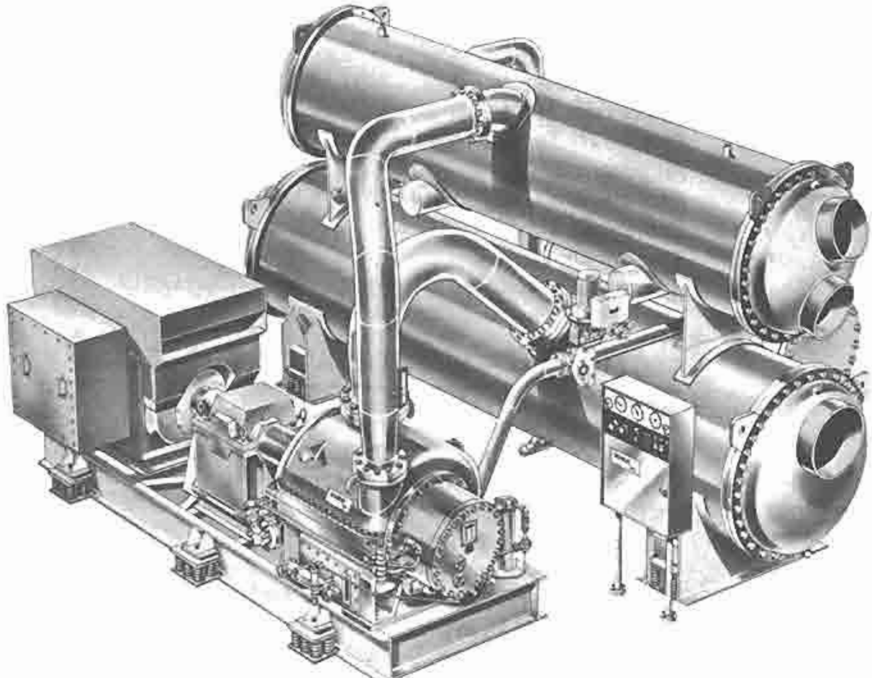
# YORK®

# OM TURBOMASTER

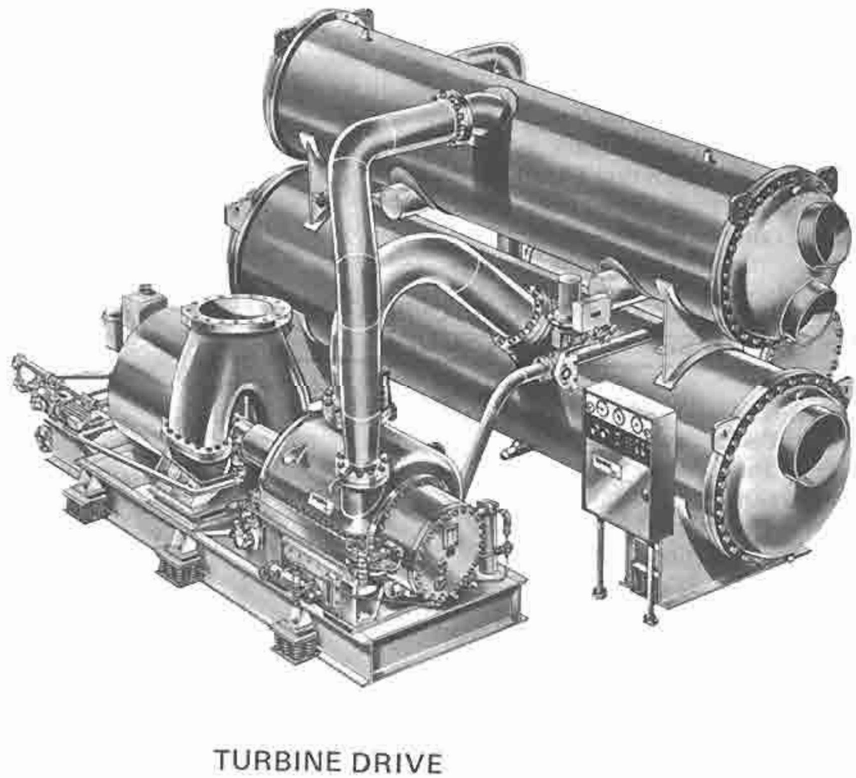
## CENTRIFUGAL LIQUID CHILLING UNITS
## 1000 THRU 8500 TONS

**OPERATING AND MAINTENANCE INSTRUCTION**

Supersedes: 160.71-01 Coded 379 | 282 | Form 160.71-01



MOTOR DRIVE



TURBINE DRIVE

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# SECTION I
# GENERAL INFORMATION

## INTRODUCTION

The purpose of this manual is to provide operating and preventive maintenance instructions for the OM Turbomaster Liquid Chilling Unit. The information contained in this instruction describes the unit components and functions, refrigeration cycle, and controls.

After the installation and during the Initial Start-Up the York Start-Up Engineer shall instruct the operator in the operation and necessary maintenance to be performed to maintain the OM Turbomaster Unit. This instruction should be thoroughly read by the operator to familiarize himself with the operation of the unit. The duties of the operator are as follows;

1. Starting and stopping the unit daily, weekly and seasonally.

2. Maintaining complete records of operating conditions including all temperatures, pressures, control settings, refrigerant and oil levels.

3. Inspect and perform preventive maintenance daily, weekly, seasonally or as necessary.

4. Make necessary minor adjustments.

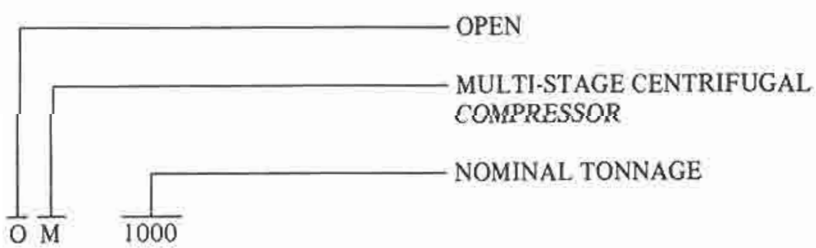
5. Maintenance required during shutdown to prevent freezing and other hazards.

## UNIT DESCRIPTION

The OM Turbomaster Centrifugal Liquid Chilling Unit is most commonly applied to large air conditioning systems, but may be used on other applications. The unit is field erected and consists of the following major components:

1. Centrifugal Compressor
2. Driver such as an electric motor and speed increaser, or steam turbine or gas turbine.
3. Cooler
4. Condenser
5. Liquid Intercooler
6. Control center and other controls
7. Necessary interconnecting piping and wiring.

## NOMENCLATURE



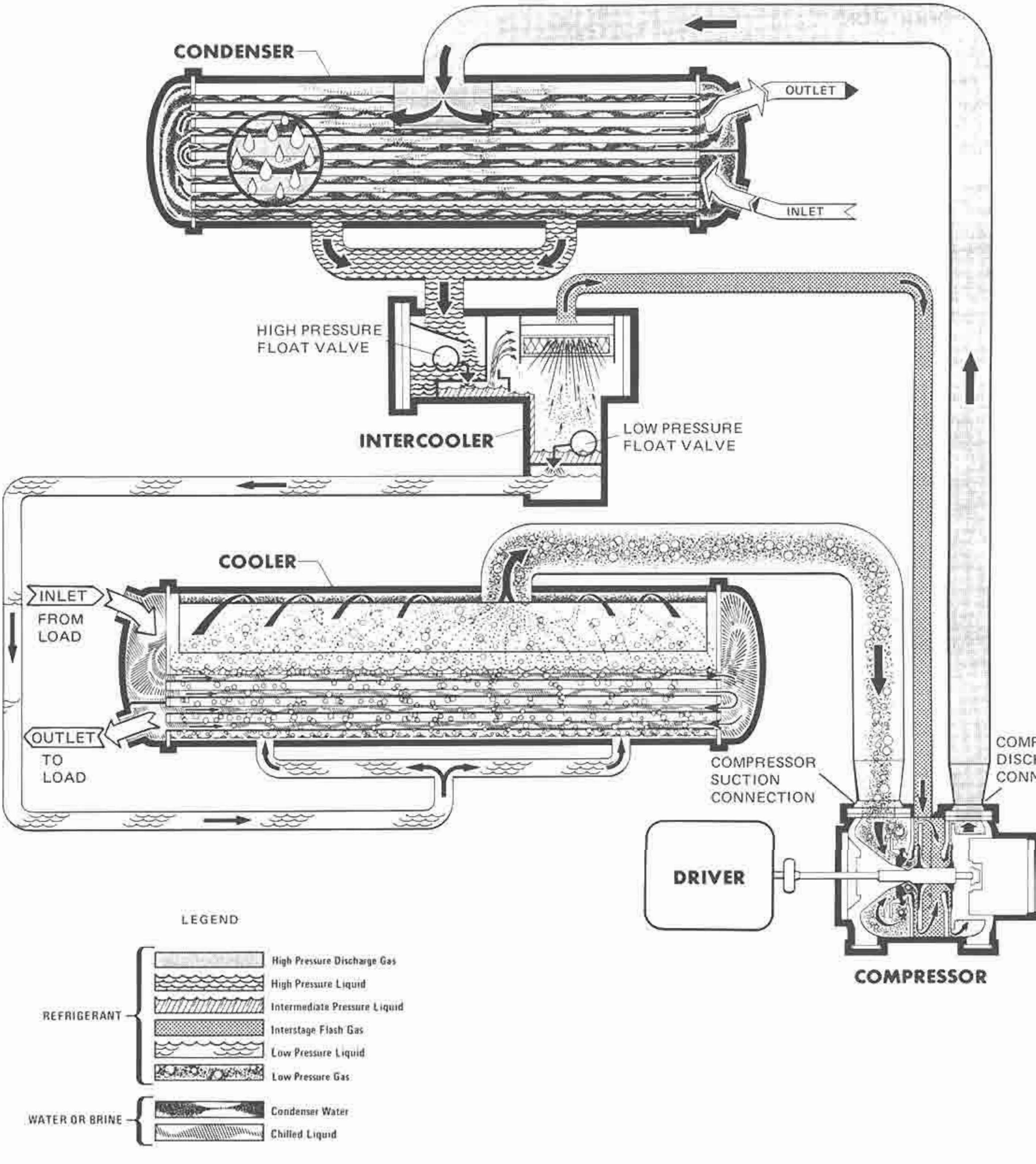



FIG. 1 — REFRIGERANT CYCLE

## REFRIGERANT CYCLE (REFER TO FIGS. 1, 2 & 3)

In operation, a liquid (water or brine) is chilled as it flows through the cooler, where evaporating refrigerant absorbs heat from the chilled liquid. The chilled liquid is then piped to the load. The warmed liquid is returned to the cooler to complete the chilled liquid circuit. (See Fig. 1.)

The refrigerant low pressure vapor, produced by the boiling action in the cooler, flows to the compressor through the compressor suction connection where the rotating impellers increase its pressure and temperature discharging it into the condenser.

Water flowing through the condenser tubes absorbs heat from the higher temperature refrigerant gas, causing it to condense into liquid. The condenser water is supplied to the unit from an external source, usually a cooling tower.

The liquid refrigerant at condensing pressure flows from the condenser into the intercooler high pressure chamber. As the liquid refrigerant level rises in the high pressure chamber the float ball is lifted, allowing the liquid to expand through the opening in the float valve into the intermediate pressure chamber where the pressure is reduced to that of the compressor second stage inlet (the inlet to the compressor second stage impeller wheel). As the refrigerant liquid expands, part of it flashes to a gas, cooling the remaining liquid to a temperature corresponding to the intermediate pressure. To permit adequate separation of the interstage flash gas from the mixture, the flash gas is routed through baffled passages (36" dia or smaller intercoolers) Fig. 2 or a filter (40" and 50" OD intercoolers) Fig. 3. The inter stage flash gas passes through eliminators in the intercooler and is introduced through a piping connection to the second stage of the compressor. The eliminator reduces the amount of entrained liquid refrigerant in the gas.

The cooled liquid refrigerant accumulates in the vertical drop leg of the intercooler causing the float ball to rise and open the valve permitting the liquid refrigerant to expand into the supply header to the cooler. The resulting mixture is distributed into the cooler through distribution baffles surrounding the tube bundle, completing the refrigerant cycle.

