiver tank can be used to remove excess oil from the refrigerant charge (see paragraph [516-8.2.29.6](#)). For corrective procedures following a seawater leak, refer to paragraph [516-8.2.29.7.2](#).

516-8.2.29.4 Refrigerant Flush Hermetic Motor Burnout. Do not conduct this R-113 flush if the contamination associated with motor burnout is only minor (that is, motor burnout debris is in motor housing only). Remove oil and refrigerant. Overhaul or replace the motor and clean out all accessible debris from the motor burnout using solvent and lint-free rags. Use gloves and eyewear because burnout by-products are acidic. Ensure adequate ventilation if solvent is flammable or toxic. Renew oil, filters, and dehydrators. Leak-test, air-dry, evacuate, and dehydrate system in accordance with paragraphs [516-8.2.12](#) through [516-8.2.17](#). Restore to service with new refrigerant. Operate the system for 8 hours. Replace oil, oil filter, and dehydrators. Operate the system for an additional 4 hours and take oil samples. Replace oil if the moisture content is greater than 100 ppm using ASTM D1744, or if the acid number is greater than 0.20, using ASTM 974 or 644. If the refrigerant is not clear, remove and replace it instead of doing an R-113 flush. Repeat this removal (replacement) process until the refrigerant is clear. If motor burnout debris extends throughout the air-conditioning plant, remove the refrigerant and oil. Overhaul or replace the motor, and rebuild the compressor as necessary. Clean all accessible debris using solvent and

lint-free rags. Use protective gloves and eyewear because burnout by-products are acidic. Ensure adequate ventilation if solvent is flammable or toxic. Perform R-113 flush procedure.

516-8.2.29.5 Acid Cleaning. Acid cleaning should be used to clean the plant only if the accumulation of rust is so extensive as to cause compressor failures or major system malfunctions, such as restricting refrigerant flow between the condenser and the chiller. Acid cleaning as a routine action following a compressor rebuild is discouraged, since no clear relationship has been found between minor system rust and compressor failure in R-114 plants. Examples of plants requiring acid cleaning include a unit that had been flooded with seawater and not promptly flushed with water and dried, or a unit on which accesses cut into the chiller revealed large flakes of rust inside. A small number of rust particles in the lube oil will not accelerate bearing failure. A compressor that has failed because of system rust will contain accumulated rust and typically have clogged oil passages. After any acid cleaning procedure, mechanical cleaning shall be done via access holes cut in the chiller shell to remove any residual rust. Methods include brushing, scraping, and vacuuming. Acid cleaning should be conducted at the same time as compressor rebuild if there is clear evidence that the compressor failure was caused by rust. When severe corrosion with rust chunks is discovered during compressor rebuild or other maintenance, and the compressor failure was not caused by rust, then acid cleaning may be postponed until the next ship overhaul. R-113 flushing has been eliminated as a final step to acid cleaning. It has been found to be faster to air-dry the plant shell following the final water flush using the procedure in paragraph 516-8.2.16. Advice on air-conditioning plant cleaning and flushing can be obtained from Carderock Division, Naval Surface Warfare Center, Codes 9213 and 6243. The production of iron oxide in a plant can be arrested by making plants leak-tight and proper evacuation. Fine dirt and rust particles in refrigeration plants can be removed by routine maintenance. In summary, the main prerequisites for acid cleaning are:

- a. Compressor failure clearly caused by rust and contamination, or a major flow restriction in the refrigerant system
- b. Seawater leak into the refrigerant side of the air-conditioning plant where the seawater has sat in the refrigerant side for longer than 1 month
- c. Ample time, manpower, and facilities. Concluding the flush before contaminants are completely removed can cause the remaining acid- or water-soaked iron oxide sediment to begin a more serious problem after the plant is returned to service.

516-8.2.29.5.1 Acid Cleaning - Prerequisite Resources. The following are essential to the success of this procedure:

- a. Ample time for flushing and postflush dehydration
- b. Adequate pump capacity and multiple entry and exit points for the flushing solutions to promote optimum circulation
- c. The on-site services of a chemist and a mechanical engineer to monitor solution chemistry and make ongoing procedural decisions
- d. Complete and thorough neutralization and dehydration after acid cleaning has been completed
- e. Mechanical removal of residue

NOTE

Mechanical cleaning is a mandatory part of this procedure. Past experience has shown that dirt and debris remaining after acid cleaning too often caused compressor failure.

516-8.2.29.5.2 Acid Cleaning - Chemicals Required.

- a. Trisodium Phosphate, anhydrous (TSP), NSN 9G-6810-00-141-6080, 200 pounds (lb) per 1000 gallon (gal) volume.
- b. Wetting agent, nonionic, NSN 9Q-7930-00-282-9699, 2 quarts per 1000 gallons.
- c. Diammonium citrate (ammonium citrate, dibasic), 1 pound per gallon.
- d. Sodium nitrite, NSN 6810-00-270-3254, 10 pounds per 1000 gallons.
- e. Sodium carbonate, OS-571 (for neutralizing diammonium citrate spills).

516-8.2.29.5.3 Materials Required.

- a. Safety equipment, including coveralls, rubber aprons, acid impervious gloves, rubber boots, chemical workers' goggles, face shields, and safety shower and eye wash station. Also needed are these warning signs: **NO SMOKING; NO BURNING; and NO WELDING**.
- b. Source of distilled water for rinsing, oil removal, and diammonium citrate cleaning. Source of steam, fresh water, and electrical power.
- c. Acid mixing tank, carbon steel, steam-heated.
- d. Assorted acid-resistant hoses
- e. Steam hoses
- f. Acid and alkali-resistant pump
- g. Explosimeter, Mine Safety Appliances Model 3 or equivalent
- h. Nonsparking tools, including hammers, wrenches, and screwdrivers
- i. pH test equipment
- j. Thermometers
- k. Log sheets

516-8.2.29.5.4 Safety Precautions. The accomplishing activity shall coordinate the cleaning work through cognizant safety personnel to provide adequate protection of personnel from acid and other chemical hazards. The following precautions apply:

- a. Trisodium phosphate is highly alkaline and can burn skin and eyes. Flush affected skin thoroughly with water; flush eyes with potable water for at least 15 minutes, occasionally raising and lowering the eyelids, and obtain immediate medical attention. Use of coveralls, dust mask, face shield, chemical worker goggles, rubber gloves, and rubber apron is mandatory by involved personnel when handling this chemical, the wetting agent,

and their solutions. Diammonium citrate is an acidic material while sodium nitrite is a strong oxidizing agent. Use the same procedures as noted above when working with these chemicals and solutions.

- b. Sodium nitrite and acids like diammonium citrate are incompatible. If they or their solutions are mixed, toxic fumes (nitrogen oxides) will be released.
- c. Safety shower and eyewash stations shall be located close to the cleaning operation.
- d. Neutralize diammonium citrate spillage with sodium carbonate. Then wash down the area with water.
- e. Tie down and secure all steam and rubber hoses enough to prevent movement during operations.
- f. It is possible that hydrogen gas (explosive) may be liberated during the ammonium citrate acid cleaning phase in the area of the mixing tank. Post **NO SMOKING, NO BURNING, and NO WELDING** signs in the area of the mixing tank. Use nonsparking tools if it becomes necessary to work on the unit during the ammonium citrate phase. This is not applicable to the oil removal phase or the nitrite phase.
- g. The gas-free engineer shall use an explosimeter around the unit to determine the absence of explosive gas before proceeding with the inspection after acid cleaning.

516-8.2.29.5.5 Plant Preparation Details.

- a. Obtain detailed shell drawings for tube-to-shell clearances, thickness of shells, and other dimensional data.
- b. Remove the condenser and chiller heads in preparation for postflush cleaning and leak-testing of watersides.
- c. On centrifugal units with the compressor mounted on top of a box-like chiller/condenser shell, remove the compressor, scroll, and motor. On units with a deck-mounted compressor, remove compressor suction and discharge pipes.
- d. Remove and seal gauge lines. Remove all sight glasses, float valve covers, drain flanges, hot gas bypass valve, etc. Remove valve internals where possible to increase flow area.
- e. Prepare fittings for separate flushing of condenser and chiller.

CAUTION

No alterations to the plant are permitted without the permission of NAVSEA 03L22 or Naval Surface Warfare Center Ship System Engineering Station, Philadelphia, PA, Code 9213.

- f. As necessary, install connections at the lowest and highest shell points.
- g. For improved liquid circulation, install additional vent and drain connections. The services of an on-site chemist and mechanical engineer for locating additional shell penetrations is very important.
- h. On plants furnished with stainless steel or copper-nickel receivers, the receivers shall not be acid-flushed, but shall be included in the hot water flush.
- i. If the receivers for R-11 units are made of red brass, they shall be acid-cleaned. Accesses for mechanical cleaning are not recommended due to the thin (1/2-inch) wall thickness and the difficulty involved with welding red brass.
- j. Hydrostatic leak-test to 1.35 times the pump shutoff head. Local procedures give details. Maximum hydrostatic test pressure shall be 50 psig for R-114, 100 psig for R-114 and R-236fa, 30 psig for R-11, and later psig for R-134a.

- k. Remove mist eliminators from chillers if so equipped. It may be necessary to cut and reweld accesses for removal.
- l. Determine whether chiller has refrigerant distribution channels. Ensure that distribution channels are clear when flushing is complete.
- m. Study the plant drawings carefully to select flow penetrations for highest internal velocities. Note that some plants have internal division plates that create voids in which refrigerant velocity is near zero.
- n. Some cylindrical chillers have a trough-like channel underneath for refrigerant distribution. These channels contain baffles that shall be removed.
- o. Obtain necessary safety equipment.

NOTE

The procedures provided in this section assume that the refrigerant charge was contaminated and has been removed. Refrigerant that is not suitable for reuse shall be recovered and recycled, reclaimed, or properly disposed of to prevent damage to the Earth's ozone layer. Paragraph 516-8.2.58 provides procedures for removing the refrigerant charge for storage in recovery cylinders.

516-8.2.29.5.6 Trisodium Phosphate (TSP) Flush. This oil removal process is to be accomplished before acid cleaning. Acid cleaning will be ineffective if oil is not removed before cleaning.

516-8.2.29.5.7 TSP Flushing Procedure. Refer to paragraph 516-1.10 for safety precautions.

NOTE

The condenser and chiller shall be flushed separately.

WARNING

Trisodium phosphate is a highly alkaline chemical that can cause burns to the skin and eyes. Affected personnel shall flush the skin with large amounts of water; flush eyes with potable water for at least 15 minutes, raising and lowering the eyelids to rinse away all of the chemical, and obtain immediate medical attention. Use of coveralls, dust mask, face shield, chemical worker goggles, rubber gloves and rubber apron is mandatory when handling this chemical and the wetting agent.

- 1. Vent system high points and voids so that floating oil will be carried to the mixing tank. Maintain a log of all events.
- 2. Using in-bottom, out-top, flush rig hookup; fill shell, hoses, and tank with fresh water. Circulate water through the heat exchanger while bringing it up to 180° F to avoid thermal shock of the tube bundle. (that is, do not heat the water to 180° F and then pump it into the shell.) Circulate the water until return water reaches 180° F. Vary the flow pattern inside the shell by adjusting flows through the various fill/vent valves.

3. After the specified temperature has been reached, add sufficient quantities of TSP to achieve a 2 to 3 percent by weight solution. Add the wetting agent at the same time (0.05 percent by volume). Use a plastic or wooden broom handle for mixing.
4. Circulate this solution, maintaining a constant $180^{\circ}\text{ F} \pm 5^{\circ}\text{ F}$ temperature at the tank return, for a minimum of three hours. After 3 hours, reverse flow to in top - out bottom and continue to circulate for 1 hour at $180^{\circ}\text{ F} \pm 5^{\circ}\text{ F}$.
5. Periodically check for free oil floating on the top of the solution in the tank. Manually skim off and dispose of as much as possible. As flush time proceeds, the quantity of this oil will decrease.
6. After 1 hour, drain the TSP solution. Disposal shall be in accordance with **NSTM Chapter 593, Pollution Control**. Disposal shall comply with local, state, and federal regulations. Flush with plain water until all traces of TSP have been removed. A pH of 7.0 should be evident in the return water. Return water shall be within 0.5 pH of supply water.
7. Drain completely and remove one or more convenient accesses. Inspect shell for evidence of oil. If oil is present, repeat process until none is found.

516-8.2.29.5.8 Acid Cleaning Procedure. From this point to the end of the sodium nitrite preservation cycle, work should continue without a break. Manpower and inspection teams shall be scheduled for 24-hour operation. A log of all events including temperatures and pH results shall be maintained.

1. Prepare a 10-percent diammonium citrate acid flushing solution for removing rust. Use distilled water. For ordering purposes, approximately 1 pound diammonium citrate will be required per gallon of water. Fill the system with the flushing solution and ensure that no air is trapped in the plant shell.

WARNING

Diammonium citrate is a moderate irritant to eyes, skin, and mucous membranes. In case of contact, affected personnel shall flush skin with large amounts of water; flush eyes with potable water for at least 15 minutes, raising and lowering the eyelids, and obtain immediate medical attention.

2. Circulate the acid solution as you bring it up to temperature to avoid thermal shock of the tube bundle. Heat the acid to $180^{\circ}\text{ F} \pm 5^{\circ}\text{ F}$ and maintain this temperature throughout the flushing process.
3. Periodically vary the flow pattern inside the shell by adjusting the various inlet and outlet valves. Note that the temperature of 180° F is measured as the solution leaves the shell.
4. After 1 hour, the chemist should test the solution for acid activity. An active pH reading is 3.0 to 4.0. Acceptable ranges are to be determined or confirmed by the on-site chemist. This test shall be performed after each hour of flushing and, if at any time the solution is depleted to 0.5-percent free acid by volume (pH of 5.5), drain and replace it with fresh solution.

NOTE

Disposal of spent acid shall be in accordance with local, state, and federal regulations.

5. The flush is to continue for not less than 10 hours and, in the case of R-11 plants with float valves, 10 hours

on each shell (do not flush both shells at the same time). After not less than 10 full hours of circulation at 180°F with an active acid solution, drain completely and dispose of properly. Refill with fresh water.

6. Circulate the water as you bring it up to 180°F to avoid thermal shock of the tube bundle. After the return water temperature is 180°F, continue circulating for one hour. Drain the system of fresh water and open all flushing connections for inspection.