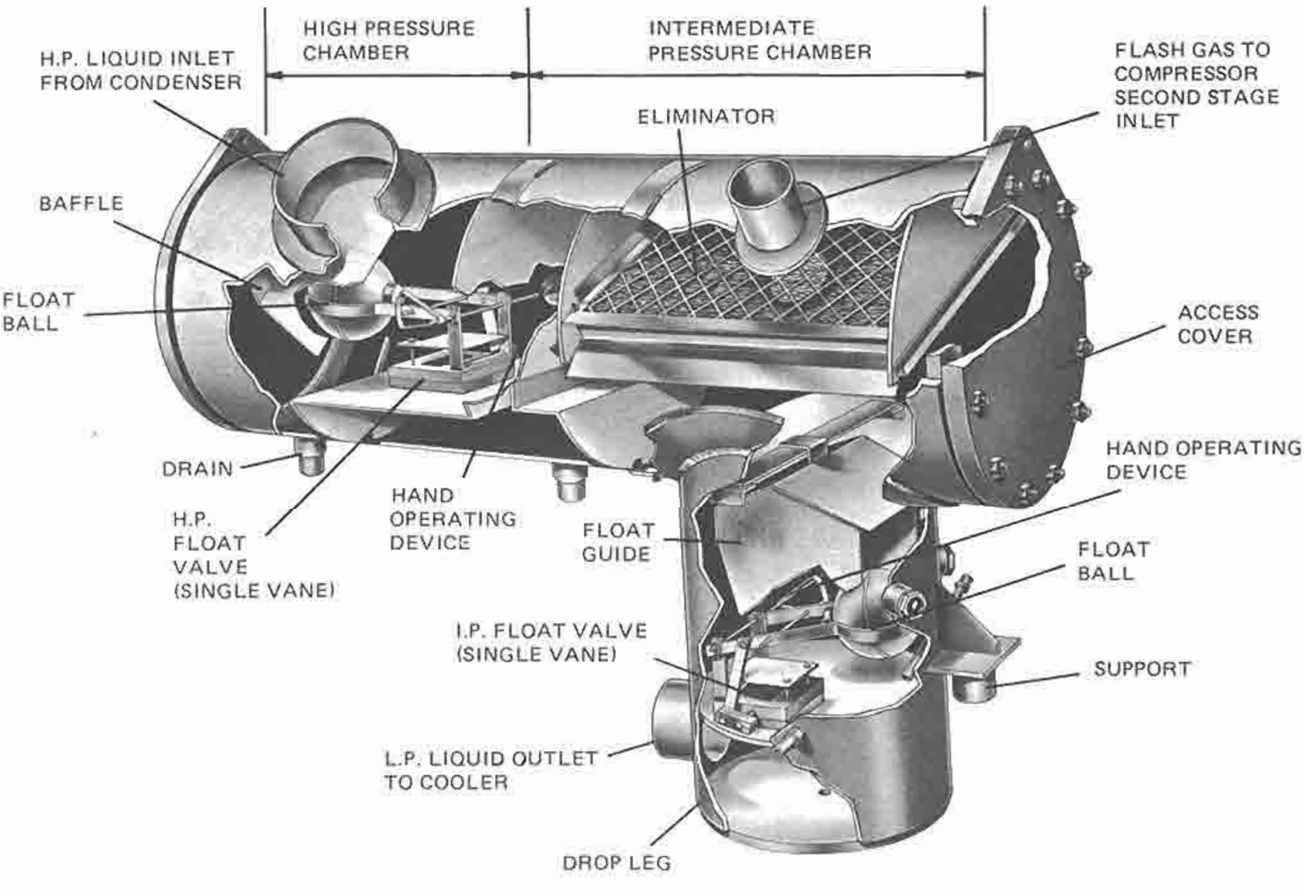



FIG. 2 – CUT-AWAY VIEW, SINGLE STAGE INTERCOOLER (36" DIA & SMALLER)

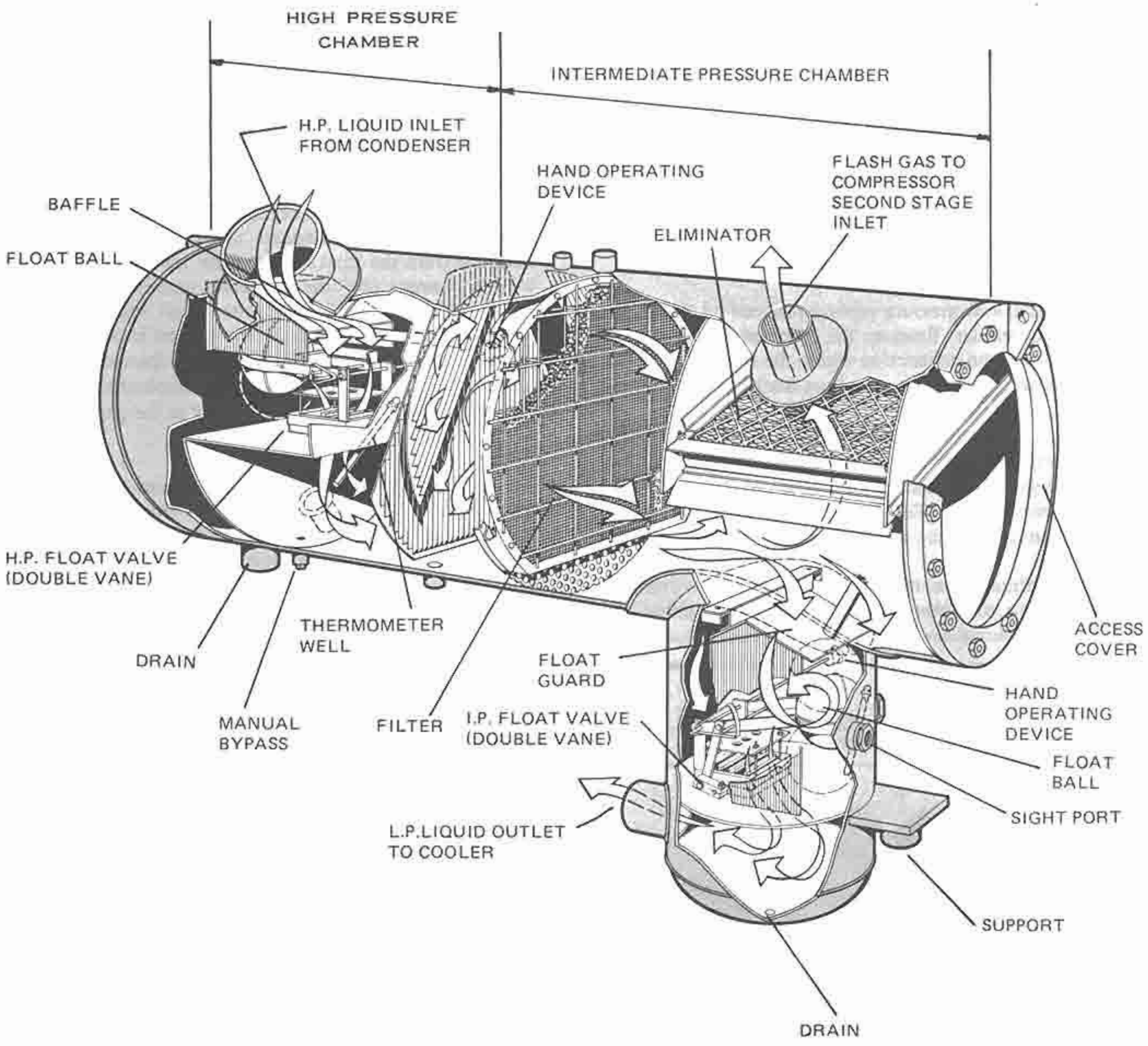



**FIG. 3** — CUT-AWAY VIEW, SINGLE STAGE INTERCOOLER (40" DIA. & LARGER)

# SECTION II
# COMPRESSORS

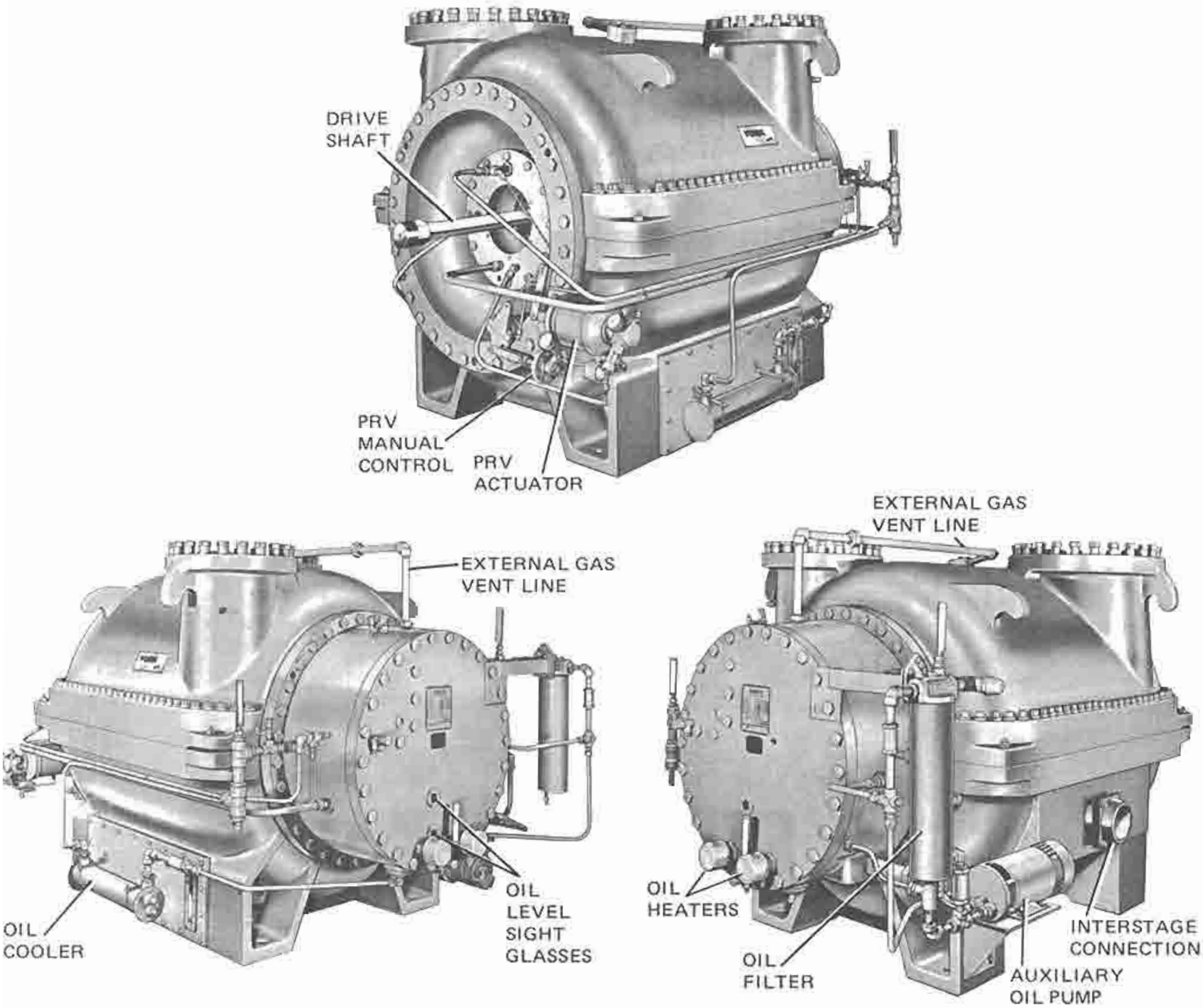



FIG. 4 — OM TURBOMASTER CENTRIFUGAL MULTI-STAGE COMPRESSOR

## GENERAL DESCRIPTION

The OM TURBOMASTER Centrifugal Compressor is a two-stage industrial type. The compressor casing is manufactured of close grain, high grade cast iron and is horizontally split to provide access to the rotor assembly. The casing top includes vertically oriented flanged suction and discharge connections. A flanged interstage gas connection for the intercooler is located on the side of the bottom casing. All major wearing parts (journal and thrust bearings, shaft seal and main oil pump) can be inspected or replaced without removing the upper half of the casing.

The rotor consists of a heat treated alloy steel main shaft and two aluminum alloy shrouded type impellers with backward curved blades. The rotor assembly is designed and constructed to resist corrosion and pitting, and to maintain initial balance and performance characteristics. It is designed to operate without vibration and is over speed tested, static and dynamically balanced. A balance piston on the second stage impeller minimizes axial thrust on the thrust bearing. A 3-1/2" gauge on the casing indicates the balance piston pressure.

The journal bearings are one piece aluminum alloy precision bored inset type and the thrust bearing is aluminum alloy hydro dynamic fluid film type designed to absorb any unbalanced axial thrust in either direction.

The drive shaft is manufactured of flexible alloy steel designed to provide access to the shaft seal and front journal bearing without disturbing the main drive alignment.

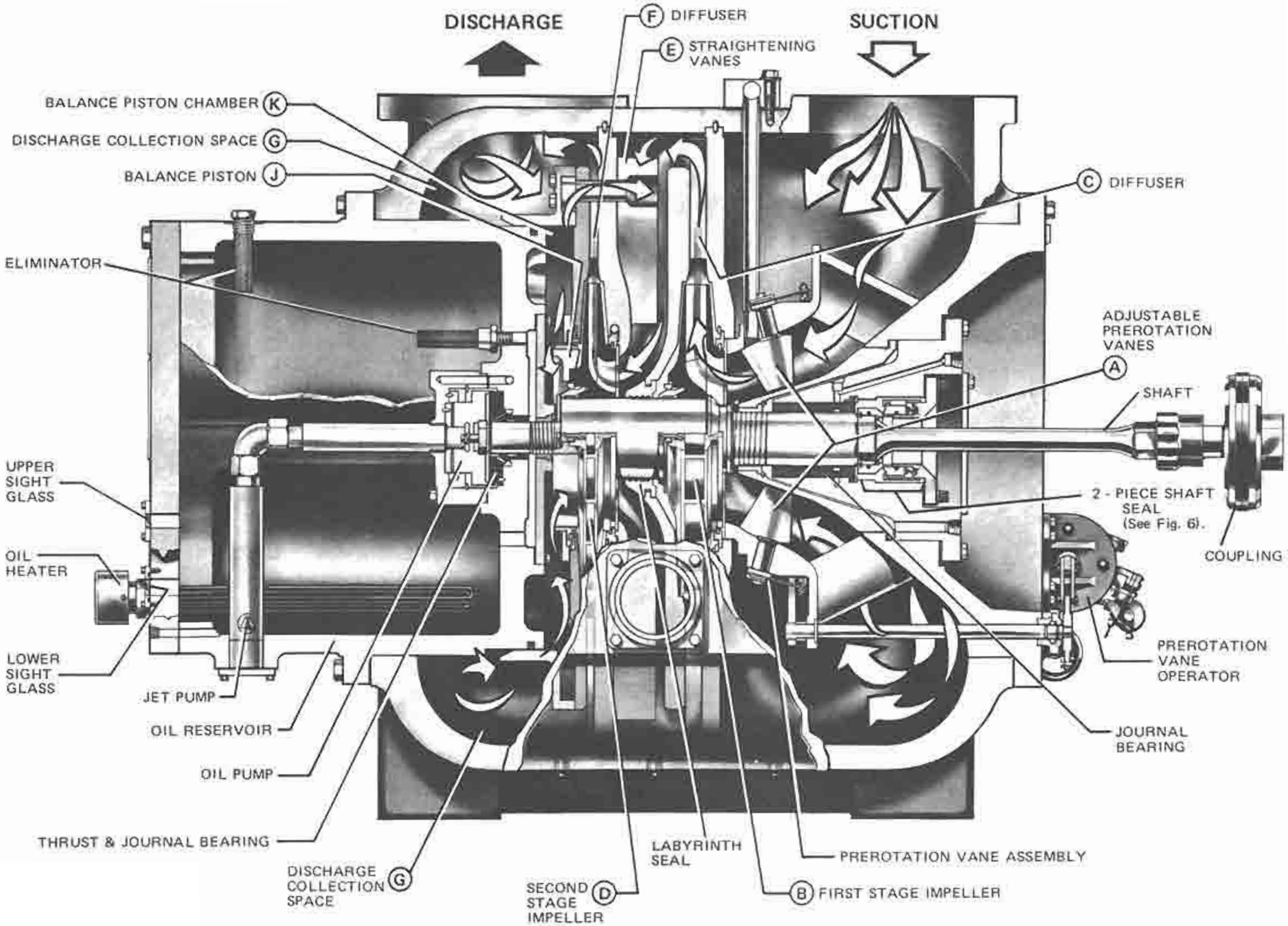



FIG. 5 — CUT-AWAY VIEW — OM CENTRIFUGAL COMPRESSOR

### External Gas Vent Line (See Fig. 4)

The compressor is equipped with an external vent line which carries refrigerant gas from the oil reservoir to the inlet of the first stage impeller. Gas flows into the reservoir from the oil return system and from the two oil seals described below.