CAUTION

The gas-free engineer shall use an explosimeter around the unit to determine the absence of explosive gas before proceeding with the inspection.

7. Determine whether a satisfactory degree of rust has been removed. Hand-wash with a high-velocity fresh water nozzle to remove any surface rust. Metal should be bare and a clean, metallic surface should be evident. Repeat the acid flush, as required, to achieve the desired results.

516-8.2.29.5.9 Sodium Nitrate Preservation.

CAUTION

Sodium nitrite is an oxidizing agent that may support combustion. If it comes into contact with paper, rags, or other organic material there may be a fire. It will release toxic fumes if allowed to contact acids.

1. Fill the system with fresh water and heat to 180° F. Mix 180° F tap water with sodium nitrite in solution in a ratio of 0.1-percent dry sodium nitrate by weight (10 pounds of powder with 40 gallons of water per 1000 gallons of required solution). Maintain a heated solution temperature of 180° F $\pm$ 5° F and circulate for 1 hour. Routinely vary the flow pattern and ensure that there are no air-filled voids.
2. After 1 hour of circulation, secure the pump(s) and drain the system.

NOTE

Dispose of sodium nitrite solution in accordance with local, state, and federal regulations.

3. Leak-test, air-dry, evacuate, and dehydrate the system in accordance with paragraphs [516-8.2.12](#) through [516-8.2.17](#).

516-8.2.29.6 Excess Lube Oil in Refrigerant - Centrifugal. Excessive oil in the refrigerant is indicated by amber colored refrigerant and, in extreme cases, reduced plant capacity. The compressor will also have a history of high oil consumption. The refrigerant charge can be removed, distilled, and replaced to eliminate excess lube oil in centrifugal refrigeration systems, where the oil cannot be removed through oil reclaiming processes. The recommended method is to use the purge and pump-out unit to transfer the oil-rich refrigerant liquid to the receiver, and then pump oil-free refrigerant vapor back to the air-conditioning plant. Then drain and dispose of the lube oil left behind in the receiver. Refer to equipment technical manual. If technical manual purge and

pump-out procedures do not describe how to remove excess oil from refrigerant, contact Naval Surface Warfare Center Ship System Engineering Station, Philadelphia, PA, Code 9213.

516-8.2.29.7 Flooding. Refer to paragraph [516-1.10](#) for safety and preliminary information.

516-8.2.29.7.1 Fresh Water Flooding. If the air-conditioning plant refrigerant system becomes contaminated with fresh water from a ruptured chiller tube or oil cooler failure, proceed immediately as follows:

1. Remove refrigerant and drain water from system.
2. Inspect the lube oil system for signs of water contamination. If it is contaminated, the compressor has probably been damaged. Repair compressor while the shell is being repaired and dried.
3. Air-dry the plant in accordance with paragraph [516-8.2.16](#).
4. Replace or plug leaking tube in accordance with paragraph [516-8.2.24](#).
5. Conduct refrigerant side leak-test in accordance with paragraphs [516-8.2.12](#) through [516-8.2.14](#).
6. Install new lube oil filters, filter-dehydrators, and moisture indicators.
7. Conduct evacuation (dehydration) with a vacuum pump in accordance with paragraph [516-8.2.17](#).

516-8.2.29.7.2 Seawater Flooding. If the air-conditioning plant become flooded with seawater, as from a ruptured condenser tube, proceed immediately as follows:

1. Remove the refrigerant and drain the water from the system. Remove the compressor, drain all fluids, and seal it up from the atmosphere using blank flanges. Apply positive pressure (1 to 2 psig) with dry nitrogen, and make arrangements to have it inspected as a candidate for rebuilding.
2. Flush refrigerant system with fresh water. One fill-drain cycle will be sufficient to dilute and remove the salt.
3. Air-dry the plant in accordance with paragraph [516-8.2.16](#).
4. Replace or plug leaking tube in accordance with paragraph [516-8.2.24](#).
5. Conduct a refrigerant side leak-test in accordance with paragraphs [516-8.2.12](#) through [516-8.2.14](#).
6. Install new lube oil filters, filter-dehydrators, and moisture indicators.
7. Conduct evacuation (dehydration) with a vacuum pump in accordance with paragraph [516-8.2.17](#).
8. Refill the compressor with new oil. Recharge the system in accordance with paragraph [516-8.2.29.8.4](#).

516-8.2.29.8 Preparation for Operation. The following paragraphs pertain to the completion of all the above flushing procedures.

516-8.2.29.8.1 Reassembly. Reassemble compressor and all interconnecting piping. Replace all sight glasses, valves, inspection covers, etc., with new gaskets, O-rings, or pipe thread compound, where required.

516-8.2.29.8.2 Leak-Test. Use accepted refrigeration practice for locating and correcting leaks. Conduct a leak-test as described in paragraphs [516-8.2.12](#) through [516-8.2.14](#).

516-8.2.29.8.3 Dehydration - Moisture Removal. The success of the entire cleaning operation and the future reliability of the plant depend on satisfactory dehydration. See paragraphs [516-8.2.16](#) and [516-8.2.17](#) for air and vacuum pump dehydration of shells. Some minor rust may remain on the steel internals after dehydration is complete, even if nitrite preservation is used. This rust will be minor and superficial and should not cause concern.

516-8.2.29.8.4 Recharging and Performance Testing. Refer to the equipment technical manual for recharging and performance testing.

516-8.2.29.9 Reciprocating Compressor System Contamination. All refrigerant systems contain various amounts of particulate contamination such as iron oxide and construction debris. These particulates do not affect heat transfer or reduce plant capacity. As in other piping systems, dirt particles are controlled by strategically placed strainers. There are occasional reports of big chunks of rust in the condenser and receiver. Although this condition is seldom confirmed, corrosion of these ferrous shells would be expected over a long period of time. These corrosion products are no threat to the system, since they usually stay in place. Small particles that break free are caught by system strainers and dehydrators. Water is by far the most common and troublesome refrigerant system contaminant. Water enters the system with lube oil, refrigerant, inward air leaks, and condenser and chiller leaks. It should never be assumed that a malfunctioning system is dry. Moisture removal should always be the first maintenance action. Water reacts with the steel condenser and chiller shells to form two types of iron oxide, red and black. The most common type is black and is called magnetite. This oxide is magnetic and granular, and is frequently mistaken for spent sand blasting compound. Finely divided magnetite has a sooty appearance. The foreign appearance of magnetite is frequently used to erroneously justify requests for system flushing. Red iron oxide is uncommon, and results when a wet system is left open. Red rust in the compressor sump or the dehydrator cartridge indicates this condition. Plants that had condenser tube leaks and were left for long periods with seawater inside would be expected to contain large quantities of red oxides. This does not happen, however, since the corrosion process stops when the dissolved oxygen in the seawater is used up. Particles of all solid contaminants will eventually migrate to the compressor crankcase. By examining the sediment at the bottom of the crankcase with a magnifying glass, magnet, etc., most system contaminants can be identified. The particles found in strainers can be similarly identified. Neither red nor black iron oxide particles are a threat to compressor bearings.

516-8.2.29.9.1 Lube Oil Condition. In Navy systems, the lube oil typically becomes brown with time and black from high temperature carbonization. Less frequently, the presence of red and black iron oxides can cause brown and black oil colors. Cloudy lube oil indicates that the oil is saturated with dissolved water; tiny droplets of free water cause the cloudiness. Larger quantities of water contamination result in emulsification. The emulsion resembles mayonnaise and ranges in color from tan to black. Discolored, emulsified, or cloudy lube oil should be replaced immediately. Lube oil moisture content indicates how much moisture is in the refrigerant system. Lube oil moisture of less than 100 ppm for mineral oil and less than 200 ppm for POE oil will confirm that the refrigerant in the system is dry. This is a useful alternate indicator since refrigerant moisture indicators no longer function after they have been exposed to excessive water. More information on lube oil condition can be found in paragraphs [516-4.1.14](#) and [516-8.2.29.2.1](#).

516-8.2.29.9.2 Contaminant-Caused Operating Problems. The most common contamination caused problem in refrigeration systems is when moisture (ice) restricts flow through the thermal expansion valve (TXV). This results in refrigerant shortage symptoms, compressor short cycling, high box temperatures, and generally unsatisfactory plant performance. Less commonly, dirt particles will clog a TXV and produce the same symptoms. System contamination is incorrectly attributed to many operating symptoms and events. Inadequate heat transfer is commonly reported. This is also reported as insufficient chilled water temperature difference, or **oil in circulation**. The types of contamination found in refrigerant systems do not affect heat transfer. The condition

reported as "oil in circulation" is actually the result of incorrectly set TXVs, refrigerant shortage, or both. Ship personnel frequently discover small amounts of system contamination while troubleshooting operating problems, and then incorrectly conclude that the main problem is system contamination. These situations are covered by paragraph [516-8.2.29.10.2](#).

516-8.2.29.10 Reciprocating Compressor System Cleaning - General. Cleanup of reciprocating refrigeration systems is best accomplished by operating the plant with lint-free felt filters installed in the compressor suction strainer while frequently changing dehydrator cartridges. An alternate method for systems with less than 2 tons of capacity is to use the York tank type system cleaner. This would include most fleet ship stores systems. Tenders and other maintenance activities are usually equipped with system cleaners. If a system cleaner is not readily available, conduct system cleaning using the felt filter method, which is just as effective. Flushing systems with R-113 is no longer approved or recommended, except for certain unique new construction applications. The toxicity of R-113 was the initial reason for discontinuing the use of R-113. Subsequent reexamination of the entire flushing process revealed that the felt filter cleanup method was easier and more effective. Navy systems are already well protected by filter/dehydrators and strainers to catch particulate contamination. From studies of past flush jobs conducted in Navy refrigeration plants, it was concluded that the repair actions accomplished with the flush were the actual reason for the success of the system flush. Leak repairs, restoration of proper refrigerant charge, and relieving the system of moisture all result in marked improvement in the system, without a flush job. Water flushing for brazing flux removal following system repairs is no longer recommended since it has been phased out of commercial refrigeration practice.

516-8.2.29.10.1 Reciprocating Compressor System Cleaning - Conventional. Refer to paragraph [516-1.10](#) for safety and preliminary information. Use this procedure for new construction, after repairs, or for in-service plants with suspected system contamination. This procedure will correct most cases of reported reefer system contamination, since moisture is the actual cause of most complaints.

1. For ship stores systems, defrost the cooling coils.
2. Temporarily install lint-free felt filter sock (this filter sock is made of felt material similar to SAE F-1) or an ASTM 2475 16R1 filter in the suction strainer and operate the plant under supervision until periodic inspection of the felt filter indicates that contaminants have been removed from the system.
3. Install new dehydrator cartridges. Ensure that the correct safety cap assembly is properly installed so refrigerant flows through the cartridges.
4. Operate plant at full load if possible. If several cooling coil circuits are connected to one compressor, clean each circuit separately. The time required to clean each cooling coil circuit will depend on the size or length of line. In the case of an empty reefer box, elevate the plant load by ventilating the box(es). Use Red Devil fans to ventilate if boxes are empty.
5. If TXVs are not feeding, use a hair dryer (heatgun) to heat each TXV body until warm. Do not heat the power assembly. Some TXVs will make a noise, or the liquid line will warm up, to indicate that the ice has melted and flow has been restored. This heating routine shall continue for 24 hours, on a typical wet system, with the TXVs being heated every half hour.
6. Inspect and clean or replace the felt filters every 4 hours for 24 hours.
7. Remove felt filters.
8. Replace dehydrator cartridges every hours.
9. Leak-test the system per paragraphs [516-8.2.12](#) through [516-8.2.15](#) and then repair any leaks found.

516-8.2.29.10.2 Reciprocating Compressor System Cleaning - Problem Plant. For plants with persistent operating problems, to which system contamination is believed to be a major contributor, complete the work items listed below and then perform the procedure in paragraph 516-8.2.29.10.1. Almost all the refrigerant system contamination problems reported by the Fleet are eventually corrected using this procedure.

1. Conduct compressor suction and discharge valve tests.
2. Change compressor oil.
3. Check adjustments of TXVs, EPRs, and all switches and controls.
4. Replace packing in all packed valves, particularly the compressor inlet and outlet stop valves. Ensure valve caps are reinstalled whenever the valves are not being operated.
5. Inspect and clean compressor suction strainers.
6. Inspect and clean liquid line strainers.
7. Perform procedure in paragraph 516-8.2.29.10.1.
8. Leak-test the system per paragraphs 516-8.2.12 through 516-8.2.15 and then repair any leaks found.

516-8.2.29.10.3 Refrigerant Tank System Cleaner Procedure. On small systems, the introduction of a dirt interceptor, or tank system cleaner into the system permits the accumulation and the removal of harmful grit and dirt washed into it by the refrigerant. The tank type cleaner shown in Figure 516-8-18 is available to tenders, repair ships, and installing activities. Some repair facilities and contractors have an "off ship" condensing unit for system cleaning. These are large refrigerant recovery/recycle units (RRU).

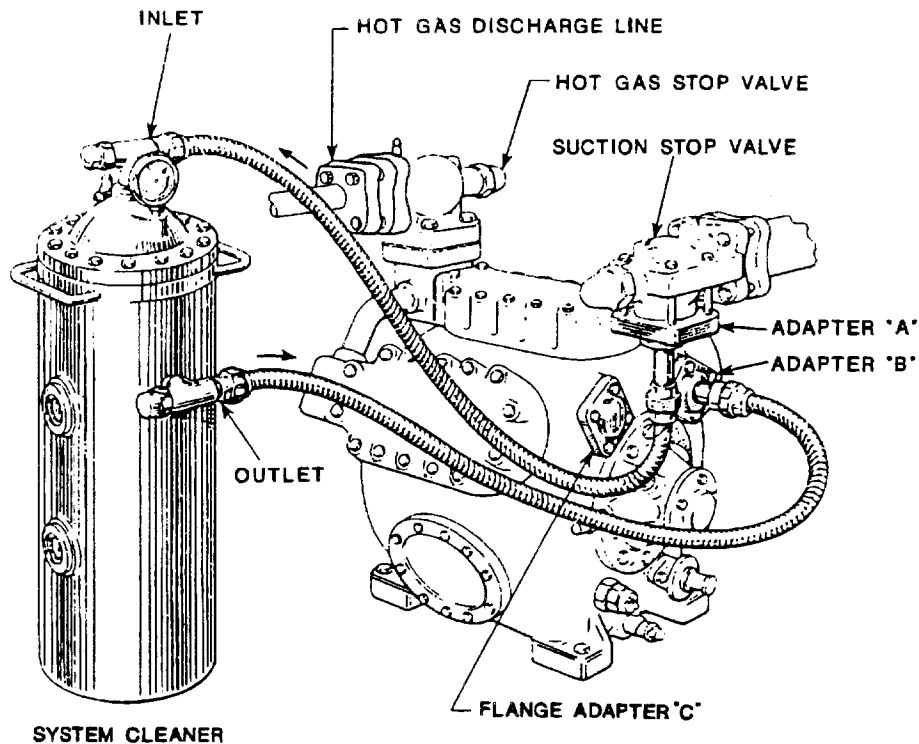


Figure 516-8-18. Typical Installation of System Cleaner

- a. The tank system cleaner is a special surge drum containing a screen and replaceable lint-free filter medium.