### Internal Seals (See Fig. 5)

Labyrinth Seal

Gas leakage between stages is kept to a minimum by means of labyrinths mounted between the diffuser plates and the rotating shaft. The close radial clearance between the labyrinths and the rotor shaft reduces gas leakage along the shaft to a minimum.

Balance Piston Seal

Leakage from the high stage impeller along the balance piston is minimized by means of the balance piston seal ring. The balance piston seal ring assembly consists of floating seal ring in spring and balance piston cover. The close clearance between the floating ring and the rotating balance piston reduces gas leakage to a minimum.

Oil Seals

Oil leakage from the main bearings into the impellers is prevented by means of the oil seals, located on the rotor shaft inboard from the main bearings. These seals permit a slight gas leakage into the lubricating system which opposes and prevents oil leakage. The front seal is pressurized by a shaft hole from the second stage inlet while the rear seal is pressurized by the balance piston.

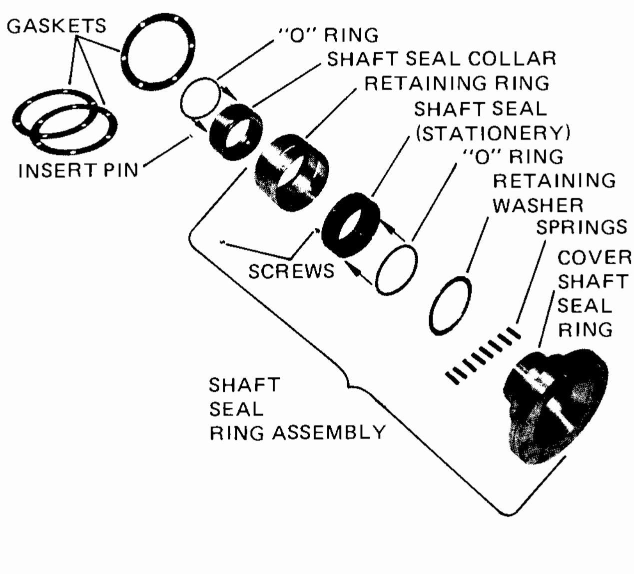



**FIG. 6** — SHAFT SEAL

### Shaft Seal (See Fig. 6)

Gas leakage along the shaft to the atmosphere is prevented by means of a spring loaded mechanical seal assembly, which consists of a rotating cast iron shaft seal collar with "O" ring, and a spring loaded carbon shaft seal ring assembly (consisting of 8 or 12 helical springs and "O" ring). These springs keep the carbon seal ring in contact with the rotating shaft seal collar.

The rotating collar driven by pins turns with the shaft, while the stationery carbon seal assembly is mounted on the shaft seal-cover and is prevented from rotating by keys. The friction surface between these parts is lubricated and cooled by the oil circulated through the seal cavity. (See the LUBRICATION SYSTEM and Fig. 7.)

## REFRIGERANT FLOW THROUGH COMPRESSOR (SEE FIG. 5)

The following paragraphs describe the path of the refrigerant gas flow through a TURBOMASTER Centrifugal Compressor and the effect upon the gas as it passes from the inlet to the discharge connection of the compressor.

Suction gas is drawn from the suction connection through the prerotation vanes Ⓐ and enters the first stage impeller Ⓑ . As the impeller rotates it imparts kinetic energy to the refrigerant gas in the form of velocity energy and pressure rise. The refrigerant gas then enters the diffuser Ⓒ where the velocity energy is transformed into pressure rise. The gas enters the straightening vanes Ⓔ prior to entering the second stage impeller Ⓓ in order to achieve a uniform and controlled flow plattern. A second impeller diffuser combination Ⓓ - Ⓕ discharges the refrigerant gas into a collection space Ⓖ where it enters the discharge connection to flow to the condenser.

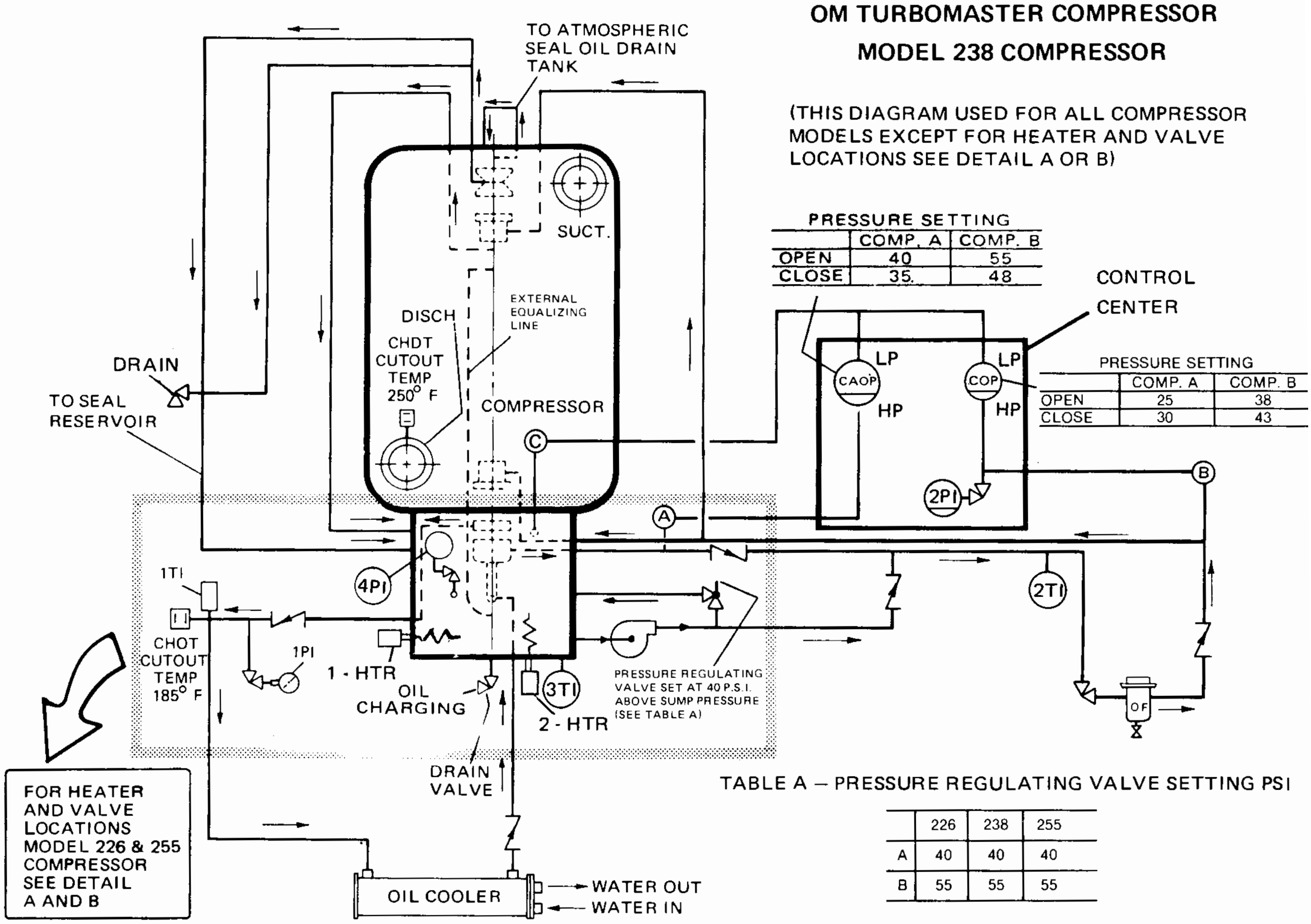
As a result of the pressure differential between stages, a thrust force is set up at each impeller, the higher pressure acting on the back of the impeller, with a lower pressure acting on the impeller inlet. The sum of these forces provide an axial thrust which is compensated for by the balance piston Ⓙ machined or attached as an integral part of the second stage impeller Ⓓ . The piston operates in a balance piston chamber Ⓚ and is vented to the previous stage. The high pressure on the front face of the second impeller acting against the lower pressure in the balance piston chamber behind the impeller provides a compensating force which almost balances the thrust of the rotating assembly. The amount of counter thrust has been carefully engineered to have a slight axial thrust in the direction of the coupling, thus preventing any shifting during load changes.

## THE LUBRICATION SYSTEM

The lubrication system consists of the main oil pump, auxiliary oil pump, oil filter, oil cooler, the oil reservoir and all interconnecting oil piping. (See Fig. 7.) There are four main points of lubrication within the YORK TURBOMASTER

# OIL FLOW DIAGRAM
## OM TURBOMASTER COMPRESSOR
## MODEL 238 COMPRESSOR

(THIS DIAGRAM USED FOR ALL COMPRESSOR MODELS EXCEPT FOR HEATER AND VALVE LOCATIONS SEE DETAIL A OR B)




PRESSURE SETTING (CAOP)

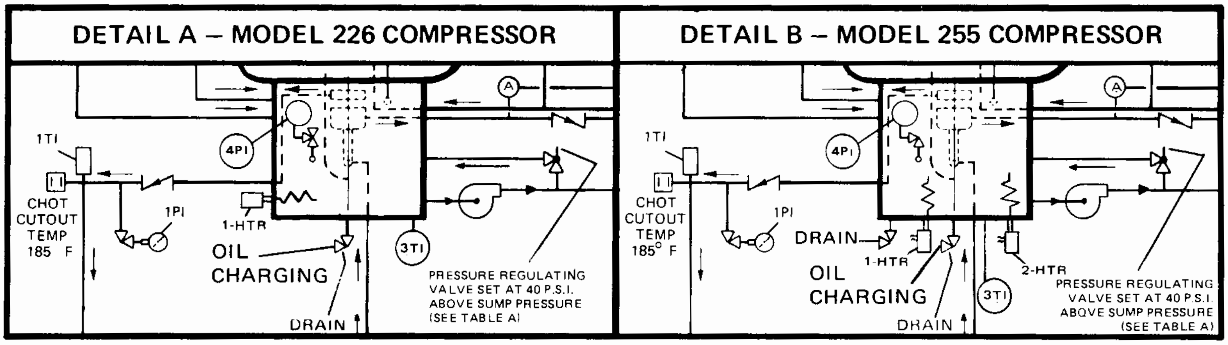
| | COMP. A | COMP. B |
|---|---|---|
| OPEN | 40 | 55 |
| CLOSE | 35. | 48 |

PRESSURE SETTING (COP)

| | COMP. A | COMP. B |
|---|---|---|
| OPEN | 25 | 38 |
| CLOSE | 30 | 43 |

TABLE A – PRESSURE REGULATING VALVE SETTING PSI

| | 226 | 238 | 255 |
|---|---|---|---|
| A | 40 | 40 | 40 |
| B | 55 | 55 | 55 |




### LEGEND

| | |
|---|---|
| | Auxiliary Oil Pump |
| | Seal |
| | Journal Bearing |
| | Thrust Bearing |
| | Centrifugal Main Oil Pump |
| | Vertical Jet Oil Pump |
| OF | Oil Filter |
| | Seal Cap Angle Stop Valve |
| | Screw Check Valve |
| | Heater |
| | Flow Lines |
| 1TI | Thrust Bearing Oil Temp. (Thermometer) |
| 2TI | Bearing Supply Oil Temp. (Thermometer) |
| 3TI | Sump Oil Temp. (Thermometer) |
| CHOT | Thrust BRG. Oil Thermoswitch |
| CHDT | Discharge Temp. Thermoswitch |
| 1PI | Thrust Oil Press. Gauge |
| 2PI | Bearing Oil Press. Gauge |
| 4PI | Compressor Balance Piston Press. |
| (A) | To HP Side of CAOP |
| (B) | To HP Side of COP |
| (C) | To LP Side of COP & CAOP |
| 1HTR | Heater 1000W |
| 2HTR | Heater 1000W |
| COP | Oil Pressure (Compressor) Differential Control |
| CAOP | Aux. Oil Pump Oil Press. Differential Control |
| | Pressure Regulating Valve |

**FIG. 7** – SCHEMATIC OIL FLOW DIAGRAM

Compressor which must be supplied with forced feed lubrication by the oil pumps as follows:

1. Thrust Bearing
2. Journal Bearing -- Suction End
3. Journal Bearing -- Discharge End
4. Shaft Seal

The centrifugal main pump is bolted to and is directly driven by the end of the rotor shaft.

### The Oil Circuit

To trace the oil flow through the compressor, refer to Fig. 7. The centrifugal main oil pump on the end of the rotor shaft takes suction from the oil reservoir and discharges through a 15 micron oil filter.

From the filter, the oil flow is divided as follows:

1. Part of the oil flows to the discharge end journal and thrust bearing.

2. The remainder flows to the suction end of the compressor to lubricate the journal bearing and shaft seal.

At the discharge end, oil from the filter enters a drilled passage in the side of the oil sump housing and flows to the space around the shaft, at the location of the combination thrust and discharge end main bearing. From this space, part of the oil passes through the main bearing toward the impellers and the remainder passes toward the oil pump (between the shaft and thrust bearing) to the load surface of the thrust bearing.