The cleaner shall be connected into the suction line of the system using special adapters made to fit the connectors at compressor and suction piping. These lines shall be as large in diameter as practicable, taking into consideration the size of the openings in each adapter. The system cleaner shall be located as close to the compressor as possible.

- b. [Figure 516-8-18](#) shows connection of the system cleaner to a typical compressor. The manifold, which is a part of the compressor (in this example), may be removed; adapter A is attached to the suction valve flange and connected through flexible pipe to the cleaner inlet. Adapter B connects the suction inlet to the compressor. The refrigerant passes from the suction line through the cleaner before entering the compressor. Flange C is used in this example to blank off the additional suction opening occasioned by removal of the suction manifold piping. After connection to the system, the compressor may be operated. Each individual cooling coil circuit shall be flushed out with liquid refrigerant by warming the thermal bulb of the expansion valve for that circuit, and cracking open the hand bypass valve around the expansion valve, where furnished. The internals of the TXVs, solenoid valves, and some shutoff valves may be removed to increase flow. Where a solenoid valve is in the liquid control circuit, make sure that it is in the open position during operation. If several cooling coil circuits are connected to one compressor, clean each circuit separately. The length of time required to clean each cooling coil circuit will depend on the size or length of line; the flushing procedure, however, should not be less than 1/2 hour for each cooling coil circuit. Start at the cooling coil that is the greatest distance from the compressor. Proceed toward the compressor, cleaning one coil at a time; then isolate the cleaned coil. This will prevent foreign matter from being deposited in a cooling coil that has been cleaned. Take care that the level of liquid refrigerant in the system cleaner is low enough not to be drawn into the compressor. The level shall be constantly observed through the sight glass indicators in the cleaner tank. It will be necessary to provide heat at the bottom of the cleaner by means of an electric hot plate, radiant heater, strip heater, or by standing the cleaner in a container of warm water, or steam jacket. Do not use direct flame for heating. Be extremely careful in heating to prevent violent evaporation, which could cause liquid to spill into the compressor. To ensure that only vapor returns to the compressor, maintain proper liquid level by controlling the liquid through the cooling coil, throttling the stop valve provided in the inlet of the cleaner, or controlling the heat applied to the cleaner.
- c. The oil level in the compressor crankcase shall be carefully watched and maintained at approximately its correct operating level by the addition of pure, clean, compressor oil, when necessary.
- d. After cleaning the last cooling circuit in each system, the suction stop valve should be closed and the refrigerant remaining in the cleaner sump should be pumped down to approximately 1 psig, leaving a positive pressure in the cleaner. The inlet and outlet valves of the system cleaner and compressor are then closed and the adapter removed and compressor suction connection replaced. The system cleaner should be cleaned after use.
- e. Restore the system by replacing valve internals, then leak-test, air-dry, evacuate, and dehydrate the system in accordance with paragraphs [516-8.2.12](#) through [516-8.2.17](#).

516-8.2.30 CHILLER MAINTENANCE. Maintenance and repair procedures for water chillers are, in general, similar to those for condensers. Since the chilled water system is a closed loop, it is inherently clean. Therefore, there is no need for chiller watersides cleaning. However, if it ever becomes necessary to clean the chilled water side, follow the cleaning procedure noted in **NSTM Chapter 533, Potable Water Systems**. Retubing a chiller is similar to a condenser; follow the procedure in the technical manual. Water chillers for reciprocating plants have water in the shell and refrigerant in the tubes, whereas in centrifugal plants, the water is in the tubes and the refrigerant is in the shell. Tubes in the reciprocating plant generally have inner fins or turbulators. Centrifugal plants have tubes with outside fins similar to condenser tubes. Centrifugal plant chiller tubes can therefore be brush-cleaned where reciprocating chiller tubes need to be flushed.

516-8.2.31 CHILLER FREEZING. Freezing chilled water in a reciprocating plant chiller in the event of derangement or maloperation normally does not cause problems, as the ice accumulates on the outside of the tubes and generally no damage occurs, unless the plant is completely neglected. Freezing in the chiller tubes of a centrifugal plant, however, is a serious matter. When centrifugal chiller tubes freeze, the tubes bulge, and sometimes split, due to expansion of the freezing water. Bulged and leaking tubes cannot be removed by conventional methods since they have become distorted to the point where they will not pass through the tube sheet and tube support hole. In most cases, this does not become apparent until after the tube is loosened in the tube sheet and pulling has started. If a centrifugal chiller freezeup occurs, it is advisable to perform a pressure test of the refrigerant side to find and plug any leaking chiller tubes. After chiller reassembly is complete, perform a hydrostatic test on the water side to ensure that additional tubes do not burst when the plant is returned to service. Hydro to 1.5 times the ship's chilled water working pressure and hold the pressure for approximately 1 hour. If no loss in pressure occurs, the plant may be placed back into service if no water had previously entered the refrigerant circuit. Tubes can also be pressure tested using a pneumatic gun type tube tester. In a freezeup, the tubes typically bulge, and then split longitudinally. Thus a leak will tend to be a long tensile fracture, and not a pinhole leak as caused by corrosion. Eddy current testing may be used to locate any tubes that are bulged but not split. This testing requires an experienced technician in the eddy current testing process.

516-8.2.31.1 Bulged tubes are not likely to split or develop leaks after the plant is restored to service. A typical integral finned copper tube with 0.049 inch wall thickness has a bursting pressure of 5300 psi and a safe working pressure of 1300 psi. The typical 100 psi shipboard chilled water working pressure is far below the bursting pressure to expect additional splitting, even with the reduced bursting pressure expected at the bulge area. The repair and replacement of bulged tubes requires cutting a section of the chiller shell near the damaged tubes at the tube support. The bulged tube portions can then be cut away and removed through the shell opening. Depending on the location of damaged tubes, however, good tubes may first have to be removed to enable removal of the damaged tubes. This type of repair should be done under the supervision of a knowledgeable repair activity or manufacturer representative.

516-8.2.32 CHILLER LEAK-TESTING. Leak-testing a chiller in a centrifugal plant is the same as for a condenser. For reciprocating plants, leak-testing is somewhat different since the refrigerant is in the tubes. The procedure for leak-testing a reciprocating chiller is in paragraph [516-4.1.23](#). When replacing tubes in chillers, ensure that tubes have fins or turbulators, otherwise a serious capacity loss will result. To plug leaking tubes, refer to paragraph [516-8.2.24.4](#). If a plant is flooded with chilled water because of a leak, replace the refrigerant and oil, blow out the excess water, and triple-evacuate the plant as indicated in paragraph [516-4.1.16](#).

516-8.2.33 PACKLESS VALVE DIAPHRAGM REPLACEMENT. The majority of packless valves installed in Navy systems are Henry valves. If it is necessary to dismantle these valves for any reason, such as cleaning or replacing parts, use a new set of diaphragms when reassembling the valve. Note that replacement cap assemblies are supplied with the diaphragm set installed in the bonnet and need not be taken apart for assembly to the valve body. [Figure 516-8-19](#) shows the valve bonnet and diaphragm set. Use the following procedures for assembling replacement diaphragms in packless valves containing threaded bonnets:

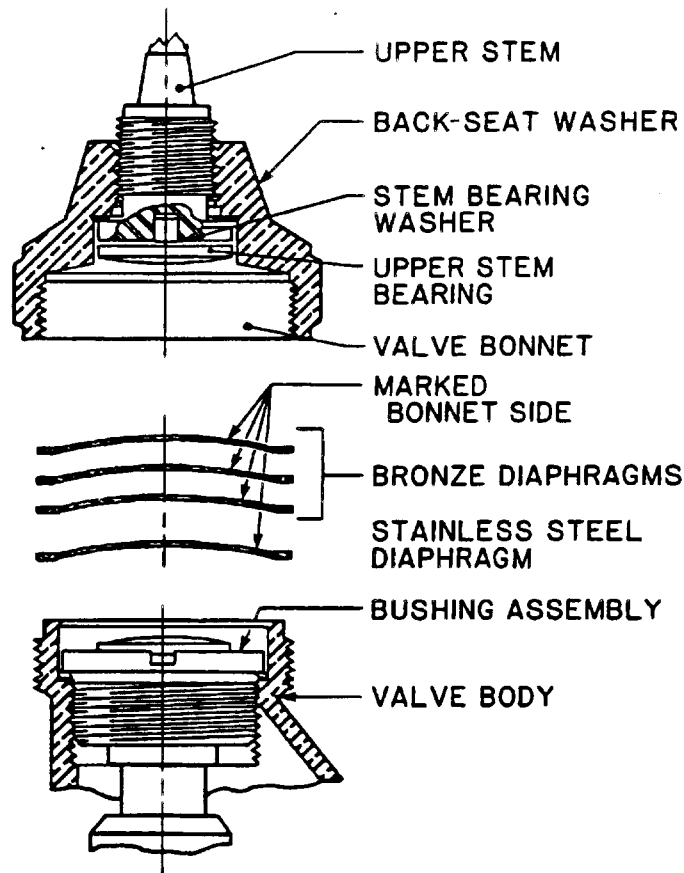


Figure 516-8-19. Packless Valve Bonnet

1. Diaphragms are furnished in a cupped form and may be flexed by hand from concave to convex or vice versa. As received, they will be flexed in the correct position for insertion into the valve bonnet. In this position, the convex (raised) side of the diaphragms will bear the marking BONNET SIDE.
2. Before placing the diaphragms in the bonnet, back-thread the upper stem into the bonnet as far as it will go and in contact with the back seat washer. Place the stem bearing washer over the center post of the upper stem bearing and apply a small amount of refrigerant oil or Vaseline to the bearing washer before positioning the stem bearing in the upper stem. This will provide lubrication and assist in holding parts in place until the diaphragms are assembled.
3. With the bonnet parts in place and diaphragms flexed in the correct position (refer to step 1 above), insert the first diaphragm into the bonnet with the side marked BONNET SIDE facing towards the bonnet ([Figure 516-8-19](#)). Press the entire outside edge of the diaphragm firmly into contact with the bonnet at the base of the bonnet threads. Insert remaining diaphragms into the bonnet in the same manner, with the stainless steel diaphragm inserted last, so that it will be positioned next to the valve body.
4. Before assembling the bonnet to the valve body, invert the assembly to be certain that diaphragms will remain secure while the bonnet is being threaded onto the body.
5. A slight force is normally required to press diaphragms into position in the bonnet. If diaphragms are loose and inclined to drop out, a small amount of Vaseline or refrigerant oil in the bonnet and between the diaphragm will generally be sufficient to hold them in place while the bonnet is threaded to the valve body.
6. Thread the bonnet assembly by hand onto the valve body until diaphragms engage the sealing tongue on the body. Wrench-tighten the bonnet while the body is firmly held with a suitable wrench applied to the flats on

the valve body forging. A small amount of refrigerant oil on the body or bonnet threads and the body sealing tongue will reduce friction and allow the maximum force to be applied for sealing purposes. [Table 516-8-2](#) shows the recommended tightening torques.

Table 516-8-2. RECOMMENDED BONNET TIGHTENING TORQUES

Valve Size (in.)	Diaphragm Set No.	Tightening Torque (ft-lb)
1/4 to 3/8	D201-8	70
1/2 to 5/8	D211-8	90
3/4 to 7/8	D241-8	225
1-1/8	D251-8	270

516-8.2.34 PACKLESS VALVE BUSHING REMOVAL TOOL. If it is necessary to replace the valve bushing, bushing removal tools are available. The bushing is replaceable as an assembly. The bushing removal tool is designed to screw over the existing valve body. This is done by first removing the valve cap, handwheel, and diaphragm assemblies. The prongs of the bushing tool engage the slots of the valve bushing assembly. To remove the valve bushing, apply a wrench to the top of the bushing removal tool, turning the wrench in the counterclockwise direction. The bushing removal tool is made from case-hardened steel and will establish centerline alignment between the valve bushing assembly and the removal tool axis. Also, the required perpendicular contact is maintained during the torquing operation regardless of the type of side loading imparted to the bushing removal tool ([Figure 516-8-20](#) and [Figure 516-8-21](#)). Do not attempt to remove the valve bushing assembly with a chisel or screwdriver; this will only result in damage to the valve and possibly nick the sealing tongue where the diaphragm seats. The proper tools may be made or are available from Henry Valve Company.

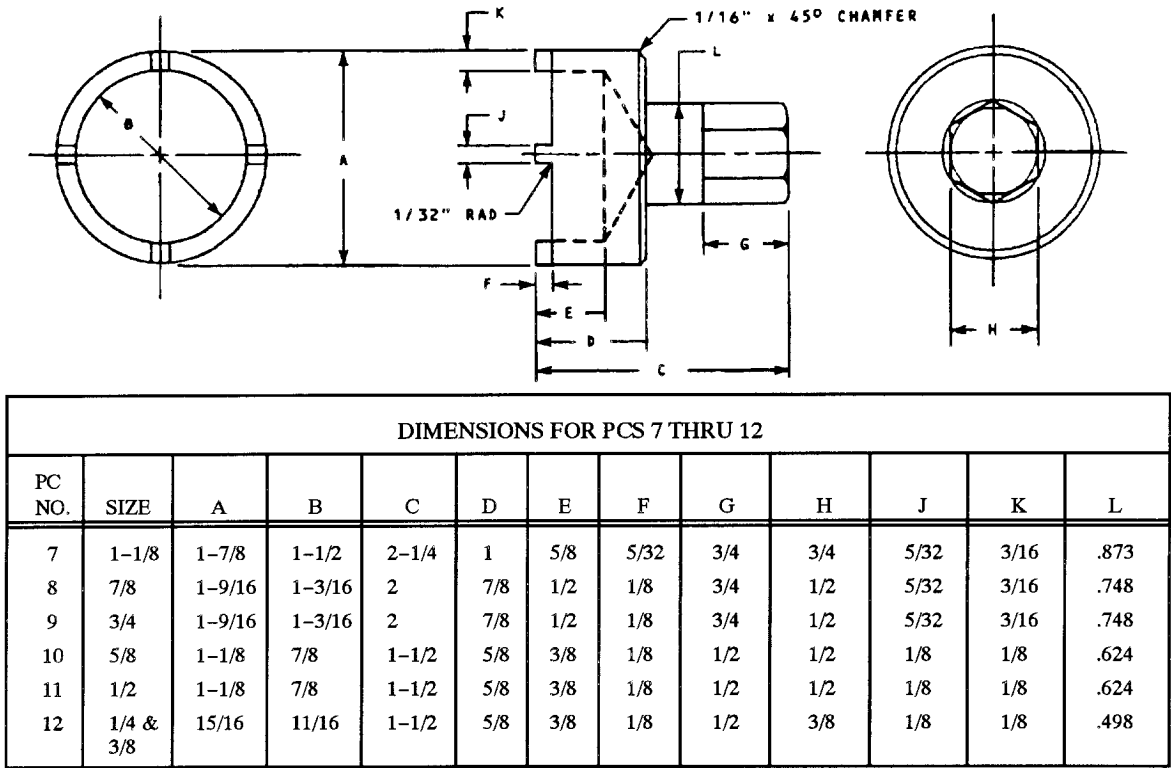


Figure 516-8-20. Bushing Removal Tool

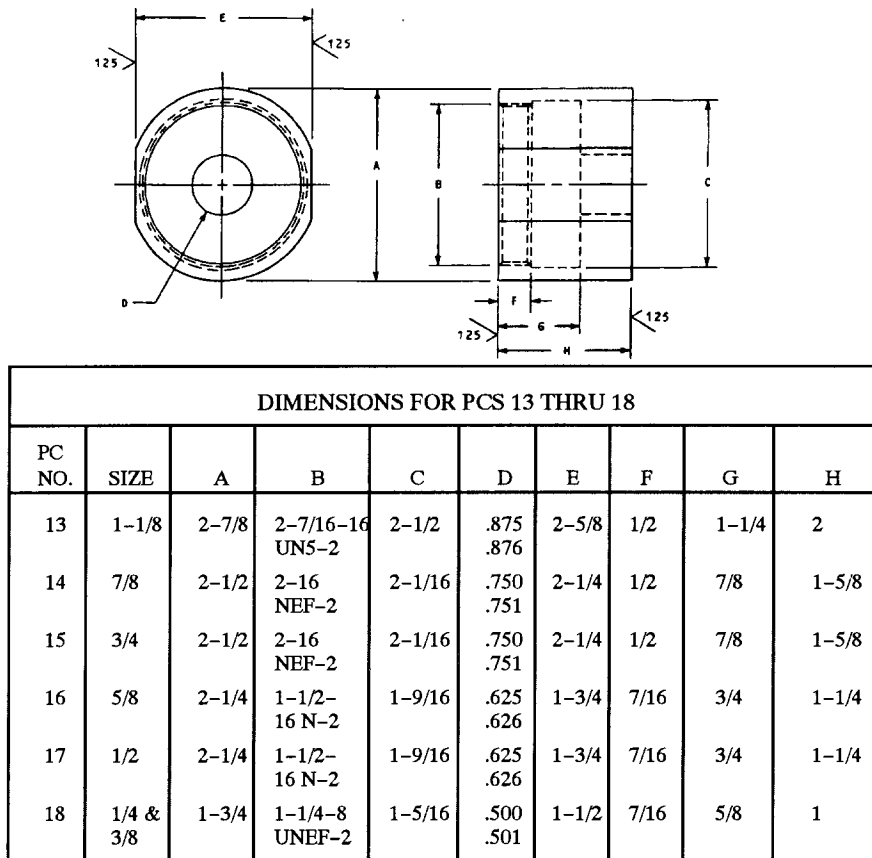


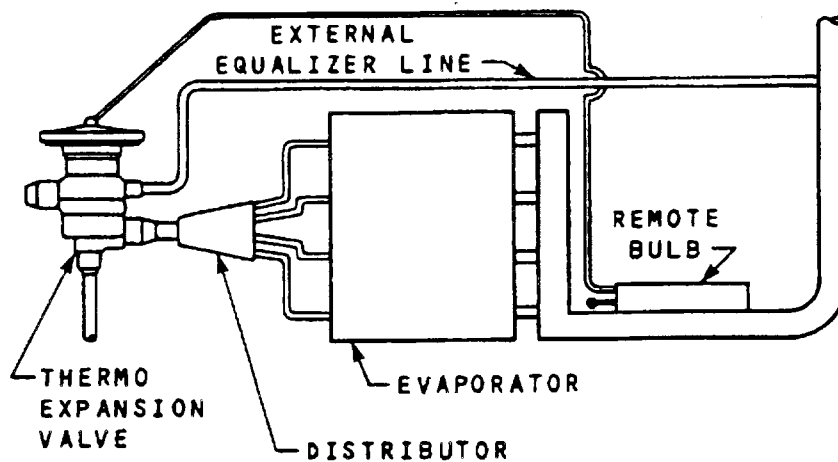
Figure 516-8-21. Bushing Removal Tool Retainer

516-8.2.35 PACKED VALVES. In replacing or installing packed globe and angle valves, the best practice is to disassemble the valve with the bonnet and internal parts removed from the body during brazing operations. Even though internal parts of the valve have been removed, be cautious in applying heat to the valve body. Excessive heat may warp or distort the body, deforming the seat so that the valve disk will not seat properly. Repair parts are available for both globe and angle valves. Where part replacement is required, see [Figure 516-3-129](#).

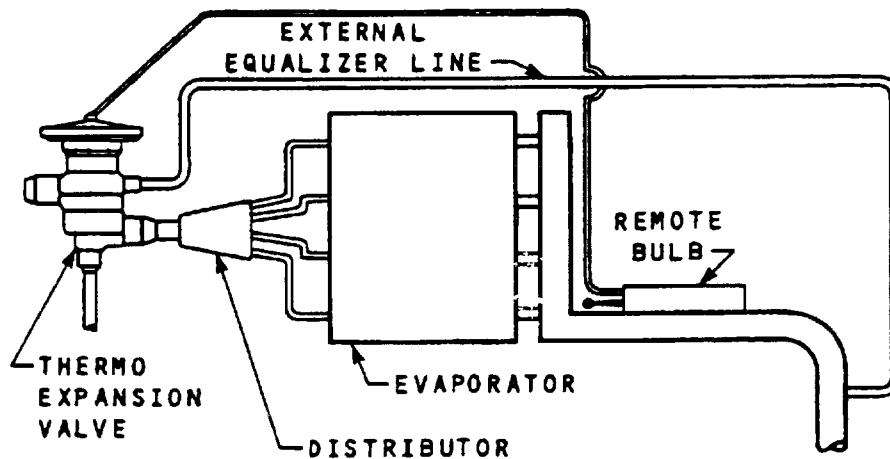
516-8.2.36 THERMOSTATIC EXPANSION VALVE. Disassemble thermostatic expansion valves for installation so that heat is applied only to inlet and outlet connections. To prevent distortion, take care not to overheat the body flange. If distorted, the flange face will not mate properly with the valve body, causing a leakage problem. On some valves the external equalizer line connection is a brazed fitting. Although this is a small fitting, be extremely cautious to prevent overheating and damage to the diaphragm. Wrapping the diaphragm end of the power assembly with a wet rag during brazing of the external equalizing line is recommended. After installation, take care in the installation of the thermal expansion valves to ensure proper operation.

516-8.2.36.1 Locate the valve so that it will be readily accessible for inspection and servicing. An upright position with power assembly on top is recommended. Locate a gas-charged valve so that the valve body temperature is higher than the thermal element temperature. With liquid charged valves, or all purpose charge valves, this precaution is not necessary. The location of the remote bulb thermal element is extremely important because it controls the flow of liquid refrigerant through the evaporator. Locate the thermal element as close as possible to the outlet of the evaporator on a horizontal portion of suction pipe. The thermal element shall not be placed on a vertical run because the thermal element will not be able to rapidly and consistently detect liquid refrigerant in the suction pipe. Also, the thermal element should not be located where there is a trap in the suction pipe. Liq-

liquid refrigerant or a mixture of liquid refrigerant and oil boiling out of the trap will falsely influence the temperature of the thermal element and result in poor valve control. For installations with an external equalizer, locate the thermal element just upstream of the external equalizer connection (Figure 516-8-22).



INCORRECT
REMOTE BULB LOCATION SHOWN TRAPPED.



CORRECT
REMOTE BULB LOCATION SHOWN FREE DRAINING.

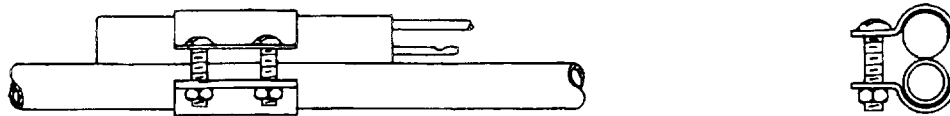
Figure 516-8-22. Correct and Incorrect Remote Bulb Location

516-8.2.36.2 Locate the thermostatic expansion valve thermal bulb on the 12 o'clock position of small (up to and including 5/8-inch OD) suction lines. On large suction lines, 7/8-inch OD and larger, locate the thermal bulb in a 4 or 8 o'clock position as shown in Figure 516-8-23. Occasionally, when valve hunting occurs, moving up the thermal bulb from its normal 4 or 8 o'clock position on the 7/8-inch OD suction line, closer to the 12 o'clock position will improve valve operation. In these occasional instances the best location of the thermal bulb can only be determined by trial and error. Never locate the thermal bulb on the bottom of the suction line between the 4 and 8 o'clock positions. Insulate the bulb and pipe, with the insulation extended over each side of the bulb. The

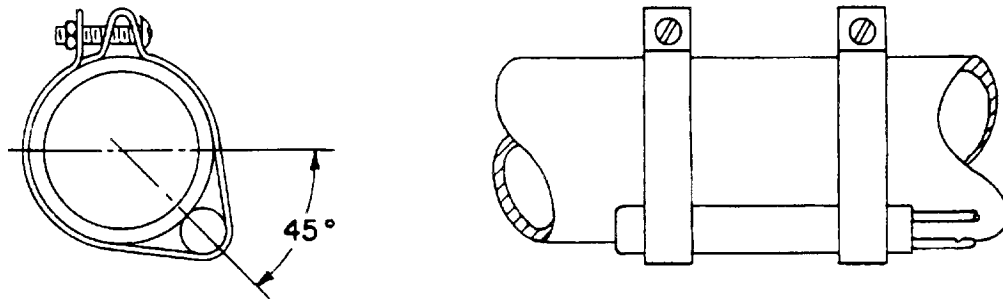
insulation shall be fitted tightly around the bulb and suction pipe leaving no voids. Improper contact, insulation, or location of the thermal element may cause liquid refrigerant to flood past the coil, and may seriously damage the compressor. When it becomes desirable to increase the sensitivity of the remote bulb, in some installations the bulb may be installed in a well.

NOTE

If adjacent thermal expansion valves feed adjacent evaporators, make sure that the remote bulb of each valve is applied to the suction line of the evaporator fed by that valve.



EXTERNAL BULB ON SMALL SUCTION LINE



EXTERNAL BULB ON LARGE SUCTION LINE

Figure 516-8-23. Location of External Bulb - Small and Large Lines

516-8.2.37 TESTING EXPANSION VALVES. Symptoms of improper expansion valve adjustment are outlined in [Figure 516-4-7](#). If it is impossible to adjust the expansion valve to the desired setting by referring to these symptoms, or if it is suspected that the expansion valve assembly is defective and requires replacement, certain expansion valve tests may be conducted as described below. First, be sure that the liquid strainers are clean, solenoid valves are operative, and the system is sufficiently charged with refrigerant. The major equipment required for expansion valve test is as follows:

- a. A cylinder of dry nitrogen or a supply of clean, dry air at 70 to 100 psig. The service drum is merely for supplying gas under pressure, and for this reason the gas used does not have to conform to the gas used in the thermal element of the valve being tested.
- b. A high-pressure gauge and a low-pressure gauge. The low-pressure gauge shall be calibrated and in good condition so that the pointer does not have any appreciable lost motion. The high-pressure gauge is not absolutely necessary, but is desirable to show the pressure on the inlet of the valve. The procedure for testing is as follows:
 - 1 Connect the valve inlet to the gas supply with the high-pressure gauge attached to indicate the gas pressure to the valve and with the low-pressure gauge loosely connected to the expansion valve outlet. The low-pressure gauge is connected loosely to provide a small amount of leakage through the connection.

- 2 Insert the expansion valve thermal element in a bath of crushed ice. Do not attempt to conduct this test with a container full of water and a small amount of crushed ice floating on top.
- 3 Open the valve on the service drum or in the air supply line and be sure that the gas supply is sufficient to build up the pressure to at least 70 psig on the high-pressure gauge connected at the valve inlet.
- 4 The expansion valve may now be adjusted. If it is desired to adjust the valve for, say 105 superheat, the pressure on the outlet gauge should be 22 1/2 psig for R-12 refrigerant or 20 psig for R-134a. This is equivalent to an R-12/R-134a evaporating temperature of 22°F ([Table 516-1-1](#) and [Table 516-1-8](#)), and since the ice maintains the bulb at 32°F, there is a difference of 105 or, in other words, the valve adjustment is for 10°F superheat. For a 5°F superheat adjustment, adjust the valve to give a pressure, read from the low-pressure gauge, of about 26.1 psig for R-12 or 23.7 psig for R-134a. Be sure to have a small amount of leakage through the low-pressure gauge connection while making this adjustment.
- 5 Tap the body of the valve lightly with a small weight to determine if the valve exhibits smooth operation. The low-pressure gauge needle shall not jump more than 1 pound.
- 6 Now tighten the low-pressure gauge connection to stop the leakage at the joint and determine if the expansion valve seals tightly. With the valve in good condition, the pressure will increase a few pounds and then either stop or build up very slowly. With a leaking valve the pressure will build up rapidly until it equals the inlet pressure.
- 7 Again loosen the gauge to permit leakage at the gauge connection and then remove the thermal element or control bulb from the crushed ice and warm it with the hand or by putting it in water at about room temperature. The pressure should increase rapidly, showing that the power element has not lost its charge. If the pressure does not increase when this is done, it is a sign that the power element is dead.
- 8 With high pressure showing on both gauges as outlined above, the valve may be tested to determine if the body joints, bellows, or diaphragms leak. This may be done using a halide leak detector or electronic leak detector to detect any escaping refrigerant gas. Use soapy water to indicate leaks if the testing is done with air. When performing this test, it is important that the body of the valve have a fairly high-pressure applied to it and that the gauges and other fittings are made up tightly at the joints to eliminate leakage at these points. Take the following precautions when testing expansion valves:
 - (a) See safety precautions in handling refrigerants.
 - (b) Be sure that the service drum has liquid in it and is warm enough to build up sufficient pressure or, if air pressure is used, that an air pressure of 70 to 100 psig is available for the test. The use of a high-pressure gauge will often save a lot of trouble because it will show when there is insufficient pressure on the inlet side of the valve to conduct the test properly.
 - (c) Be sure that the ice container is full of finely crushed ice.