Oil passes through the discharge end journal bearings toward the impellers and into the space between the oil sump and seal ring housing. This oil drains into the oil reservoir.

The oil sump pressure is equalized with the first stage impeller inlet pressure as outlined under EXTERNAL GAS VENT LINE.

The oil which lubricates the thrust surface (inboard surface of oil pump and outboard surface of thrust bearing) flows through the cooler and returns to the centrifugal oil pump suction via the oil jet pump. As oil flows through the jet pump, additional oil from the oil sump is induced to flow to the compressor oil pump suction.

The oil which flows from the filter to the suction end of the compressor enters the bearing housing and flows through a drilled passage to a circular space around the suction end journal bearing. The journal bearing is drilled radially to permit the oil to flow into the bearing surfaces. Part of this oil flows through the journal bearing (toward the impellers) and drains back to the reservoir through the external oil return line.

The remainder of the oil in the suction end main bearing flows into, and completely floods the shaft seal. From the shaft seal, the oil returns to the oil reservoir. Any oil leaking through to the atmospheric side of the shaft seal drains by gravity to the oil drain tank which is cast into the underside of the compressor housing.

The discharge end oil seal is designed so that some gas from the balance piston leaks into the oil reservoir.

## CHECKING OIL TEMPERATURES

To facilitate checking oil temperatures in the lubrication system, thermometers are located as follows:

1. In the oil line leaving the thrust bearing.

2. In the main oil line to the oil filter.

3. In the oil sump.

## OIL SUMP HEATER

During periods of shutdown and also during operation, the oil in the oil sump tends to absorb refrigerant, the amount depending upon the temperature of the oil and the pressure in the oil sump.

To keep the refrigerant concentration to a minimum during normal or short shutdown periods, one thermostatically controlled oil heater for 226 compressor or two thermostatically controlled heaters for 238 and 255 compressors, are installed in the oil sump housing. These heaters are factory set at 150°F.

Heaters must be turned on during shutdown and off during operation (at the same time the auxiliary oil pump stops). The heaters are automatically controlled, however they should be checked to assure proper operation. [Refer to Form 160.71-NM1.1 and 160.71-W1.1 (Motor Drive), or 160.71-W1.2 (Turbine Drive).]

## AUXILIARY OIL PUMP

The Auxiliary Oil Pump is mounted on the side of the compressor. (See Fig. 4.) This pump is automatically controlled, through the auxiliary oil pressure differential control (CHOP) mounted in the control center.

The primary function of the auxiliary oil pump is to automatically furnish oil to the compressor lubrication system on startup while the main oil pump is coming up to speed, on shutdown while the rotor is coming to rest, or at any time the main oil pump fails to function during operation.

On variable speed drives, the auxiliary oil pump may be required to operate at low compressor speed if the main oil pump can not develop adequate oil pressure.

This pump is fed from the compressor oil sump.

The auxiliary oil pump discharges oil through a check valve to the oil filter. The oil discharges from the oil filter feeding the shaft bearings. The pressure regulating valve is set at 40 or 55 psi depending on the compressor (See Fig. 7 Table A for correct setting), will open, relieving the pressure from the discharge line circulating oil back to the compressor sump, if the oil pressure becomes excessive.

During normal compressor operation, the auxiliary oil pump does not operate. The Manual-Automatic Switch should be set at "Automatic" during operation, and should be switched "Off" at shutdown after the compressor stops rotating.

## PREROTATION VANES

The function and use of the prerotation vanes as a method of capacity control is explained under capacity control (page 17.)

The prerotation vanes are pneumatically operated and will automatically open or close in accordance with load requirements.

If the pneumatic system fails, manual adjustment of the vanes may be accomplished by disconnecting the linkage to the PRV actuator and connecting the linkage to a handwheel on a bracket at the coupling end of the compressor.

### Model 226 and 238 Compressor

An insert pin serves as an indicator on the operating linkage and the "O" (open), "C" (closed) and "R" (reverse) positions respectively are stamped on the compressor or shaft control cover.

### Model 255 Compressor

An insert pin on the external lever serves as an indicator and the "O" (open) and "C" (closed) position are stamped on the compressor shaft control cover. Turning the handwheel so the insert pin is on "O" opens the vanes to the full open position and when the pin is on the "C" the vanes are in a closed position.

### Air Pressure

The compressor is equipped with a PRV actuator for automatic prerotation vane operation. The supply air pressure to the motor should be 100 psig maximum and 50 psig minimum for Model 226 compressors, 60 psig minimum for Model 238 compressors and 70 psig minimum for Model 255 compressors.

Air consumption will vary from static to 3.50 cfm dynamic with 100 psig air supply pressure. (If Free Cooling is used, 80 psig minimum required.)

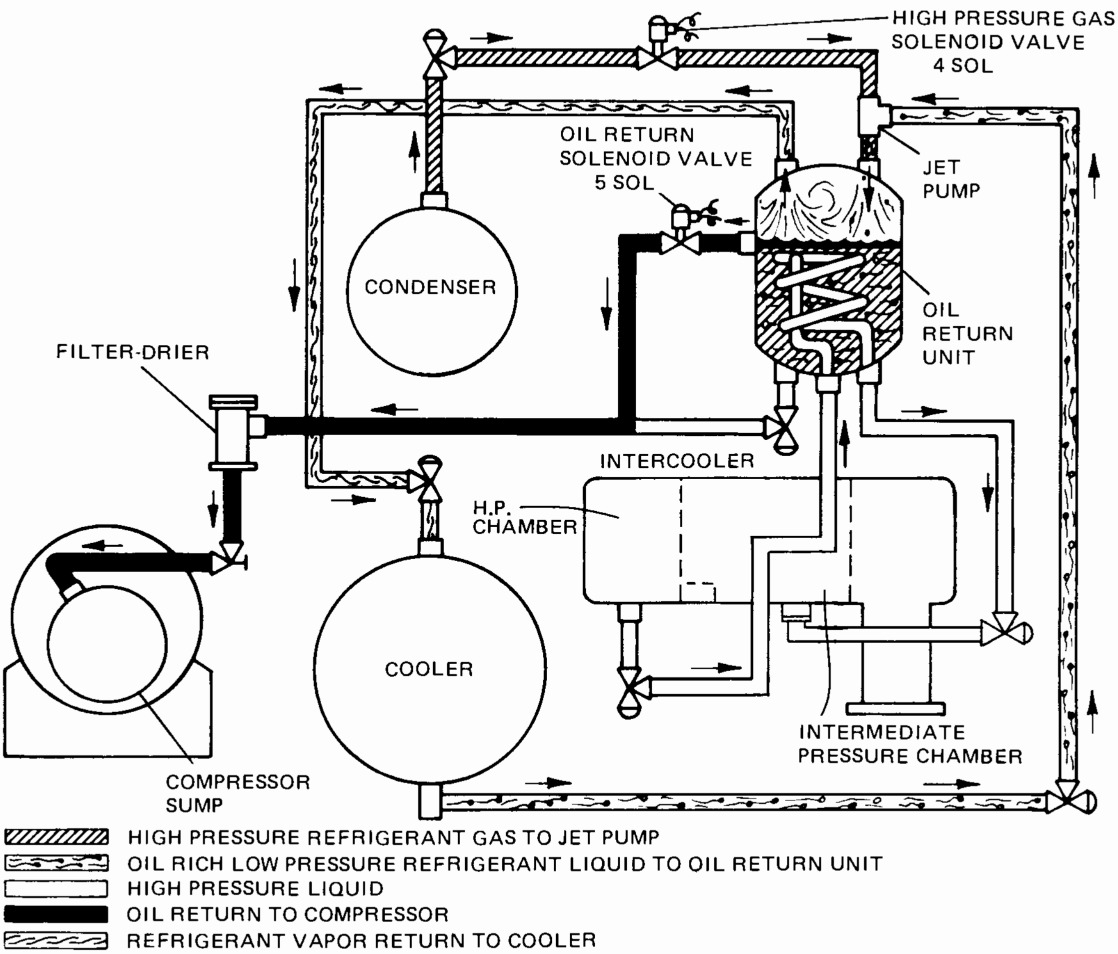



**FIG. 8** — OIL RETURN SYSTEM

## OIL RETURN SYSTEM

### Automatic Oil Return ( Refer to Fig. 8 )

OM Turbomaster Units are equipped with an automatic oil return system which returns oil to the compressor oil reservoir.

### Operation:

One hundred seconds after the unit has started to run, the two oil return system solenoid valves are energized to open, starting the oil return system to operate. The high pressure gas solenoid (4SOL) allows high pressure refrigerant gas to flow through the jet pump inducing low pressure oil rich refrigerant liquid to flow from the cooler to the oil return unit shell. When the oil rich liquid enters the oil return unit it collects at the bottom of the shell, surrounding the heat exchanger coil.

The coil is supplied with liquid from the intercooler. High pressure liquid circulates from the intercooler high pressure chamber, through the coil of the oil return unit and returns to the intercooler intermediate pressure chamber. The high pressure liquid in the coil has a higher temperature than the low pressure oil rich liquid surrounding the coil. The exchange of heat causes the low pressure liquid to boil, causing the oil to foam and concentrate on the top of the refrigerant liquid. The oil and some refrigerant flow through the open oil return solenoid and a filter-drier to the compressor oil sump. The boiled off refrigerant vapor is returned through a connection located at the top of the oil return shell to the top of the cooler.

The oil return system operates constantly during the unit operation.



# SECTION III
# SHELL ASSEMBLIES

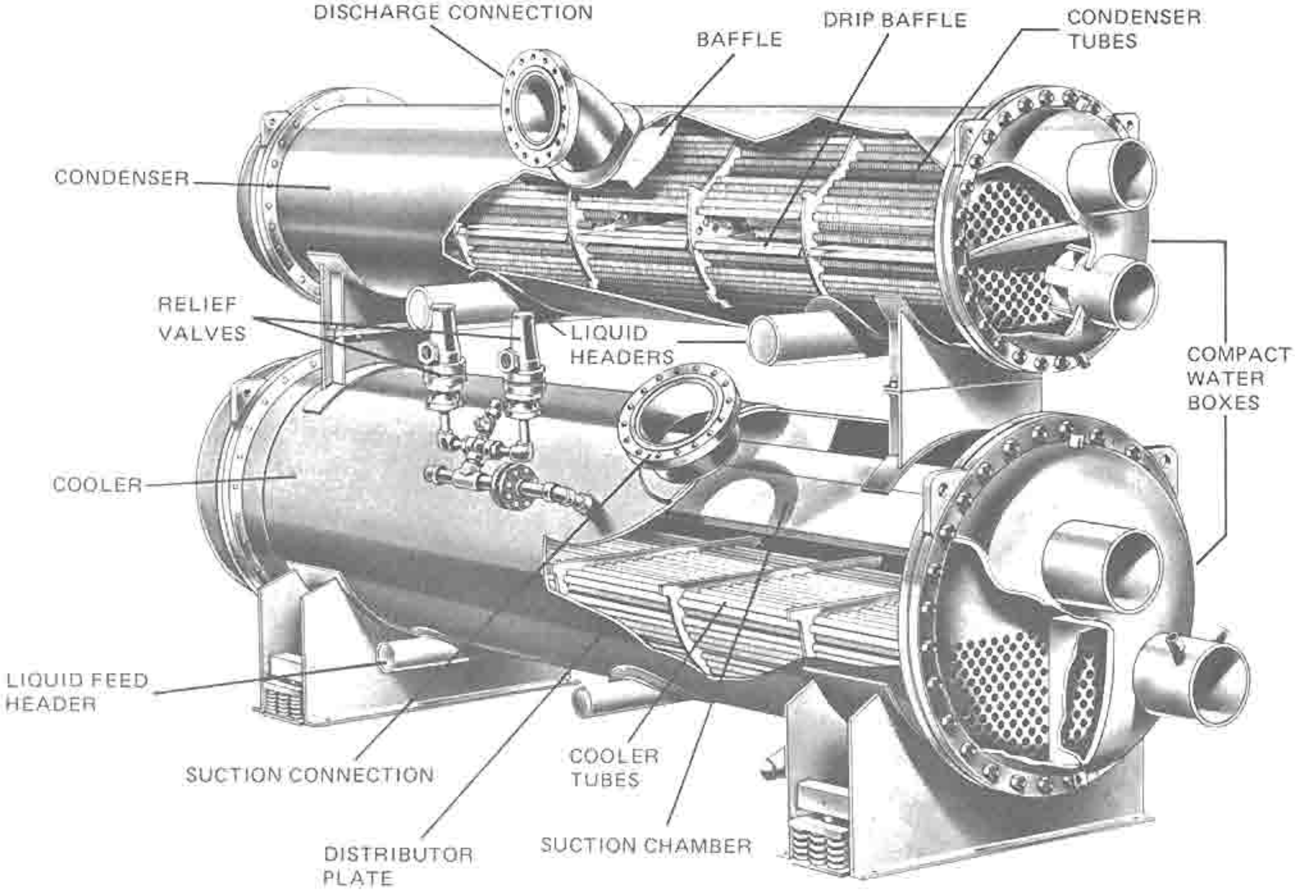



FIG. 9 — SHELL ASSEMBLIES

## INTRODUCTION

The shell of each heat exchanger is formed from rolled steel plates with necessary longitudinal and girth seams fusion welded to complete the shell. Tube sheets are welded to each end of the shell to support the tube ends and accommodate the sealed joint with the tubes. Internal tube supports are spaced as necessary to suit the tube length. Each shell is furnished with integral supporting stands. All shells are designed, constructed, tested and stamped in accordance with Section VIII of the ASME code for Unfired Pressure Vessels and conform with the ANSI-B9.1 Safety Code.

The tubes are 3/4" seamless copper heat exchanger type. Tube ends are roller expanded into the tube sheets and are individually replaceable.

Compact Water Boxes

Each end of the heat exchanger is provided with a fabricated dished head type, removable compact water box assembly. The compact water box has axially oriented pipe stub-out water connections suitable for welding to connecting fill pieces or flanges. The water box connections are provided with welded closures for shipment. Steel water baffles are furnished for 2 or 3 pass arrangements with vent and drain connections (plugged for shipment). Water boxes are gasketed and bolted to the shell. Lifting lugs are provided to facilitate removal. The Design Working Pressure is 150 psig.
(Optional marine style water box designs are available, either fixed or removable type).