516-8.2.38 REPLACEMENT OF EXPANSION VALVE. If it is evident that the expansion valve is defective, replace it. It is generally only necessary to replace a faulty power element, cage assembly, or gaskets without the necessity of replacing the entire valve assembly. It is generally unnecessary to replace the valve body or to remove it from the refrigerant system. When replacement of expansion valves is necessary, it is important to use a valve designed for the same refrigerant and of the same capacity and type as the one being replaced.

516-8.2.39 PILOT-OPERATED THERMOSTATIC VALVES. Pilot-operated thermostatic expansion valves used in naval shipboard refrigerant systems are provided with bolted flanges for installing the valve in the main liquid line. Disassembly of these flanges during brazing operations is required while installing these valves. The pilot valve is a thermal expansion valve ([Figure 516-3-127](#)). Disassembly of the valve and removal of internal

parts is required during brazing of the pilot piping to the fitting in the upper valve body. The pilot valve shall be located as close as possible to the main valve. The thermostatic valves may be disassembled for maintenance, repair, and replacement of defective parts.

516-8.2.40 REGULATING VALVES. Disassemble smaller sizes of evaporator pressure-regulating valves, hot gas bypass control valves, and solenoid valves and remove the internal parts when the valve body is being brazed into the piping system. Larger sizes of these valves are provided with bolted flanges that are removed from the valve body during brazing operations. Valves may be disassembled for maintenance, repair, and replacement of defective parts.

516-8.2.41 STRAINERS AND DEHYDRATORS. Remove the strainer, dehydrator cartridges, and gaskets from the shell during brazing operations. It is important to observe the in-and-out directions during installation of the strainers and dehydrators. Some Henry dehydrators have side outlets while others have side inlets. While the external construction of dehydrators with different directions of flow is identical, the safety cap is the one distinguishing feature. Dehydrators with the flow in-the-side out-the-end use a plain safety cap with NO handle. Dehydrators with the flow in-the-end out-the-side, use a safety cap WITH a basket handle. If there is a doubt as to what direction of flow the dehydrator was designed for, an examination of the safety cap will provide the answer. This information is applicable to dehydrators manufactured by Henry Valve Company, which are predominant in the fleet ([Figure 516-8-24](#)).

WARNING

When installing new cartridges, take time to determine if the refrigerant flow through the dehydrator is from the side to the end or from the end to the side. This is to ensure that the correct safety cap assembly is used and is installed on the down stream side of the cartridges. The direction of flow should be verified from the piping arrangement.

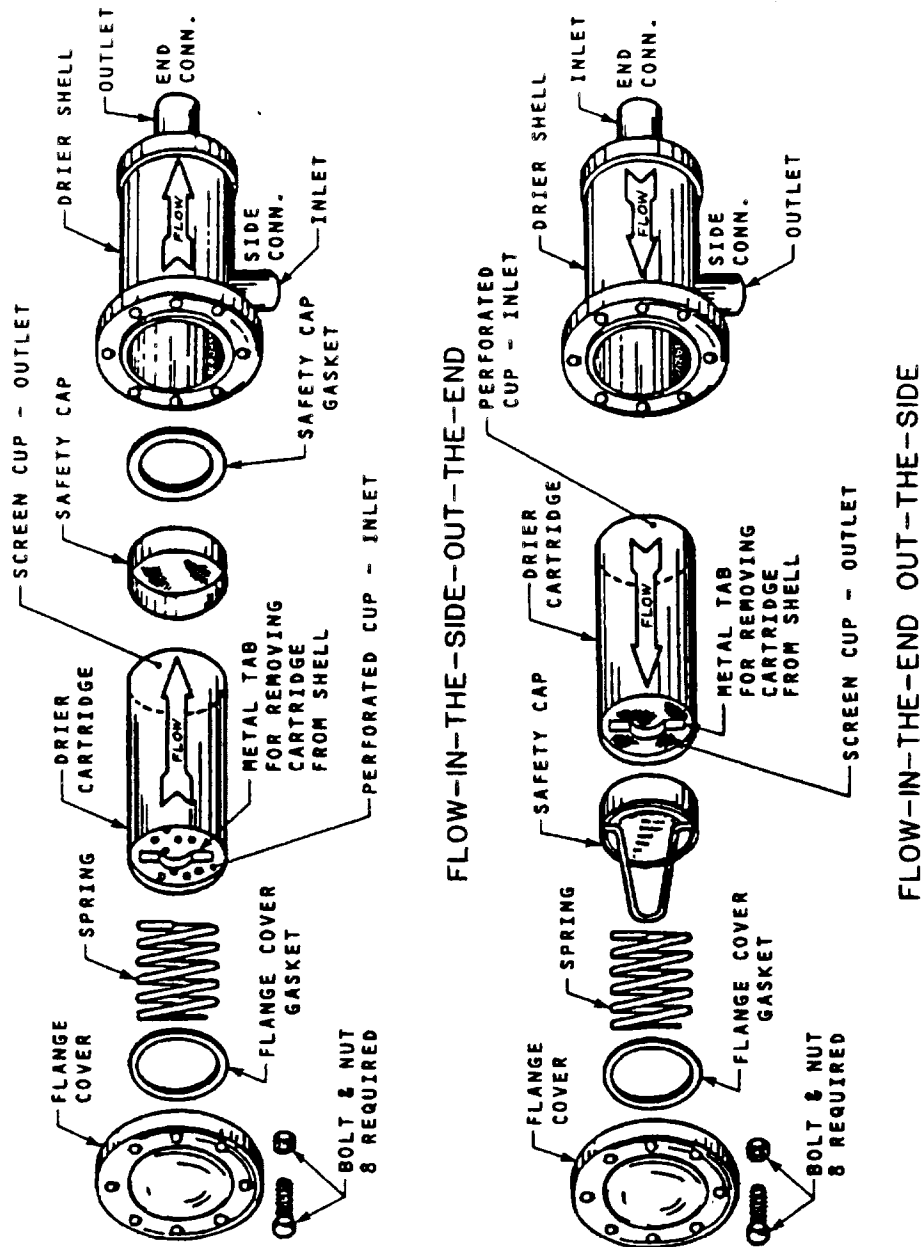


Figure 516-8-24. Dehydrator Flow Arrangement

516-8.2.42 REPLACING THE DEHYDRATOR CARTRIDGE. When the dehydrator is installed in-line and provided with a moisture indicator, the moisture indicator will indicate when the drying element shall be replaced. When the dehydrator is the type installed in a bypass line, it is only intended to be used when charging or adding refrigerant, or when the presence of moisture in the system is suspected. In such cases, a moisture indicator is not usually provided and there is no definite rule governing the length of time the dehydrating cartridge will remain effective, since the cartridge life depends on the actual amount of moisture removed from the refrigerant. Where a moisture indicator is not provided on a Henry dehydrator, a new dehydrator cover that includes a moisture indicator can be requisitioned. It is generally advisable, however, to renew the dehydrator cartridge after it has been used for a total of 12 to 15 hours in a new or newly charged system.

WARNING

Do not open sealed cartridge container until the dehydrator shell is clean and ready for the new cartridges to be installed.

516-8.2.42.1 The drying element is a cartridge that absorbs moisture from the liquid refrigerant that passes through it. Procedures required for the removal of the cartridge for reactivation or replacement are described below. If a spare cartridge is not available for renewal, the original cartridge may be removed and reactivated for emergency use only. Use the metal pull strip at one end to remove the cartridge, and subject the cartridge to dry heat (300°F) for 12 hours. The degree of reactivation depends upon the amount of moisture, oil, and foreign substances that have been absorbed. The high temperature used for reactivation, however, may carbonize the contained oil that seals off the capillaries in the desiccant and reduce its moisture pickup capacity to about 50 percent of the original capacity. To remove the cartridge for replacement or reactivation, close the stop valve between the receiver and dehydrator and continue operation for a few minutes to allow any remaining liquid to flow to the evaporator. Then close the valve at the outlet of the dehydrator, or the next downstream valve, and carefully and slowly loosen the cap bolted to the end of the dehydrator body. Protect your eyes with goggles. When pressure has been released from the dehydrator, remove the cap and lift out the cartridge. After placing the new cartridge or cartridges back in the shell, flush refrigerant gas through the shell from the inlet side to blow out the air, then tighten the end cap. See paragraph [516-3.2.36](#) for a complete description of the dehydrator.

516-8.2.43 EVAPORATOR PRESSURE-REGULATING VALVE ADJUSTMENT. Adjust evaporator pressure-regulating valves in accordance with detailed instructions in the valve or equipment technical manual. Evaporator pressure-regulating valves are adjusted by changing the pressure exerted by an auxiliary spring against the valve disk. For a given setting the valve maintains a substantially constant pressure in the cooling coil regardless of changes in the compressor suction pressure, provided that the suction pressure is about 4 psig or more lower than the one the regulator is set to maintain in the coil. Adjustment to increase the spring pressure, which tends to close that valve, increases the evaporating pressure. Similarly, decreasing the spring pressure decreases the evaporating pressure. If a gauge is not permanently installed, a test gauge may be temporarily connected to the cooling coil side of the valve when adjustment is to be made. The pressure setting for any individual application depends on coil design and the amount of coil surface available. In general, settings are not critical where the refrigerant circuit is also controlled by a solenoid valve, except that the pressure setting shall be maintained low enough to provide a temperature differential between the refrigerant evaporating temperature and the compartment temperature. Where temperature and humidity control depend on the pressure-regulating valve, the setting shall be high enough to permit the humidity desired (keeping in mind the temperature differential required for satisfactory compartment temperature control). The procedure required to set evaporator suction pressure-regulating valves for good humidity control are as follows:

1. After loading a chill space and after the temperature in the space has been pulled down to its normal operating temperature, adjust the setting of the evaporator suction pressure-regulating valve in each space to increase the coil pressure (temperature).
2. Gravity-type cooling coils in ship store spaces are designed for 20°F temperature differences between compartment temperature and evaporator temperature. This would indicate a design evaporator temperature of 13°F (16 psig for R-12 or 14 psig for R-134a) for a 33°F chill room. The higher the evaporator temperature, the higher the relative humidity in the space and the less moisture loss in vegetables.
3. Forced circulation cooling coils may be designed for 10°F to 14°F temperature differences between compartments and evaporator temperatures. Here the setting may be 23°F to 19°F (22 to 19 psig).

516-8.2.43.1 Where the medium being cooled is water, as in process and drinking water coolers, the setting of the suction pressure-regulating valve is very critical and, if improperly or hastily adjusted, may cause derangement. A change in the pressure setting of 1 pound will appreciably change the temperature of the delivered water. Too low a pressure setting will result in an almost immediate freezing of the water in the cooler with possible rupture. Consequently, adjust this valve in a water-cooler application very carefully. Turn the adjusting screw only 1/8 turn at a time and take frequent samples of delivered water to check the temperature. [Figure 516-8-25](#) shows an exploded view of a typical valve that demonstrates the ease of disassembly for repairing or replacing the parts without disturbing piping soldered joints. Dirt or foreign matter under the seat or in moving parts can cause erratic operation.