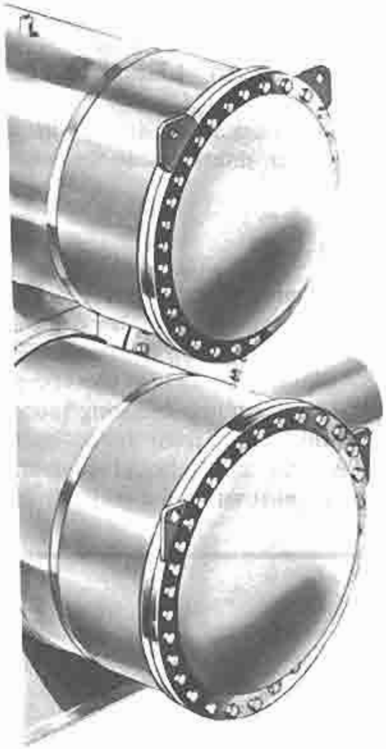


**FIG. 11** — INTEGRAL MARINE WATER BOX (OPTIONAL)

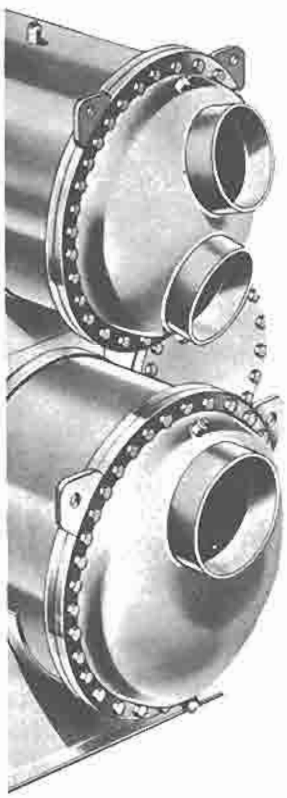


**FIG. 10** — COMPACT WATER BOX

**FIG. 12** — BOLTED-ON MARINE WATER BOX (OPTIONAL)

## COOLER

The Cooler is a horizontal, flooded, shell and tube type and the refrigerant side design working pressure is as follows:

R-12 – 135psig
R-500 – 165psig
R-22 – 225psig

Each cooler has two 4" sight ports, and is furnished with series connected relief valve and bursting disc assemblies in accordance with ANSI-B9.1 safety code. A baffle is located under the tube bundle to distribute the incoming refrigerant liquid and flash gas. The top portion of the shell provides space for liquid separation and gas flow. A steel suction baffle, located on top of the shell and extending nearly the full length of the tubes minimizes liquid carryover to the compressor.

A hot gas by-pass inlet connection is located on the side of the shell. A gas impingement distributor is located within the shell to provide an even distribution of the hot gas as it enters the cooler. Liquid transfer, pumpout and gauge connections are provided.

## CONDENSER

The condenser is a horizontal shell and tube type with a design refrigerant side working pressure as follows:

R-12 – 150psig
R-500 – 180psig
R-22 – 250psig

The condenser includes a gas impingement baffle beneath the gas inlet connection. Larger condensers are furnished with baffles in the tube bundle to enhance gas distribution and condensate drainage. Dual liquid outlet connections are provided for effective liquid drainage. Hot gas bypass, pumpout and gauge connections are provided.

## INTERCOOLER

The intercooler is an external horizontal type consisting of high, intermediate and low pressure chambers. The intercooler includes, a liquid inlet deflector plate; a YORK float valve in the high pressure chamber; interstage gas mist eliminators; a YORK float valve in the intermediate pressure chamber; manual float valve adjusters; thermometer wells for high and low pressure chambers; 2" sight ports for observation of the float valves; bolted-on cover plates for float valve and eliminator accessibility; necessary connections for high pressure liquid inlet, interstage flash gas and a low pressure liquid outlet.

SECTION III

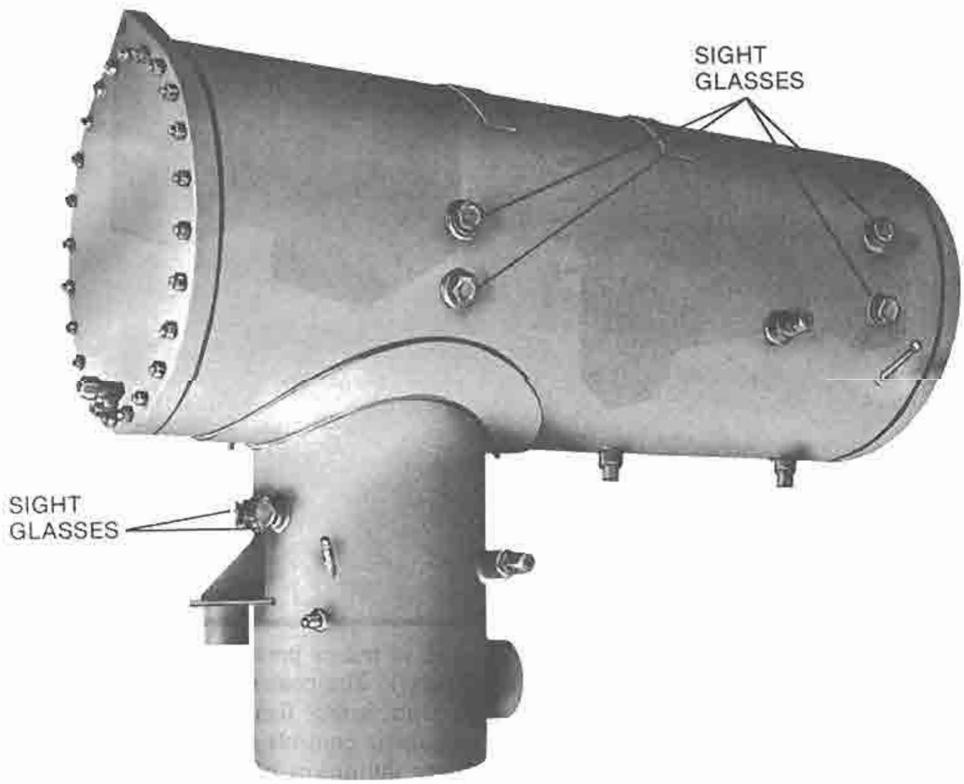



FIG. 13 – INTERCOOLER

# SECTION IV
# CONTROLS

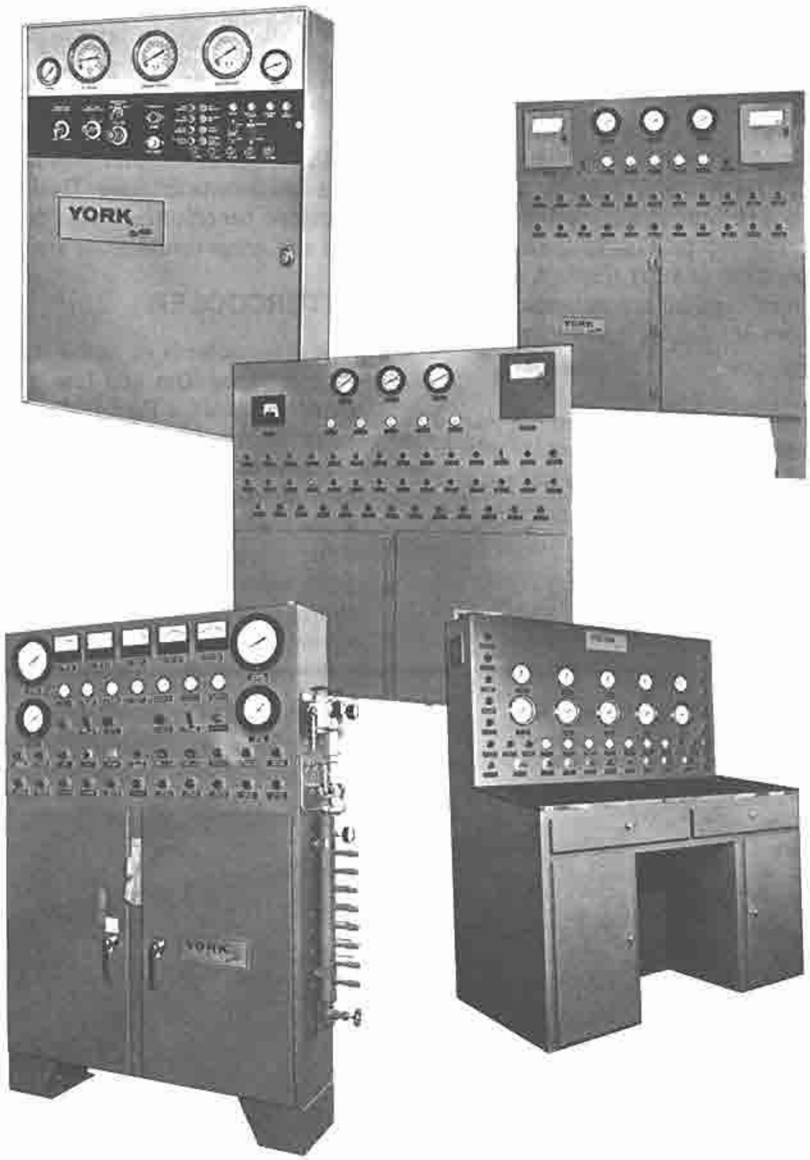


FIG. 14 – TYPICAL CONTROL CENTERS

## CONTROL CENTER

The control center is an eye level enclosure, custom designed, internally factory wired and piped and provided with a floor stand. It is installed adjacent to the compressor. The electric power supply required is 115V-1PH-50/60 Hz and the control center is fused with 15 ampere fuses. The pneumatic control system requires 3.50 SCFM, (includes automatic hot gas by-pass, automatic interstage valve, PRV) air supply at 100 psig (a filter regulator is supplied to reduce pressure to 20 psig for pneumatic controls supply.) The control center includes all necessary gauges, controls, safety lights, relays, timers, terminal blocks and pneumatic controls necessary for automatic operation and safety shutdowns of the OM Turbomaster Unit. For description and operation of the various control center components and external controls, see Instruction 160.71-NM1.1 and Wiring Diagram Motor Drive 160.71-W1.1 or Turbine Drive 160.71-W1.2.

## CAPACITY CONTROL

### General

The OM TURBOMASTER Liquid Chilling Unit is designed to operate at various load conditions with maximum efficiency. Capacity is controlled to maintain a nearly constant chilled water temperature leaving the cooler under all conditions. Prerotation vanes (PRV) located within the compressor near the inlet to the first stage impeller, compensate for variation in load. The position of the vanes is automatically controlled through a lever arrangement attached to a pneumatic PRV actuator motor located on the outside of the compressor housing. The automatic adjustment of the vane position, in effect, alters the compressor performance characteristic to match various load conditions encountered during hour by hour operation of the unit, from full load with vanes open to a minimum load with vanes partially closed.

At low load conditions, after the PRV is partially closed and the interstage modulating valve begins to close, the hot gas by-pass and liquid injection valves open to extend the low load operating capability of the compressor. (See HOT GAS BY-PASS AND LIQUID INJECTION, and CAPACITY CONTROL AND SEQUENCE OF OPERATION.) Page 19.

### Operation (Motor Driven Unit)

With the unit in a pre-start condition the air signal to the prerotation vane actuator is exhausted to the atmosphere and the prerotation vanes, the interstage valve and the hot gas valve are closed. When the starting cycle is initiated the vanes will open slightly as determined by the "minimum Opening" setting on the electronic restrictor. The vanes will continue to open after the compressor has achieved operating speed, which will occur after the motor starter has transferred the motor connection to the running condition. When operating speed is achieved and if the compressor motor current requirement is within the limit permitted by the setting of the "Maximum Load Adjustment," the current limit relay (CLR) will open to impose signal air at the prerotation vane actuator, thus opening the vanes to the extent permitted by the adjustment setting. The desired control conditions are established by adjusting the "MAXIMUM LOAD ADJUSTMENT in %" and the WATER TEMPERATURE "CONTROL POINT" setting. The interstage valve is set to modulate in conjunction with the PRV actuator for control of the intermediate pressure in the intercooler.

During normal operation, as the heat load increases, the cooler water temperature will rise. The temperature sensor will respond to the rise, signaling the temperature controller. The temperature controller will cause the prerotation vanes to open, maintaining the desired leaving cooler water temperature as indicated by the "Temperature Control Point" setting on the control center.

If the unit is not operating and the Low Water Temperature light is "ON", the Low Water Temperature Cutout (LWT) stops the unit operation. This results when the heat load decreases below the capacity capability of the unit, causing it to lower the leaving cooler water temperature to the setting of the "Low Water Temperature Cutout" (LWT) 38°F. When the unit is stopped the current limit relay (CLR) exhausts the pneumatic signal causing the prerotation vanes to close. The compressor will automatically restart when the cut-in temperature setting of the Low Water Temperature Control (LWT) 45°F is sensed. This also de-energizes the Low Water Temperature Light.

During normal operation a reduction in the heat load will cause the prerotation vanes to automatically close and the hot gas valve to open to a position necessary for maintaining a constant leaving chilled water temperature.

The opening and closing of the vanes is controlled by the Water Temperature controller. See CAPACITY CONTROL for low load sequence of operation.

### Operation (Turbine Driven Unit)

When the unit is started solenoid valve (2-SOL) located in the control center is energized to allow signal pressure to to flow to the PRV actuator and the interstage valve. When operating speed is achieved the temperature controller (TC) permits a flow of signal pressure to the PRV actuator and the interstage valve. The PRV will open to the "Temperature Control Point" setting of the Temperature Controller (TC). The interstage valve is set to modulate in conjunction with the PRV actuator to allow the required interstage refrigerant flash gas to enter the second stage of the compressor.

During normal operation, if the heat load increases the cooler temperature will rise. The temperature controller will cause the prerotation vanes to open maintaining the desired leaving water temperature as indicated by the "Temperature Control Point" setting on the control center.