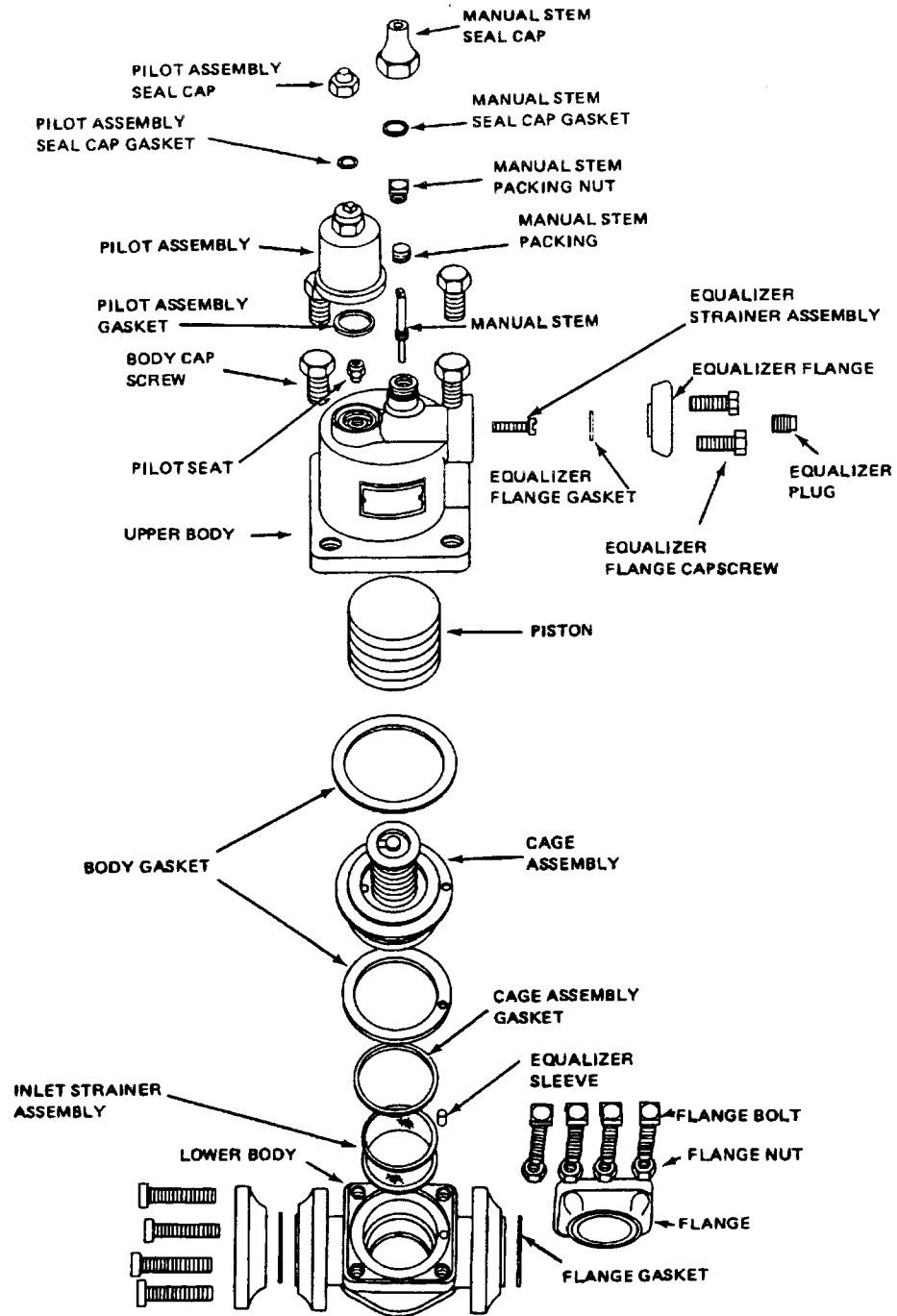


Figure 516-8-25. Evaporator Pressure Regulator

516-8.2.44 WATER-REGULATING VALVE MAINTENANCE. The adjustment of water-regulating valves shall be done in accordance with the detailed instructions in the valve or equipment technical manual. The following general procedure is, however, applicable for most types of water-regulating valves. Water-regulating valves are adjusted by changing the pressure exerted by auxiliary springs on the power element. Turning the adjusting devices to increase the pressure exerted by the springs against the power element reduces the flow of circulating water for any given condensing pressure. Water should cease to flow, that is, the valve should close automatically shortly after the compressor stops. If the compressor operates in a high ambient temperature, gas pressure may remain high enough to cause the valve to be open when the compressor is idle. When this happens, raise the opening point of the valve as high as necessary to cause the valve to close during compressor idle periods. Periodically clean and flush the regulating valve. The valve seat and disk may become pitted, worn, or wire drawn, which will prevent the valve from closing. These parts are readily replaceable.

516-8.2.44.1 When disassembling the valve, follow the manufacturer instructions for the easiest method to disassemble without disturbing the spring arrangement. An excess of cold water may reduce the pressure appreciably, as a forewarning to readjust the water-regulating valve. Conversely, if the head pressure cannot be reduced to the correct value, when there are no noncondensable gases in the condenser, the temperature of the inlet water may be too high; the water flow too low; or there may be a clogged condenser or water strainer ahead of the water-regulating valve. The water pressure to the inlet of water-regulating valves shall be approximately 30 to 35 psig. Regulate this pressure by adjusting the pressure-reducing valve or the stop valve ahead of the water regulating valve in the fire and flushing main, the auxiliary machinery seawater cooling system, or the branch connection as applicable. Be aware that excessive inlet pressure causes high velocity and valve erosion. When a plant is to be secured for any length of time, drain the valve. The valve is designed so that the seawater and refrigerant circuit are independent; in the event of a leak or derangement, seawater cannot enter the refrigerant circuit. Refer to the technical manual for valve details.

516-8.2.45 SOLENOID VALVE MAINTENANCE. Adjust and maintain solenoid valves in accordance with the detailed instructions in the valve or equipment technical manual. The following general procedure is, however, applicable to most types of solenoid valves:

- a. To clean, inspect, or repair solenoid valves, pump down the plant or piping segment where the valve is located. Secure and tag out power to the solenoid valve. Disassemble, inspect and clean the valve as indicated in the technical manual. Reassemble the valve, replacing all parts (including coil sleeves) in the proper order, and check for tightness of the gasket joints.
- b. To replace a burned out solenoid valve coil, it is not necessary to pump down the system as the coil is not subject to refrigerant pressure. Secure and tag out power, remove the coil housing, and replace the burned out coil with a new one.

516-8.2.46 HOT GAS BYPASS VALVE. Hot gas bypass valves are usually the take-apart type; maintenance shall be done in accordance with the valve technical manual or manufacturer instructions. Disassemble the valve for cleaning and inspection if operation is faulty. Repair or replace defective parts such as diaphragms, power assemblies, or cage assemblies.

516-8.2.47 SUCTION LINE THERMOMETER REPLACEMENT. If the suction line thermometer is removed from its socket for any reason, moisture from the atmosphere may condense on the inside of the socket. Dry the socket thoroughly before replacing the thermometer, because any remaining moisture may freeze, damaging the instrument or bursting the socket.

516-8.2.48 AUTOMATIC SWITCH MAINTENANCE. Details as to the exact procedure to be followed in adjusting the various automatic control switches in refrigerant systems vary with the design of the particular switch. Consult the particular switch or equipment technical manual. The following general procedure will, however, be applicable to all types. (Refer to [Figure 516-8-26](#) for illustration of a typical automatic switch.) Switches that cut out with a reduction in actuating pressure or temperature, such as the low pressure control, low temperature thermostats, and water failure switches, are adjusted to open when the pressure exerted by the refrigerant or thermostat bulb is less than spring pressure. They are adjusted to close when the thermostat bulb pressure is greater than spring pressure. Switches that cut out with an increase in actuating pressure or temperature, such as the high-pressure cutout switch, are adjusted to cut out when the pressure exerted by the refrigerant or thermostat bulb is higher than the spring pressure. Automatic switches generally are provided with a differential adjustment device used to adjust the switch to the desired differential between the cutin and cutout points and a range adjusting device that adjusts both cutin and cutout points. Turning the range adjusting screw to the right raises both the cutin and cutout points, and turning it to the left lowers these points. The differential adjustment affects only the cutout point. Turning this adjustment to the right (wider), raises the cutout point, increasing the differential between cutin and cutout pressure. Turning it to the left lowers the cutout point, decreasing the differential. First set the cutin point with the range screw and then set the cutout point with the differential adjustment. Use a gauge comparator to provide the pressure to set and adjust each of the following switches, if available.

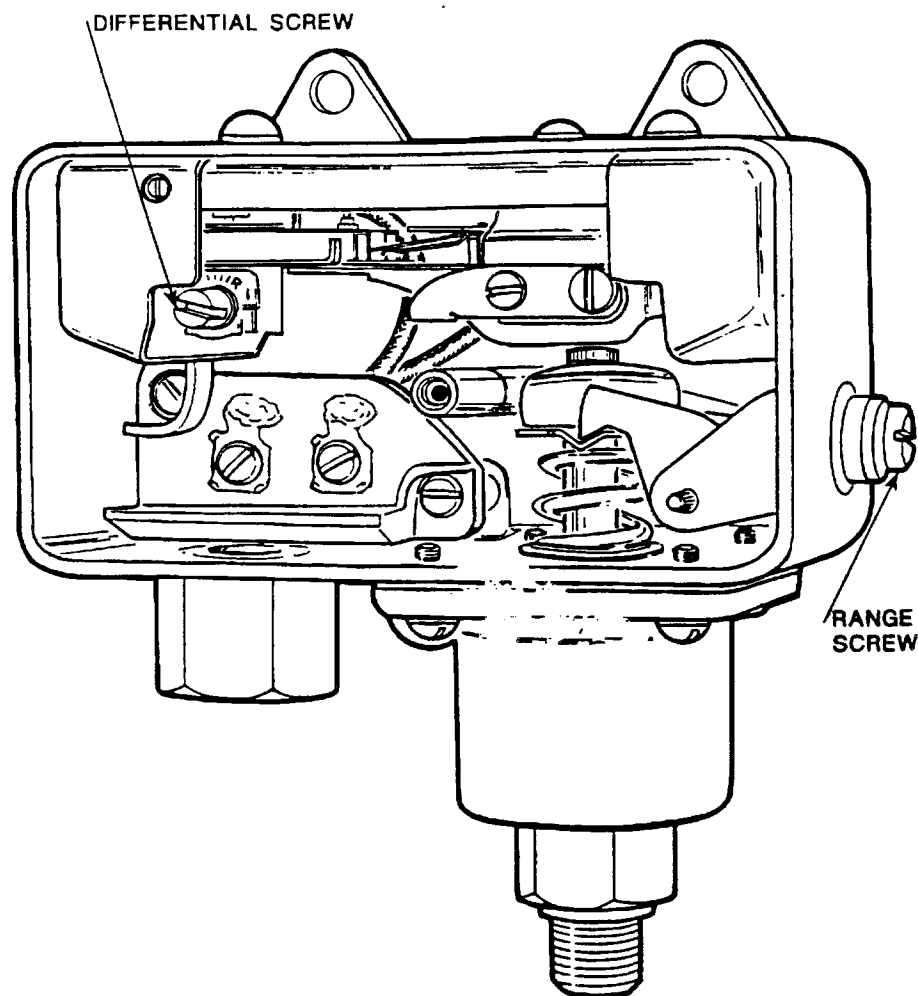


Figure 516-8-26. Typical Automatic Switch

516-8.2.48.1 A gauge comparator simplifies the switch setting procedure and provides a higher degree of accuracy in setting the switch cutin and cutout points. Another advantage of using the gauge comparator is that the refrigeration system operation is not disturbed to as great an extent when the gauge comparator is used to set the switch, since the pressure sensed by the switch is adjusted by the gauge comparator and not by manipulating the compressor controls or system valves. Securely fasten switches to the gauge board or, using brackets, to the case. Replacement shall be made using a duplicate switch or at least one having similar performance and rating. Switches are rated electrically in amperes and shall be large enough for the electrical load imposed.

516-8.2.49 SUCTION PRESSURE CONTROL SWITCH SETTING. Adjust suction pressure control switches in accordance with the detailed instructions in the switch or equipment manufacturer's technical manual. The following general procedure is, however, applicable for most types of suction pressure control switches used in naval shipboard systems. Make sure that the power supply is off before attempting to adjust the control to prevent the possibility of electrical shock. Turn the differential adjustment screw to the wider position (to the right). Bring the suction pressure to the desired cutin point. Turn the range adjustment point until the switch just cuts out. Then turn back slowly until the switch just cuts in. This fixes the cutin point. Bring the pressure to the desired cutout point. Then turn back the differential adjustment slowly until the switch just cuts out. This fixes the cutout point. As indicated above, use a gauge comparator to provide the pressure to set and adjust these switches if available.

516-8.2.50 HIGH-PRESSURE CONTROL SWITCH SETTING. Adjust high-pressure cutout switches in accordance with the detailed instructions in the switch or equipment technical manual. The following general procedure is, however, applicable for most types of high-pressure cutout switches. Set the high-pressure cutout switch for R-12 and R-134a plants to cut out at about 150 psig, and to cut in at 125 psig, as recommended in [Table 516-4-1](#). To set the high-pressure control switch, turn the differential adjustment to its minimum differential. Bring the compressor discharge pressure up to about 125 psig, ± 2 psi. Turn the range screw to the left until the contactor in the switch closes. This sets the cutin point. Turn in the differential adjusting screw to its widest limit and raise the discharge pressure to 150 psig ± 2 psi. Then turn the differential adjustment until the contactor opens to set the cutout point. For other applications use the pressures specified in the technical manual.

516-8.2.51 WATER FAILURE SWITCH SETTING. Water failure switches shall be adjusted in accordance with the detailed instructions in the switch or equipment technical manual. The following general information is, however, applicable to most types of water failure switches. Set the water failure switch to cut in at approximately 15 psig and cut out at approximately 5 psig. This switch is similar to the low (suction) pressure switch, in that it opens on lowering pressure and closes on increasing pressure. Thus, the same procedure shall be used for setting the water failure switch as for the low-pressure cutout switch. If a comparable gauge is not available, the water failure switch may be set by regulating the waterflow as follows:

516-8.2.51.1 Throttle the condenser water valve until a pressure of 15 psig ± 2 psi is maintained at the condenser inlet. Turn the range screw until the switch contacts open, and then slowly in the opposite direction until the contacts close. Slowly shut off the water supply, thus decreasing the pressure. The switch contacts should open at 5 psig ± 2 psi. If not, turn the differential adjustment to set the cutout point. Check the settings by opening or throttling the water valve.

516-8.2.52 THERMOSTAT SWITCH SETTING. Adjust thermostats in accordance with the detailed instructions in the switch or equipment technical manual. The following general procedure is, however, applicable to most types of thermostat switches:

a. Set the thermostat switch to open the circuit to the solenoid valve coil it serves when the temperature of the

compartment or water chiller in which its control bulb or element is located has been decreased to the desired point (Table 516-4-1). These switches are usually provided with a differential as well as a range adjustment mechanism. It is good practice to set the differential adjustment for 3°F or less between the cutin and cutout points if possible. Take care that the cutout setting of thermostatic control switches used in water cooling applications is kept at a temperature above 32°F, to avoid freezing the water.

- b. These thermostats open on a decrease and close on an increase of temperature. Thus the switches are similar to low-pressure switches. Adjust in the same way except that, rather than using a gauge comparator to change pressure, some means for changing the temperature of the thermostatic bulb by a variable temperature bath is required.

516-8.2.53 RECEIVER MAINTENANCE. The receiver requires little or no maintenance. Thoroughly wire-brush any signs of rust on fittings or on the outside of the shell, and coat the surfaces with an approved rust-preventive primer and paint. The only other part of the receiver that may require maintenance is the liquid level indicator in reciprocating plants. Receiver liquid level indicators usually consist of a gauge needle magnetically connected to a float-actuated lever to indicate the liquid refrigerant level. If difficulty is experienced with the liquid level indicator, isolate the receiver from the rest of the refrigerant system, remove the liquid refrigerant, and inspect the liquid level indicator mechanism. Repair or replace a faulty liquid level indicator mechanism if necessary, and put the system back in operation. Some receivers have bull's eye sight glasses to determine liquid level. These should require no maintenance except perhaps for cleaning if dirty refrigerant has deposited some dirt.