If the unit is not operating and the Low Water Temperature light is "ON" the Low Water Temperature Cutout (LWT) has stopped the unit operation. This results when the heat load decreases below the minimum capacity of the unit, causing it to lower the leaving cooler water temperature to the setting of the Low Water Temperature Cutout (LWT) 38°F, causing the compressor to stop. The 3-way air solenoid valve will be de-energized venting the signal pressure to the atmosphere. During normal operation a reduction in the heat load will cause the prerotation vanes to close to a position necessary for maintaining a constant leaving chilled water temperature. If the load continues to decrease after the vanes are closed automatically to the setting of the CAPACITY CONTROL SYSTEM, the unit will be stopped by the Low Water Temperature Cutout (LWT).

During normal operating periods, the prerotation vanes will automatically open and close under the control of the Water Temperature Controller. (See Form 160.71-NM1.1 for a description of all controls.) SEE CAPACITY CONTROL SEQUENCE OF OPERATION, page 19.

## HOT GAS BY-PASS AND LIQUID INJECTION

The purpose of hot gas by-pass and liquid injection is to keep the compressor from surging when low load conditions prevail (spring, fall, winter, morning or night time operation). In other words, the compressor is not loaded with refrigerant vapor during this period of operation as the cooler demand is insufficient to satisfy the capacity of the compressor.

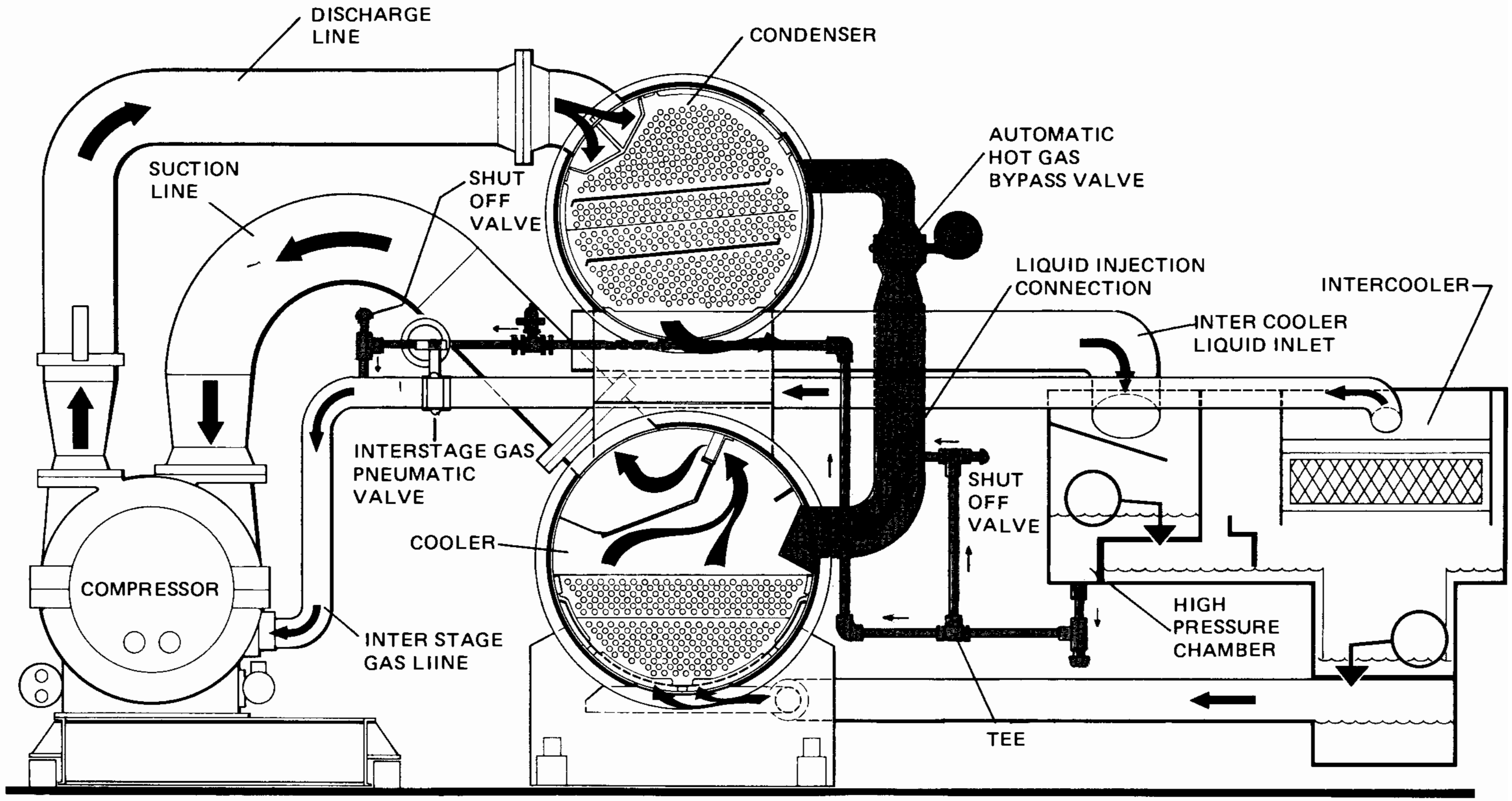



FIG. 15 — HOT GAS BY-PASS AND LIQUID INJECTION LINE

To compensate for this, a hot gas by-pass valve and liquid injection valve are controlled automatically to more efficiently stabilize the operation of the compressor. (See Fig. 15.)

The hot gas by-pass consists of a piped connection from the condenser to the cooler. This connection includes the automatic HGBP Valve with necessary pneumatic controls. The liquid injection system consists of a piped connection from stream of the HGBP valve. These shut-off valves should be opened during unit operation.

### Operation

The minimum PRV setting is determined during the initial running of the unit to prevent the vanes from completely closing at low load conditions. When low load conditions exist, the automatic hot gas by-pass valve opens because of the pressure setting of the pneumatic controls, and the signal of the low temperature control. The opening of the HGBP valve allows high pressure hot gas to be forced through the valve, and at the same time high pressure liquid refrigerant is injected into the hot gas by-pass line desuperheating the hot gas before it enters the cooler. This desuperheated refrigerant gas enters cooler and mixes with the boiled off refrigerant vapor in the top of the cooler. The additional supply refrigerant vapor provides an increased volume to the compressor suction, preventing the compressor from surging.

## COMPRESSOR SOUND CONTROL LIQUID INJECTION

The sound control liquid line injects liquid refrigerant from the high pressure chamber of the intercooler into the interstage flash gas line. The excess liquid is pulled into the second stage of the compressor, reducing the noise level of the compressor during operation at all load conditions. A solenoid valve (6SOL) in the liquid injection line prevents its operation until the starter run interlock is completed (or for the first 100 seconds of operation – Turbine Units).

The valve to the interstage line should be adjusted to result in 1°F superheat in the discharge gas.

## HOT GAS BY-PASS AND LIQUID INJECTION COMPONENTS

#### Automatic Hot Gas By-Pass Valve

The Automatic hot gas by-pass valve is controlled pneumatically. At normal or full load conditions the valve will remain closed while the signal air pressure to the HGBP valve positioner is between 15 psig and 9 psig. With the unit operating and approaching low load conditions, (before the compressor reaches a surge condition) the HGBP valve will begin to open. The valve will continue to open and will become fully open when the signal pressure is 3 psig. The valve will close when the signal air pressure increases and is fully closed at 9 psig.

The valve contains an Auto-Manual switch that should be set on "Auto" for normal operation. When the switch is set on "Manual" the valve will open. The "Manual" setting is used for checking the operation of the valve. See CAPACITY CONTROL SEQUENCE OF OPERATION.

#### Liquid Injection

Liquid injection is accomplished through a small piping connection from the high pressure liquid chamber of the intercooler to the hot gas by-pass line downstream of the hot gas by-pass valve. The high pressure liquid mixes with the hot gas, preventing the compressor from over heating at low load conditions. Isolation valves at each end of the liquid injection line must be open during normal operation.

## CAPACITY CONTROL SEQUENCE OF OPERATION

The capacity of the OM Turbomaster Unit is controlled by the control center. A pneumatic control system controls the operation efficiently at all load conditions. This system operates the PRV, Hot Gas By-pass Valve and the Interstage Modulating Valve. Refer to Fig. 17.

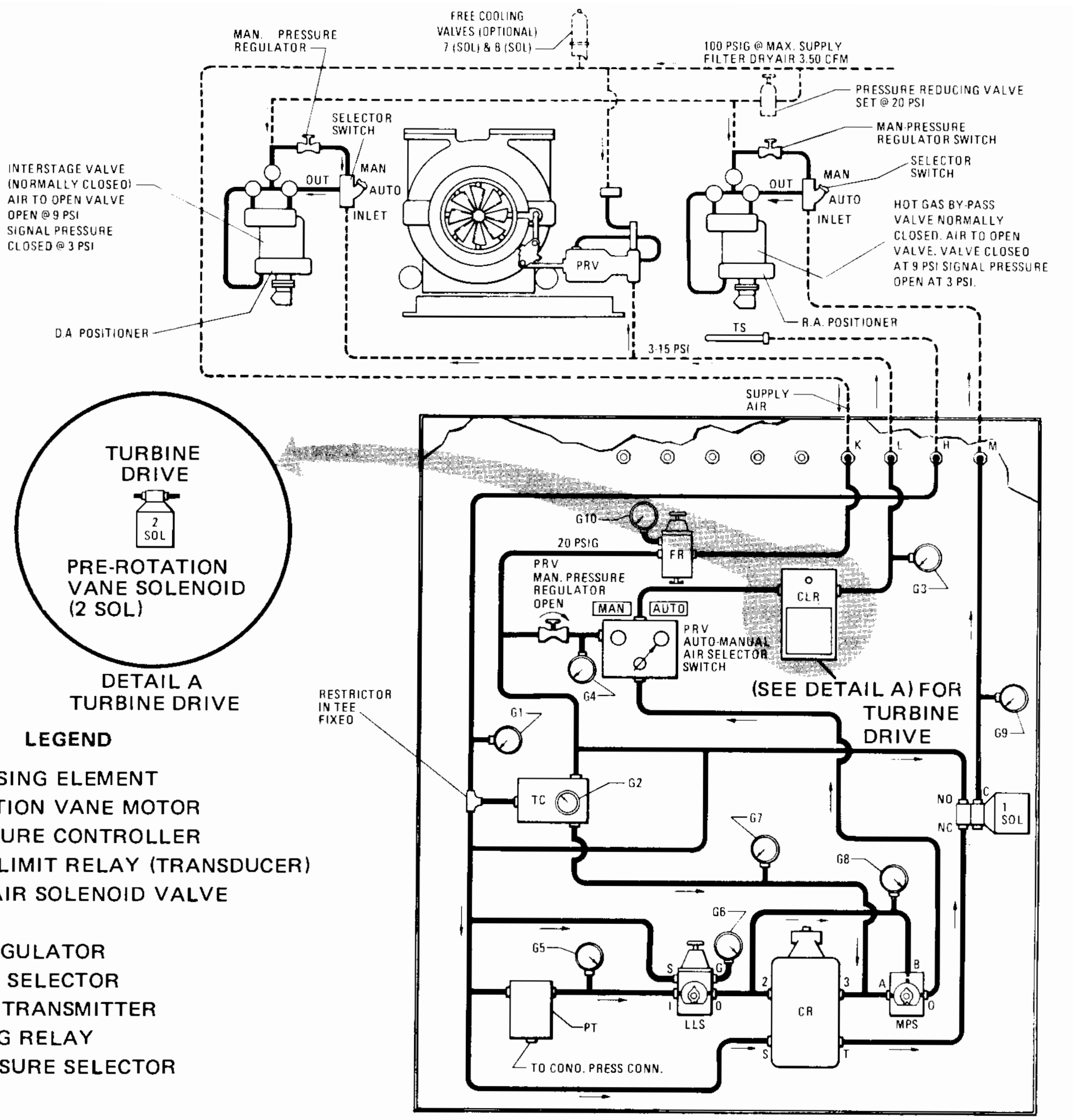
During normal operation the following unit conditions exist:

> The condensing pressure corresponds to a normal high head condition and the air signal from the Pressure Transmitter (PT) is at its normal high head set point. The compressor is operating at full capacity with the PRV fully open and the air signal from the Temperature Control (TC) is 15 psig. The output (TC) is greater than the (PT) output; thus the Computing Relay (CR) output is higher than 6 to 9 psig, so the Hot Gas By-pass Valve will remain closed.

As the cooling load falls off, the unit capacity output is reduced as follows:

> As the air signal from the (TC) is decreased, the PRV will close until the (PT) high head air signal setting is reached and the interstage valve will close when 3 psig signal is reached. This signal will prevent the PRV from closing further and the Interstage Valve from closing further. Thus the PRV and the Interstage Valve are held at minimum positions under high head conditions.

> Any further reduction in capacity must be accomplished by the addition of hot gas. The pneumatic computing relay (CR) output will remain at 6 to 9




**LEGEND**

| | |
|---|---|
| TS | TEMP. SENSING ELEMENT |
| PRV | PRE-ROTATION VANE MOTOR |
| TC | TEMPERATURE CONTROLLER |
| CLR | CURRENT LIMIT RELAY (TRANSDUCER) |
| 1 SOL | HOT GAS AIR SOLENOID VALVE |
| G1-G10 | GAUGES |
| FR | FILTER REGULATOR |
| LLS | LOW LIMIT SELECTOR |
| PT | PRESSURE TRANSMITTER |
| CR | COMPUTING RELAY |
| MPS | MAX. PRESSURE SELECTOR |

MOTOR DRIVE

**FIG. 16** — PNEUMATIC CAPACITY CONTROL SYSTEM

psig or higher as long as (TC) output is equal to or higher than the pressure control (PT) output. Thus the hot gas valve remains closed. As the (TC) output decreases below the (PT) output (or normal high head set-point), the (CR) output decreases at a 1 psi to 1 psi relationship until the hot gas valve is fully open.

The unit is now at maximum efficiency with the PRV and interstage valve at minimum allowable position and the hot gas by-pass valve open. If the condensing head decreases, new positions will be established.

As the (PT) output decreases below the high head set point, the PRV will close and the interstage valve will close until the (PT) output is the same as (TC) output or until the minimum vane position set point low limit selector (LLS) is reached. At the same time the hot gas valve signal will increase closing the valve as the differential between the (PT) and the (TC) outputs decrease.

Therefore, if the unit capacity is at minimum and a decrease in head occurs the pneumatic system will automatically close the hot gas by-pass valve, close the PRV and close the interstage modulating valve to obtain maximum operating efficiency under all conditions.

## ADJUSTING THE HOT GAS BY-PASS VALVE

If the synchronization of the opening of the HGBP valve with setting of the prerotation vanes range is too wide, the HGBP valve can be adjusted to approximately 7 psig to start opening the valve and to approximately 2 psig for the full open position. This adjustment should be made by YORK Service Personnel. Contact the nearest YORK office.

# SECTION V
# STARTING, STOPPING, AND OPERATING PROCEDURES

## GENERAL

The compressor driver supplied with each liquid chilling unit will vary due to application preferences and requirements. Refer to the driver manufacturer's starting and operating instructions for procedures that must be completed before the unit can be started.

## PRE-START COMPRESSOR CHECK

The following paragraphs describe the procedures prior to starting and operating a TURBOMASTER Compressor.

**CAUTION**

OIL HEATER

*If the heater is de-energized during a shutdown period, it must be energized for 12 hours prior to starting the compressor, or the compressor oil charge must be replaced with new oil. (See OIL CHARGING PROCEDURE, page 28.)*

1. Before actually starting the compressor, the following steps should be carefully checked.

   (a) Check the compressor oil level (see CHECKING THE OIL LEVEL, page 21.)

   (b) Add new oil, if necessary. (See OIL CHARGING PROCEDURE, page 28.)

   (c) Completely open the water valves to the oil cooler. A full flow of water is required through the oil cooler at all times during starting and operation to inhibit foaming in the oil.

   (d) Open or adjust all shut off valves necessary for the operation of the hot gas by-pass and liquid injection systems and oil return systems.

   (e) If the compressor is turbine driven, warm up the turbine in accordance with the manufacturer's instructions.

   (f) If the compressor is motor driven, be sure the prerotation vanes are closed to unload the motor during starting. Some units are equipped with a safety switch which automatically prevents the compressor motor from starting unless the vanes are closed. The starting requirements for a single shaft gas turbine are more severe and a special start-up procedure is required. (See Special Job Instructions.) With a steam turbine or a split shaft gas turbine, it is normally unnecessary to unload the compressor during starting.

## CHECKING THE OIL LEVEL

Two oil level sight glasses are located on the oil sump end of the compressor. During operation the oil level should be visible in approximately the middle of lower sight glass or 1/4 of the upper sight glass, but should not fill the upper sight glass.

If the oil level is excessively high, the compressor may tend to lose some oil under starting conditions or conditions of rapidly changing load. In this case, oil may be drained from the compressor oil charging valve, while the unit is running.

**CAUTION**

*Rapid withdrawal of oil will cause jet pump cavitation.*

If the oil level is too low, pump cavitation and low oil pressure may occur. The machine will then shut down automatically and oil should be added to the compressor.

When the unit has been shut down for a prolonged period oil level above the top sight glass is normal.



## UNIT START-UP

The following step-by-step procedure should be used to start-up the system:

1. Set the PREROTATION VANES control to AUTO.
2. Set the MAX. LOAD ADJUSTMENT in % to 100, (unless a percentage is desired to limit maximum current).
3. THE TEMPERATURE CONTROL should be set to the design point.
4. NOTE: The OIL HEATER white light should be lit and oil heaters should have been energized at least 12 hours or more. If this is not the case, the compressor oil should be drained and new oil charged into the compressor. (See OIL CHARGING PROCEDURE, page 28.)
5. Start the chilled water pump(s) and make sure water is flowing through the cooler.
6. Set the AUXILIARY OIL PUMP switch to AUTO position.

7. Depress the START switch. This will start the auxiliary oil pump and begin a 30 second pre-run of the pump to circulate oil through the compressor and establish adequate oil pressure. Then, the compressor will start and the auxiliary oil pump will continue to run for 75 seconds and stop.

8. The condenser water pump(s) and cooling tower fans, are automatically controlled. Make sure water is flowing through the condenser, when the compressor starts.

9. At this point the unit should be running and the operator should check all gauges and lights to make sure the unit is functioning in the proper manner.

10. After the compressor has started and is beginning to lower the chilled water temperature a log of unit operating conditions should be made to help analyze unit operation and shutdowns. (See OPERATING LOG SHEET, page 24.)

11. After the unit is operating adjust the sound control liquid injection valve to achieve 1°F superheat in discharge gas. The valves should be left open at the adjusted position during subsequent operation.

## CHECKING OPERATION

During operation, the following conditions should be periodically checked.

1. During the start-up period the electronic restrictor permits the prerotation vanes to remain slightly open until the compressor is up to speed; then the vane motor under the control of the control center will cause the vanes to modulate with load requirements.

2. Be sure the "Auxiliary Oil Pump" switch on the control center remains in the AUTO position. Otherwise, the pump wil continue to operate unnecessarily. The Auxiliary Oil Pump will operate and shut-off automatically in event of an unattended shut down. Shutdown without AOP during a power interruption will not harm the compressor.

3. Be sure the compressor oil sump heaters are not energized during operation.

4. Periodically check the Control Center Oil Pressure gauge. A steady decrease in oil pressure (with constant suction and discharge pressures) may be an indication of a dirty filter. The filter should be replaced when pressure loss is 20% of the original pressure differential between the sump and oil filter outlet. The actual bearing oil pressure will vary with compressor suction and discharge pressures and the speed of the compressor. When a new unit is first operated under normal full load conditions, the bearing oil pressure should be recorded as a reference for subsequent readings.

## OPERATING INSPECTIONS

Following a regular inspection and maintenance procedure will help prevent unnecessary unit shut down and repair. The following list of inspections and procedures should be used as a guide:

### Daily

1. If the compressor is in operation check the following.
   a. Main oil pump discharge pressure at the oil filter (change filter if necessary).

   b. Compressor oil level in the oil reservoir. (See Unit Operation.)

   c. Oil temperature leaving the thrust bearing should not exceed 185°F.

   d. Oil temperature supplied to bearings should not exceed 140°F.

   e. Oil level in the drain trap. If the drain trap oil level suddenly rises, a leaking shaft seal is indicated.

2. Check the entering and leaving condenser water presures and temperatures for comparison with job design conditions.

3. Check the chilled water temperatures and pressures entering and leaving the cooler for comparison with job design conditions.

4. Check the liquid refrigerant temperature leaving the condenser. Compare with the temperature corresponding to condenser pressure, and outlet water temperature, to evaluate condenser performance.

5. Check refrigerant temperatures at all thermometer locations. (Compressor Discharge, Compressor Suction, Intercooler, Cooler Liquid Header etc.)

6. Check the compressor driver for load conditions (motor-amperes, engine-exhaust temperature, oil pressure, etc.) or check turbine operation in accordance with manufacturers instructions.

7. Check for signs of fouled condenser tubes or if there is air in the unit. (The temperature difference between water off condenser and liquid refrigerant leaving the condenser should not exceed 10 - 12°F.)

### Weekly

1. Check the refrigerant charge. (Refer to CHECKING AND TRIMMING REFRIGERANT CHARGE, page 32.)

2. Check for bursting disc leakage, for fracture, by opening the "snifter" valve in the relief piping. Check with a Halide Torch.

### Monthly

1. Check the unit for leaks, using a halogen leak detector.

### Semi-Annually (more often as necessary)

1. Clean water side of oil cooler.

### Annually (More often if necessary)

1. Drain and replace the oil in the compressor oil sump.

2. Clean the compressor oil sump.

3. Clean the oil filter and replace the oil filter element (if a considerable quantity of aluminum is found in the filter or if the rotor axial play is excessive, inspect main and thrust bearings.

NOTE: *When replacing filter element, fill the oil filter canister with clean oil.*

4. Clean the strainer screen in oil cooler water supply.

5. Clean the condenser tubes. Where cooling tower water is used for oil cooling, oil cooler should also be cleaned whenever it is necessary to clean the condenser.

6. Depending on use, drain, flush, and replace transfer unit compressor oil.

7. Inspect and service electrical components, as necessary.

## STOPPING UNIT

To stop the unit, proceed as follows:

1. Push the COMPRESSOR-STOP button. The oil pump will continue in operation for a period of 45 seconds, and then stop automatically.

NOTE: *If the COMPRESSOR-STOP button is pushed within 3 minutes and 15 seconds after the COMPRESSOR-START button is pushed, the oil pump will continue to operate until the 4 minute timer times out, which then automatically stops the oil pump.*

   a. As the compressor slows down, the main oil pump pressure falls until a point is reached at which the auxiliary oil pump starts automatically. If the compressor stops due to a power failure, the auxiliary pump obviously cannot start. This will not damage the compressor because the main oil pump will supply oil while the compressor slows down, and residual oil will prevent bearing damage.

2. Open the switch to the chilled water pump (and condenser water pump).

3. Open the switch to the cooling tower fan motors, if used.

4. Shutoff water supply to compressor oil cooler.

5. Be sure the compressor reservoir oil heater is energized.

## PROLONGED SHUTDOWN

If the unit is to be shut down for an extended period of time (over the winter time), the following paragraphs outline the procedure to be followed:

1. Test all unit joints for refrigerant leaks with a leak detector. If any leaks are found, they should be repaired immediately. During long idle periods, the tightness of the unit should be checked periodically. (Added protection against refrigerant loss resulting from an undiscovered leak can be provided by transfering the refrigerant charge to the storage receiver. In this case the unit pressure should be kept above 30 –R-12 or 58 psig – R-22 or 38 psig – R-500 – See LIQUID TRANSFER, and GAS PUMPOUT, Form 160.71-NM3.) The unit should have positive refrigerant pressure at all time during prolonged shutdown, to prevent air leakage into the unit, which will cause corrosion within the shells.

2. If the unit is exposed to freezing temperatures while the system is idle, carefully drain the cooling water from the cooling tower, condenser pump, the chilled water system-cooler pump and coils, condenser and oil cooler and transfer unit condenser. Open the drains on the cooler and condenser liquid heads to assure complete drainage.

3. Open the main disconnect switches to the compressor motor (if motor driven), condenser water pump, the chilled water pump, the oil pump and transfer unit power supply.

4. Periodically, check the compressor oil heaters to be sure they are energized during shut down.

5. For turbine drive units close the main steam valve or fuel valve.

6. *IMPORTANT:*

   a. When putting the unit into operation after prolonged shut down, de-energize the oil heater and remove all oil from the compressor. Install a new filter element and charge compressor with fresh oil. Energize the 115 volt control circuit to activate the compressor sump oil heater.

   b. Operate the Auxiliary Oil Pump manually (set the oil pump switch on the front of the center in the "MAN" position) for approximately 1-1/2 minutes to flood all bearings and establish steady oil pressure prior to starting the compressor. Then return the Auxiliary Oil Pump Switch to the "AUTO" position.

FORM 160.71-F1.1

## YORK–OM TURBOMASTER CENTRIFUGAL LIQUID CHILLING UNIT
## LOG SHEET

NAME ______________________ ADDRESS ______________________

OUTSIDE DRY BULB _°F. _____ WET BULB _°F. ______ DATA BY ______________________ COMPR. SERIAL NO. __________

| BAROMETER AND TIME OBSERVED | "Hg | A.M. P.M. | "Hb | A.M. P.M. | "Hg | A.M. P.M. |
|---|---|---|---|---|---|---|

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DATE | | TIME | | | | | | | | |
| DRIVE | SPEED | RPM | | | | | | | | |
| DRIVE | MOTOR ( ) HP | AMPS | | | | | | | | |
| DRIVE | MOTOR ( ) HP | VOLTS | | | | | | | | |
| DRIVE | MOTOR ( ) HP | KW | | | | | | | | |
| DRIVE | MOTOR ( ) HP | P.F. | | | | | | | | |
| DRIVE | NAME PLATE OR TURBINE – PRES. | INLET PSI | | | | | | | | |
| DRIVE | NAME PLATE OR TURBINE – PRES. | EXHAUST PSI | | | | | | | | |
| DRIVE | NAME PLATE OR TURBINE – TEMP | INLET °F. | | | | | | | | |
| DRIVE | NAME PLATE OR TURBINE – TEMP | EXHAUST °F. | | | | | | | | |
| GEAR | | RATIO | | | | | | | | |
| GEAR | OIL | PRES. PSI | | | | | | | | |
| GEAR | OIL | TEMP. °F. | | | | | | | | |
| COMPRESSOR ( ) SIZE | BEAR OIL PRESS. | MAIN PSI PSI | | | | | | | | |
| COMPRESSOR ( ) SIZE | BEAR OIL PRESS. | THRUST PSI | | | | | | | | |
| COMPRESSOR ( ) SIZE | BEAR TEMP | MAIN °F. °F. | | | | | | | | |
| COMPRESSOR ( ) SIZE | BEAR TEMP | THRUST °F. | | | | | | | | |
| COMPRESSOR ( ) SIZE | | PRE-ROTATION VANE POSITION | | | | | | | | |
| COMPRESSOR ( ) SIZE | GAS TEMPS. PRESS. | SUCTION °F. | | | | | | | | |
| COMPRESSOR ( ) SIZE | GAS TEMPS. PRESS. | INTERSTAGE SUCT. °F. | | | | | | | | |
| COMPRESSOR ( ) SIZE | GAS TEMPS. PRESS. | DISCHARGE °F. | | | | | | | | |
| COMPRESSOR ( ) SIZE | GAS TEMPS. PRESS. | SUCT. PRES. PSI | | | | | | | | |
| COMPRESSOR ( ) SIZE | | BALANCE PISTON PRESSURE PSI | | | | | | | | |
| CONDENSER ( ) SIZE | | PRESSURE PSI | | | | | | | | |
| CONDENSER ( ) SIZE | | $T_p$ °F. | | | | | | | | |
| CONDENSER ( ) SIZE | WATER – TEMP. | IN °F. | | | | | | | | |
| CONDENSER ( ) SIZE | WATER – TEMP. | OUT °F. | | | | | | | | |
| CONDENSER ( ) SIZE | WATER | PRES. DROP PSI | | | | | | | | |
| CONDENSER ( ) SIZE | WATER | METER GPM OR ORIF. MANO. "HG. | | | | | | | | |
| INTER-COOLER | | ENTERING LIQUID TEMP. °F. | | | | | | | | |
| INTER-COOLER | | DROP LEG LIQUID TEMP. °F. | | | | | | | | |
| COOLER ( ) SIZE | | EVAP. PRES. "HG. OR PSI | | | | | | | | |
| COOLER ( ) SIZE | | COOLER Tp °F. | | | | | | | | |
| COOLER ( ) SIZE | | COOLER LIQUID TEMP. °F. | | | | | | | | |
| COOLER ( ) SIZE | WATER OR BRINE – TEMP. | IN °F. | | | | | | | | |
| COOLER ( ) SIZE | WATER OR BRINE – TEMP. | OUT °F. | | | | | | | | |
| COOLER ( ) SIZE | WATER OR BRINE | PRES. DROP "HG. OR PSI | | | | | | | | |
| COOLER ( ) SIZE | WATER OR BRINE | METER GPM OR ORIF. MANO. "HG. | | | | | | | | |
| COOLER ( ) SIZE | | HOT GAS BY-PASS POSITION (OPEN–CLOSED) | | | | | | | | |
| COOLER ( ) SIZE | | LIQUID INJECTION -(VALVES OPEN–CLOSED) | | | | | | | | |
| | | | | | | | | | | |

FIG. 18–OPERATING LOG SHEET

c. If the unit was drained because of possible freezing, fill cooling tower, chilled water system-cooler pump and coils with water. (See Initial Unit Start-Up.)