516-8.2.54 COOLING COIL MAINTENANCE. Cooling coils require little maintenance beyond regular cleaning, defrosting, and repair of an occasional leak. Minor accessible cooling coil leaks may be repaired in place by solder brazing. Defer the repair of major or inaccessible leaks to a repair facility. Do not attempt shipboard repair of such leaks except in an emergency.

516-8.2.55 HEAT EXCHANGER MAINTENANCE. Do not attempt heat exchanger repairs aboard ship. The heat exchanger shall be absolutely leak-tight to prevent liquid refrigerant (from the liquid line) from entering the compressor suction line and returning to the compressor. If the heat exchanger is out of working order, replace the entire assembly. Pump down the system and install a new heat exchanger.

516-8.2.56 ADDING LUBRICATING OIL. The following steps outline the general procedure for adding the oil charge to a compressor:

1. Do not use oil from previously opened containers. Examine new containers. If an oil film is present on the outside, do not use this oil in air-conditioning and refrigerating equipment. If oil has seeped out, moisture has seeped in.
 - a Line a 1- to 2-gallon container with a vinyl bag. In a well-lighted area, open oil cans one at a time and pour the oil into the container. If the oil is clear, continue to fill container until it contains 1 gallon.
 - b Charge the clear oil into the equipment using a hand pump, NSN 4320-367-2150. Ensure that no air is allowed to enter the system while charging oil. Continue to charge oil into the equipment in 1-gallon increments until the proper oil level is obtained.
2. If it becomes necessary to discard oil because of moisture contamination, and a test facility with the capability for performing oil tests is available, have the oil tested for moisture content. Examine the inside of the oil cans for rust. Report unsatisfactory oil in accordance with prescribed requirements with a copy sent to

NAVSEA. The report shall include moisture content, if known, color of oil, whether free water is present, and condition of the can. For testing purposes, oil containing 100 ppm or more of water is unsatisfactory: oil should have 60 ppm or less moisture content.

3. Exercise care in handling and storing refrigeration system lubricating oil to minimize the possibility of moisture contamination. Store cans in a dry location and make every effort to ensure that cans do not suffer physical damage before use. Once the container is opened, do not save excess oil for future use.
4. Lubricating oil used for refrigerant compressors operating with R-11, R-12, R-22, and R-114 shall be in accordance with FED Spec VV-L-825, Type II. This oil is available in general stores and shall be obtained in 1-quart sealed cans to prevent absorption of moisture through contact with the atmosphere. If a can of lubricating oil is only partly used in charging a compressor, it is good practice to use the remaining oil for some other suitable purpose not requiring the use of dehydrated oil. This will minimize the danger of charging oil that is not perfectly dry into the system. Add or remove lubricating oil from the compressor in accordance with the detailed instructions in the compressor or equipment technical manual. Lubricating oil for compressors operating with R-134a and R-236fa shall be commercial grade polyolester oil, in accordance with the compressor manufacturer's instructions and NAVSEA commercial item descriptions.

516-8.2.56.1 If no instructions are available, the following general procedure is applicable to most types of reciprocating compressors. If a small oil charging pump is furnished with the plant, proceed as follows:

1. Remove the protector cap from the end of the oil charging pump and wipe the pump cylinder clean.
2. Insert the oil pump into the oil container to be used after inspecting the oil.
3. Connect the pump discharge hose to the compressor crankcase oil charging valve, but do not tighten the connection.
4. Displace the air in the oil pump and connections by several strokes of the pump handle until oil appears at the oil charging valve. Then tighten the connection attaching the oil hose to the charging valve and open the valve.
5. Pump oil into the crankcase until the oil level rises to the proper point in the bull's-eye sight glass.
6. Close the charging valve tightly, replace the valve stem and seal cap, disconnect the pump hose, and plug the open end of the oil charging valve.
7. Place a protective cap on the oil charging pump when the pump is not in use.

516-8.2.56.2 If no lubricating oil charging pump is provided, and the charging opening is near the upper part of the crankcase, the required amount of lubricating oil may be added to the compressor crankcase as follows:

1. Pump down the compressor crankcase.
2. Secure the compressor.
3. Close discharge and suction line stop valves.
4. Remove the oil filler plug or oil charging valve on the compressor crankcase (slowly).
5. Add the required amount of oil through a clean, well-dried funnel.
6. Replace the oil filler plug or oil charging valve. Secure tightly.
7. Open discharge and suction line stop valves.
8. Start compressor.

516-8.2.56.3 This method of adding oil to the compressor, if properly followed, will prevent any appreciable quantity of air from entering the system. Since the refrigerant gas is heavier than air, the position of the oil charging hole near the upper part of the crankcase prevents admission of air during the oil charging procedure.

516-8.2.57 REFRIGERANT RECOVERY/RECYCLING UNITS. Refrigerant used in ACAC & R plants is recovered for reuse, reprocessed for reuse, or disposed of whenever it is removed from a system. It must not be released to the machinery space or to the atmosphere. The disposition of the refrigerant should be determined before it is removed from the equipment or system. That decision is based on considerations that include the reason for system shutdown and refrigerant removal, the condition of the equipment and system, and whether or not the refrigerant is to be reused. Refrigerant withdrawn from equipment prior to routine service or most major overhauls can usually be returned to the equipment without reprocessing. If there is any question about the quality of the refrigerant or if the system has been taken out of service because of mechanical failure, refrigerant contamination, or motor burnout, the refrigerant should be recycled before it is reused or turned into the supply system for reclamation. Recycling of refrigerant may be done on board if a refrigerant recovery/recycling unit (RRU) is available, or the refrigerant may be removed and transferred off ship for recycling. Navy shipyards may use a dedicated RRU or off-site activity to recycle the refrigerant. Typically, recycling involves filtering and drying to reduce moisture, particulates, and acid content. NAVSEA has distributed the Refrigerant Recovery Systems, Inc., Model ST-100/A or ST-1000 RRU to all Navy ships. NAVSEA has also procure a trailer stowed refrigerant recovery unit for intermediate maintenance facilities and depot maintenance facilities (shipyards).

- a. St-100A/A or ST-1000 Refrigerant RRU. Models ST-100/A and ST-1000 RRUs are designed to recover/recycle R-12, R-134a, and R-22 from reciprocating compressor plants. Model ST-100/A will recover/recycle 0.75 lb/min of R-12, while model ST-1000 will recover/recycle 1.52 lb/min of R-12.
- b. U.S. Navy Trailer Stowed Refrigerant Recovery Unit (TSRRU). The U.S. Navy TSRRU is designed to provide Navy activities with a means of recovering refrigerant from shipboard air-conditioning and refrigeration systems and to prevent the release of ozone-depleting refrigerants into the atmosphere. The TSRRU is designed to recover R-11, R-12, R-114, R-22, R-500, R-502, and R-134a from a variety of cooling systems and refrigerant storage configurations using a pneumatically drive, two-stage, liquid recovery pump and an electrically powered vapor recovery unit. This equipment, with auxiliary hardware (such as hoses, sight glasses, and fittings), can be used to transfer refrigerant from a refrigerant source, such as a shipboard air-conditioning system or a remote receiver, to a recovery cylinder, drum, or tank positioned on a pier, ship deck, etc. Liquid refrigerant is recovered by direct mechanical pumping using the portable liquid recovery pump. Refrigerant vapor is recovered by evacuation or flash distillation and vapor compression and condensation using the vapor recovery unit and liquid recovery pump in series. The TSRRU can recover refrigerant through horizontal distances of 500 feet and vertical heights of approximately 100 feet. It will evacuate a refrigerating system to a vacuum greater than 29 inches of mercury. Additionally, the TSRRU may be used to recycle refrigerant recovered from refrigerating plants and charge them with clean refrigerant.

516-8.2.58 DRAINING REFRIGERANT CHARGE. To drain the refrigerant charge from the system when it is necessary to make repairs and the refrigerant cannot be stored in installed receivers, the refrigerant shall be placed in empty service cylinders.

a. Preliminary Procedure

- 1 Tag out all refrigerant valves communicating with the atmosphere that will not be used in the recovery operation. Wire them closed and tag Do Not Open to prevent accidental opening and possible injury due to contact with refrigerant or other fluids.
- 2 Evacuate each empty compressed gas cylinder with a vacuum pump.

- 3 Do not overcharge the compressed gas cylinder with refrigerant. Use a weight scale to continuously weigh the cylinder during the recovery operation. When the weight of the refrigerant charge in the compressed gas cylinder is 80 percent of its rated water capacity, the cylinder is fully charged (refer to [Table 516-1-8](#)).
 - 4 Clearly stencil each compressed gas cylinder containing the recovered refrigerant with the words, **USED R-(identify refrigerant)** . Attach a tag identifying the refrigerant source, type of refrigerant **USED R-(identify refrigerant)** , weight of refrigerant, and possible contaminants.
 - 5 It may be necessary to cool the compressed gas cylinder during the recovery operation. Set the compressed gas cylinder in a container of ice and water when conducting the transfer operation. Account for the weight of the container and ice water when monitoring the weight scale.
- b. RRU Procedure; refer to the applicable manual (ST-100/A RRU, ST-1000 RRU, or TSRRU manual).
- 1 Ensure that the RRU and interconnecting piping (RRU system) does not contain leftover refrigerant of a different type from a previous refrigerant operation. Thoroughly evacuate the RRU system to ensure that residue of another type of refrigerant does not remain in the RRU system.

CAUTION

Never mix refrigerants or gases in a cylinder or system.

- 2 Connect a compound pressure gauge and the RRU suction to the charge and drain connection of the refrigerating plant.
 - 3 Connect the RRU discharge to the compressed gas cylinder shutoff valve.
 - 4 Ensure that the RRU system is leak-free by conducting a pressure drop test with dry nitrogen. Test R-12, R-134a, and R-22 RRU reciprocating compressor systems by pressurizing the RRU system up to the refrigerating plant charge and drain valve and the compressed gas cylinder shutoff valve with dry nitrogen to 75 psig. Secure the nitrogen and hold the test pressure for 15 minutes. For R-114 air-conditioning plants, pressurize to 50 psig; for R-11 air-conditioning plants, pressurize to 15 psig; for R-236fa air-conditioning plants, pressurize to (later) psig. For R-134a centrifugal air-conditioning plants, pressurize to (later) psig. Test all joints for leakage using soapsuds. No leakage is allowed. Repair any leaks in the RRU system and repeat the pressure drop test until the RRU system is leak-free.
 - 5 Open all refrigerant line shutoff valves including solenoid and bypass valves contained in the system to be recovered, except those communicating with the atmosphere, such as purge and drain.
 - 6 Place the empty compressed gas cylinder in the container of ice and water on the weight scale.
 - 7 Start the RRU, open the refrigerating plant charge and drain valve and crack open the fitting connected to the compressed gas cylinder shutoff valve. Allow a small amount of refrigerant to bleed from the connection to ensure that the RRU system is purged of air. Retighten the connection.
 - 8 Open the compressed gas cylinder shutoff valve. Allow the RRU to fill the compressed gas cylinder until it is filled to 80 percent of its water weight (see paragraph a3).
 - 9 Repeat steps 6 through 8 until the recovery operation is completed.
 - 10 Continue the recovery operation until a pressure below atmospheric is obtained in the refrigerating plant. Secure the RRU and the refrigerating plant charge and drain valve. Ensure the absence of refrigerant by holding a negative pressure on the refrigerating plant for 10 minutes. A rise in the pressure indicates that refrigerant is present in the plant.
 - 11 Secure the refrigerating plant charge and drain valve, the compressed gas cylinder shutoff valve, and the RRU.
 - 12 Disconnect and remove the RRU and interconnecting piping, hoses, and fittings.
- c. R-114 and R-236fa Air-Conditioning Plant Purge and Pump-Out Unit Refrigerant Recovery

- 1 Connect a compound pressure gauge to the vacuum pump gauge connection on the purge and pump-out system. Open the vacuum pump gauge connection shutoff valve.
- 2 Line up the valves on the purge and pump-out system in accordance with the refrigerating plant equipment technical manual for the refrigerant liquid transfer (draining chiller) operation.
- 3 Start the purge and pump-out unit and pump out the liquid refrigerant to the refrigerant receiver until all liquid refrigerant has been transferred to the refrigerant receiver.
- 4 Secure the purge and pump-out unit and all valves opened in step 2 above.
- 5 Connect the compressed gas cylinder to the charge and drain connection of the refrigerating plant.
- 6 Place the empty compressed gas cylinder in the container of ice and water on the weight scale.
- 7 Open the refrigerant receiver outlet valve, the refrigerating plant charge and drain valve, and crack open the fitting connected to the compressed gas cylinder shutoff valve. Allow a small amount of refrigerant to bleed from the connection to ensure that the interconnecting piping is purged of air. Retighten the connection.
- 8 Open the compressed gas cylinder shutoff valve. Allow the refrigerant receiver and cylinder differential pressure to fill the compressed gas cylinder. Secure the refrigerating plant charge and drain valve and the compressed gas cylinder shutoff valve.
- 9 Repeat steps 6 through 8 until all liquid refrigerant has been transferred to the compressed gas cylinders from the refrigerant receiver.
- 10 Line up the valves on the purge and pump-out system in accordance with the refrigerating plant equipment technical manual for the refrigerant gas pump-out and recovery operation; the receiver outlet valve is to remain open.
- 11 Place the empty compressed gas cylinder in the container of ice and water on the weight scale.
- 12 Start the purge and pump-out unit, open the refrigerating plant charge and drain valve and crack open the fitting connected to the compressed gas cylinder shutoff valve. Allow a small amount of refrigerant to bleed from the connection to ensure that the interconnecting piping is purged of air. Retighten the connection.
- 13 Open the compressed gas cylinder shutoff valve. Allow the purge and pump-out unit to fill the compressed gas cylinder.
- 14 Repeat steps 11 through 13 until a pressure of approximately 60-mm Hg absolute (27.5-inch Hg) vacuum is attained in the refrigerating plant. Secure the purge and pump-out unit and the refrigerating plant charge and drain valve. Ensure the absence of refrigerant by holding a negative pressure on the refrigerant plant for 10 minutes. A rise in the pressure indicates that refrigerant is present in the plant. Continue the refrigerant gas pump-out and recovery operation until there is no rise in pressure.
- 15 Secure the refrigerating plant charge and drain valve, the compressed gas cylinder shutoff valve, and the purge and pump-out unit.
- 16 Disconnect and remove interconnecting piping, hoses, and fittings.

516-8.2.59 SELF-CONTAINED EQUIPMENT MAINTENANCE AND REPAIR. Maintenance and repair of self-contained equipment consists of various functions in addition to maintenance and repair of the refrigerant systems. Planned Maintenance System (PMS) Maintenance Requirement Cards (MRCs) describe the functions required to maintain the various types of self-contained equipment. Some of these maintenance requirements are summarized here:

- a. Cleaning the interiors and exteriors of the equipment
- b. Adjusting latches and hinges

- c. Checking gaskets and seals
- d. Frequently flushing and cleaning water systems
- e. Cleaning condensers, both air- and water-cooled
- f. Adjusting controls
- g. Adjusting belt tension
- h. Lubricating where required
- i. Checking tightness of mounting bolts
- j. Checking cleanliness of air filters
- k. Checking for damaged, worn, or malfunctioning parts.

516-8.2.60 SELF-CONTAINED EQUIPMENT MAINTENANCE PROCEDURES. Planned maintenance of the refrigerant and electrical systems consists primarily of the following:

- a. Leak-testing refrigerant
- b. Checking proper operation of refrigerant controls
- c. Checking refrigerant pressures (where test connections are provided)
- d. Checking electrical circuits for opens, shorts, and grounds
- e. Checking for proper current (amps) draw. Repairs of self-contained equipment other than the refrigerant system will consist primarily of replacing or adjusting parts, or components. The procedures and techniques for repairing the refrigerant system will vary depending on the type or design of the equipment and refrigerant system.

516-8.2.61 SELF-CONTAINED EQUIPMENT CHARGING AND TESTING. A charging and testing manifold as shown in [Figure 516-4-4](#) is required for maintenance and repair of self-contained equipment. Where compressor shutoff valves are provided, the valves include either a male flare fitting or a female pipe tap ([Figure 516-4-7](#)), where a half-union coupling male pipe to male flare may be installed for connecting the charging hose ([Figure 516-4-4](#)).

516-8.2.61.1 On some refrigerant systems, male flare charging and test fittings are provided in the refrigerant piping. These fittings are provided with pin-operated valves ([Figure 516-4-6](#)) to prevent loss of refrigerant when the seal caps are removed to connect charging and test hoses to the equipment. Some refrigerant systems do not provide any fittings for connecting of charging or test hoses. If it is necessary to add refrigerant or repair the piping, it is necessary to install fittings in the suction and discharge piping. Either solder type or mechanical clamp-on type fittings similar to those shown in [Figure 516-8-27](#) are considered satisfactory for this purpose.

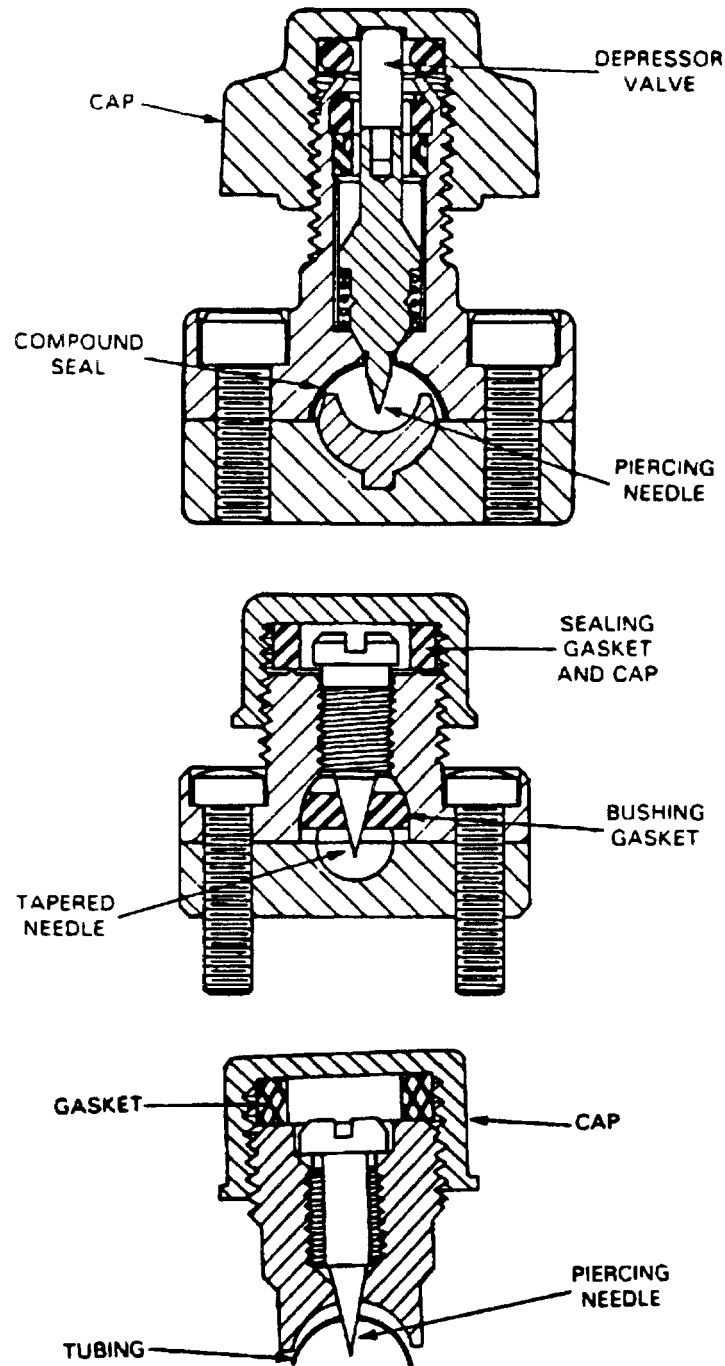


Figure 516-8-27. Line Tap Valves

516-8.2.61.2 On systems in which there are no shutoff valves or liquid receivers, it will be necessary to recover the refrigerant charge before making repairs to the piping system. Enter the system using a line tap valve. Use an RRU unit to remove and, if necessary, recycle the refrigerant. Make the piping repair and install a permanent Schrader or service shutoff valve. Leak-test the system and evacuate air and moisture. Recharge the system refrigerant. Where shutoff valves and a liquid receiver are provided, pump the refrigerant into the receiver while repairs are being made to the system. It is good practice to replace the dehydrator any time the refrigerant system has been opened. Any time a refrigerant system has been opened for several hours or longer, or the equipment has been shut down for a period of time because of an unrepaired leak, replace the dehydrator and evacuate the system with a vacuum pump before recharging with refrigerant. Generally, it is impractical to remove air from the system with a sweep of refrigerant from these units. Always use a vacuum pump to evacuate the system before recharging.

516-8.2.61.3 In systems where there is no receiver and the charge is critical, the use of a commercial charging cylinder calibrated in fractions of an ounce is recommended to provide an accurate charge. In self-contained equipment, adding refrigerant or charging the system is usually done by charging the refrigerant in a gaseous or vapor state into the low-pressure (suction) side of the system. In some of the larger systems where a charging connection is provided in the refrigerant liquid line, liquid refrigerant may be charged through this connection when the system is to be completely charged. To add a small amount of refrigerant, charging gaseous refrigerant into the low-pressure side of the system is preferred. Never add liquid refrigerant to the suction side. Keep the refrigerant cylinder upright to add gas. Make repairs to refrigerant piping systems, other than where mechanical fittings are used, by silver-brazing. Soft (lead-tin) solders may be used in some applications such as bonding the refrigerant flow control capillary tube to the suction line and attaching solder type charging and test fittings to the refrigerant piping.

516-8.2.62 SELF-CONTAINED HERMETIC UNIT OIL CHANGE. Oil need not be changed according to packaged hermetic units unless it is lost or contaminated. Always check the manufacturer's technical manual to determine the exact amount of oil required when replacing the original charge. If oil needs to be added because of leakage, add it in small amounts with the compressor running until the estimated total requirement is reached. Excess oil may disrupt the balance of a hermetic system that uses a capillary tube, causing loss of refrigeration and possibly damaging the equipment.

516-8.2.63 SELF-CONTAINED EQUIPMENT COMPRESSOR REPAIRS. The majority of compressors used in self-contained refrigeration equipment are full hermetic (completely sealed) compressors. Hermetic compressors are reliable, so when a compressor failure occurs, the failure usually can be attributed to refrigerant or electrical system problems. The most common of these problems are the refrigerant charge, moisture, and electric current transients.

516-8.2.63.1 Since the suction gas returning to the compressor is used to cool the compressor motor, a low refrigerant charge may cause the motor to overheat and possibly burn out. Conversely, too much refrigerant in the system will cause liquid floodback, damaging the compressor valves and diluting the lubricating oil. Moisture in the refrigerant system causes the formation of acids that attack the motor winding insulation, causing shorts and burnouts.

516-8.2.63.2 Variations in electric power supply voltage and frequency lead to shortened motor line. Repair of full hermetic compressors is limited to repairing or replacing external electrical parts such as relays, capacitors, and overload devices. Experience has proven that it is impractical to open and repair full hermetic compressors. The many types of magnet wire and special insulating materials used, the selective fitting of mechanical parts, and the need for special tools and procedures preclude successful and economical repair of full hermetic com-

pressors. In some self-contained refrigeration equipment, semi- or serviceable hermetic compressors are used. The various system problems described previously that affect the operation of full hermetic compressors also apply to semihermetic compressors. However, additional maintenance and repair procedures may be accomplished where semihermetic compressors are used. In addition to repairing or replacing external electrical parts, it is possible to repair or replace the valve plate assembly and compressor parts. Also, some compressors have a replaceable oil pump. The end cover may be removed to inspect the motor windings and where replacements are available, to replace the motor stator or rotor. An internal suction strainer is generally provided. This strainer may be inspected and cleaned if necessary by removing the suction shutoff valve. An oil sight glass, oil fill, and drain plug permit checking the condition and level, and adding or replacing the oil as required.

516-8.2.64 SELF-CONTAINED EQUIPMENT MOTOR BURNOUT. Motor burnouts can occur in either full or semihermetic compressors. As previously indicated, they are usually caused by system problems, moisture being the primary problem. Motor burnouts occur in varying degrees of severity. Some burnouts quickly interrupt the current flow and very few if any contaminants are released into the refrigerant system. It is very difficult, however, to determine the cause and severity of the burnout and whether any system contamination has occurred. Therefore, consider cleaning and dehydration of the system when a compressor motor burnout has occurred. Only when it has positively been determined that no contaminants have entered the refrigerant system may cleaning the system be avoided. In this case only, replacing the liquid line dehydrator and evacuating the system with a vacuum pump is required when installing the replacement compressor and recharging the system with a new refrigerant charge and oil. Install an acid-neutralizing filter or drier in the suction line to the compressor. When a capillary tube is used as the refrigerant control device, it is impractical to use the flushing procedure. When a capillary tube is used as the refrigerant control, or when the necessary equipment and material are not available for flushing, cleaning may be done by doing the following:

- a. Replacing the liquid line dehydrator
- b. Installing an acid-neutralizing filter/drier in the refrigerant suction piping
- c. Installing the replacement compressor
- d. Evacuating the system with a vacuum pump
- e. Recharging the system with new refrigerant and oil
- f. Operating the system, permitting the new liquid line dehydrator and suction line filter/drier to remove the contaminants from the refrigerant system, provided the capillary tube is not plugged up with contaminants.

516-8.2.64.1 The contaminant products from a compressor motor burnout are acidic and, if sufficiently concentrated, may burn skin. When handling system components and refrigerant from a contaminated system, wear protective gloves and glasses to prevent accidental contact with acidic contaminants. A sharp pungent odor at either the suction or discharge connection of a hermetic or semihermetic compressor recently removed from a refrigerant system indicates that a burnout has occurred. Handle this compressor with caution. Do not attempt to rewind a refrigerant hermetic motor. Field rewinding of hermetic motors has not been successful. Motor burnout occurs after a short period of operation of the rewound motor.

516-8.2.65 SELF-CONTAINED EQUIPMENT WATER LEAKS. Where water-cooled condensers are used, water leaks are always possible, either to the atmosphere or into the refrigerant system. Water leaks to the atmosphere usually are noticed before any significant damage has occurred. Water leaks into the refrigerant system cannot be seen and generally are not noticed until enough water has entered the system to cause the system to

malfunction. When seawater has entered the refrigerant system it is necessary to remove the water and thoroughly clean and dehydrate the system to prevent subsequent equipment failures. The following procedures are recommended:

1. Drain or blow all seawater from the system, using low-pressure air or nitrogen.
2. Flush with fresh water to remove any residual mineral salts.
3. Drain or blow all water from the system.
4. Flush with cleaning solvent, or where a capillary tube is used, install filter/drier as described for cleaning a system after a compressor motor burnout.
5. Evacuate system with a vacuum pump and recharge with new refrigerant and oil, and operate.

516-8.2.66 SELF-CONTAINED EQUIPMENT COMPRESSOR RESTORATION. Restoring the compressor to operating condition after it has been contaminated with seawater presents various unique problems. Open type compressors may be disassembled and rebuilt. It is recommended that the rebuilt compressor be baked at a temperature of 250°F, not exceeding 300°F, for several hours with the shutoff valves open before recharging with oil. Where facilities for baking the compressor are not available, low heat may be applied using a vacuum pump to maintain a vacuum on the compressor during this dehydration. Connect the vacuum pump to the compressor discharge valve for this procedure. Semihermetic compressors may also be disassembled and rebuilt similar to an open compressor; however, dielectric strength and insulation resistance tests should be conducted on the motor after all cleaning and dehydration have been completed. Negative results from either of these tests will necessitate replacement of the stator, rotor, or complete compressor unit. In some cases, it may be more economical to replace the complete compressor. In other cases, full hermetic compressors may be restored to normal service similar to semihermetics. If it appears justified to restore the compressor after water contamination, the following procedures are recommended:

1. Drain oil.
2. Blow out all fluids with low-pressure air or nitrogen.
3. Flush with approved cleaning solvent.
4. Drain solvent and evacuate with vacuum pump.
5. Bake for a minimum of 6 hours at 250°F to 300°F.
6. Conduct dielectric strength and insulation resistance tests.

CAUTION

Do not operate longer than 10 or 15 minutes since there is no suction gas to cool the motor. If the compressor will develop and hold discharge pressure it may be reinstalled in the system.

516-8.2.66.1 If the tests do not indicate any electrical deficiencies, charge the compressor with oil and operate it to check the suction and discharge valve operation.

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION
REPORT (TMDER) Forms can be found at the bottom of the CD list of books.
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