## NORMAL AND SAFETY UNIT SHUTDOWNS

Normal and safety unit shut downs have been built into the unit to protect it from damage during operation. Therefore, it should be understood that at certain pressures and temperatures the system will be stopped automatically by controls that respond to high temperatures, low water temperature and low and high pressures, etc. Tables 2 and 3, SECTION VIII, TROUBLESHOOTING, pages 41 and 42, include an explanation of each specific shut down.

## OPERATING LOG SHEET

A daily record of system operating conditions (temperatures and pressures) recorded at regular intervals is desirable.

Fig. 17 shows a log sheet used by YORK Personnel for recording test data on centrifugal systems. It is available from the factory in pads under Form No. 160.71-F1.1 and may be obtained through the nearest YORK office.

An accurate record of readings serves as a valuable reference for trouble shooting the unit. Readings taken when a system is newly installed will establish normal conditions with which to compare later readings.

For example, dirty condenser tubes will be indicated by higher than normal temperature differences between condenser water off and refrigerant temperature leaving condenser.

## NEED FOR MAINTENANCE OR SERVICE

If the unit is malfunctioning in any manner or the unit is stopped by one of the safety controls, consult SECTION VIII, TROUBLE SHOOTING, pages 38 thru 40 of this instruction. After consulting this chart, if you are unable to make the proper repairs or adjustments to start the compressor, or the particular trouble continues to hinder the performance of the unit, please call the nearest YORK Regional Office. Failure to correct problems could damage the unit and increase the cost of eventual repairs.

# SECTION VI

# PREVENTIVE MAINTENANCE

## INTRODUCTION

It is the responsibility of the owner to provide the necessary daily, monthly, and yearly maintenance requirements of the system.

*IMPORTANT – If a system failure occurs due to improper maintenance during the warranty period: the YORK Division will not be liable to restore the system to satisfactory operation.*

The following is a list of maintenance procedures which must be performed:

## COMPRESSOR

1. Oil Filter – The oil filter must be changed annually or when the oil pressure drops to 80% of the original differential between oil sump and oil pressure panel gauge.

   When the oil filter is changed it should be inspected thoroughly for any traces of aluminum particles which would indicate possible bearing wear. If aluminum traces are found this should be brought to the attention of the nearest YORK office for their further investigation and recommendations.

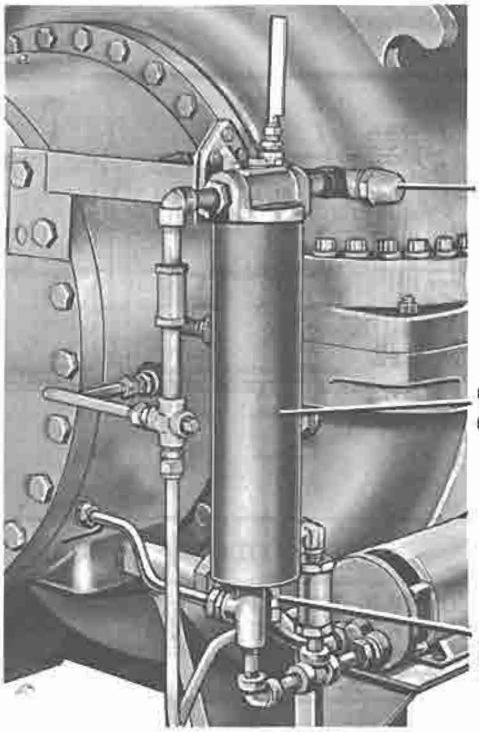



FIG. 18 – COMPRESSOR OIL FILTER

2. Oil Changing – The oil in the compressor must be changed annually or earlier if it becomes dark or cloudy. Open valve on the bottom of the filter casing to check oil in the filter.

3. Oil Cooling – Check and clean the water side of the oil cooler to prevent corrosion and the forming of mineral deposits. (A water purification system is recommended to prevent fouling of oil cooler water side (if required).

## SPEED INCREASER

1. Check and change oil in accordance with the manufacturers instructions.

2. Check and clean the oil cooler to prevent corrosion and the forming of mineral deposits. (A water purification system is recommended to prevent fouling of oil cooler.)

3. Check mounting screws frequently to insure tightness. If loose or any other condition exists that could affect alignment, contact the nearest YORK office for further investigation and recommendations.

## COMPRESSOR MOTOR (IF ELECTRIC MOTOR DRIVEN)

1. Check motor mounting screws frequently to insure tightness. If loose, or any other condition noted that could affect alignment, contact the nearest YORK office for their further investigation and recommendations.

2. Meg motor windings annually to check for deterioration of windings.

3. Perform maintenance procedures as recommended by the motor manufacturer.

## TURBINE (IF TURBINE DRIVEN)

1. Check turbine mounting screws frequently to insure tightness. If loose, or any other condition exists that could affect alignment contact the nearest YORK office for further investigation and recommendations.

2. Check all steam, water and lubrication connections.

3. Perform maintenance in accordance with the instructions by the turbine manufacturer.

4. Check and clean water side of oil cooler.

5. Change oil filter as recommended by the Turbine Manufacturer.

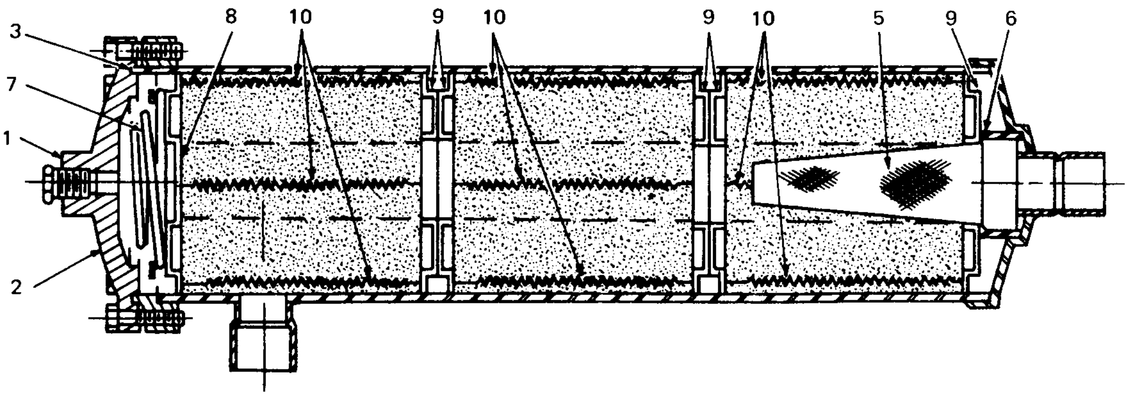
## ALIGNMENT

The alignment of the compressor drive shaft and driver should be checked against the original alignment record by the YORK Service Engineer, recorded during the initial start-up, annually to prevent wearing of compressor and driver bearings and seals. Contact the nearest YORK Regional Office for this service.

## REPLACEMENT OF OIL RETURN SYSTEM FILTER-DRIER (Refer to FIG. 19.)

The filter drier should be replaced annually or if the line does not feel cold when oil return solenoid valve is open. This is an indication the filter-drier is completely clogged and is not allowing the oil laden liquid to flow through it. To remove the filter-drier use the following procedure:

The filter-drier should be changed when the unit is shutdown using the following procedure:




| PC. NO. | DESCRIPTION | QUAN. |
|---|---|---|
| 1 | COVER PLATE | 1 |
| 2 | COVER PLATE (INDICATOR) | 1 |
| 3 | GASKET (COVER PLT.) | 1 |
| 5 | SAFETY SCREEN | 1 |

| PC. NO. | DESCRIPTION | QUAN. |
|---|---|---|
| 6 | GASKET (SAFETY SCREEN) | 1 |
| 7 | INLET SPRING | 1 |
| 8 | INLET PLATE | 1 |
| 9 | END PLATE | 2 CORE |
| 10 | CORE SPRING SET | 1 CORE |

**FIG. 19** – CROSS SECTION OF FILTER DRIER

1. Close the service valve, located between the compressor and the filter-drier.

2. Remove the screws from the head of the shell and take the head from the shell.

3. Remove the 3 used filter-drier cores and clean out the shell.

4. Remove the spring-tensioned spacer plates by unhooking spring from the used cores and clean them thoroughly.

5. Take out the fully activated filter-drier core from its sealed container and slip between the spring-tensioned spacer plates.

6. Place the 3-filter-drier assemblies in the shell and replace the head and screws. Before completely tight, open the valve at the outlet end to purge the air from the filter shell. Tighten the screws.

7. Open the two service valves. Check the filter-direr shell head for leaks after starting the unit.

## COOLER AND CONDENSER

The major portion of maintenance on the condenser and cooler will deal with the maintaining of the water side of the condenser and cooler in a clean condition.

The use of untreated water in cooling towers, closed water systems, etc. frequently results in one or more of the following:

1. Scale Formation.

2. Corrosion or Rusting.

3. Slime and Algae Formation.

It is, therefore, to the benefit of the user to provide for proper water treatment to provide for a longer and more economical life of the equipment. The following recommendation should be followed in determining the condition of water side of the condenser and cooler tubes.

1. Condenser tubes should be cleaned annually. If the temperature difference between the water off the condenser and the condensed liquid refrigerant exceeds 8 °F, it is a good indication that the condenser tubes require cleaning. They should be cleaned as instructed on pages 34 to 37 of this manual.

2. The cooler tubes under normal circumstances will not require cleaning. If, however, the temperature difference between the refrigerant and the leaving chilled water increases slowly over the operating season, it is an indication that the cooler tubes may be fouling or that there may be a water bypass in the water box requiring gasket replacement.

## TRANSFER UNIT

Clean and inspect the transfer unit valves. Drain, flush and replace compressor oil. This maintenance should be performed at least once a year.

## BURSTING DISC AND RELIEF VALVES

Check the bursting disc and relief valves for leaks with a halide torch and open the "snifter" valve in the relief piping. If any indication of a refrigerant leak is present around the bursting disc, the bursting disc cap screws and nuts should be tightened with a torque wrench and torqued to 7± 1 ft lbs. It is very important to stay within the torque tolerance; over tightening of the screws will crack the bursting disc.

## ELECTRICAL, PNEUMATIC CONTROLS AND GAUGES

1. All electrical, pneumatic controls and gauges should be inspected for obvious malfunctions.

2. It is important that the factory settings of controls (operation and safety) not be changed. If the settings are changed without YORK's approval, the warranty will be voided.

3. If control settings and gauge calibrations are necessary contact the nearest YORK Regional Office. Gauges should be calibrated annually and controls calibrated at 1 to 2 year intervals.

# SECTION VII

# MAINTENANCE AS REQUIRED

## COMPRESSOR MAINTENANCE

Maintenance for the compressor assembly consists of checking the oil level, charging oil into the compressor, checking and changing the oil filters, checking the operation of the oil heater and observing the operation of the compressor.

Internal wearing of compressor parts could be a serious problem caused by improper lubrication, brought about by restricted oil lines, passages, or dirty oil filters. If the unit is shutting down on (HOT) High Oil Temperature or Low Oil Pressure (COP), change the oil filter element. Examine the oil filter element for the presence of aluminum particles. If aluminum particles are noticeable and the same conditions continue to stop the unit operation after a new filter element is installed, notify the nearest YORK office to request the presence of a YORK Service man.

All major maintenance should be performed by YORK Service Personnel within your district or region, unless your own maintenance department has been authorized by YORK to do so.

## CHARGING COMPRESSOR WITH OIL

### The Oil Charge

The operating oil level of this compressor should be maintained at approximately 1/4" above the bottom of the upper sight glass. When this level falls so that it becomes visible below the middle of the bottom sight glass, oil must be added as outlined below. Add oil whenever it is low during operation.

The oil capacity is 10 gallons for 26" compressors, 35 gallons for 38" compressors, and 50 gallons for 55" compressors. When changing oil, use only YORK Compressor Oil "C".

### Oil Charging Procedure

The oil should be charged into the system using the York Oil Charging Pump - York Part No. 070-10654. This pump is supplied with the tool kit that is furnished with the unit. To charge oil into the system proceed as follows:

1. The unit should be shut down.
   *NOTE: If charging oil to restore the correct level – the unit may be kept in operation.*
2. Immerse the suction connection of the oil charging pump in a clean container of new oil and connect the pump discharge connection to the oil charging valve located at the end of the oil sump of the compressor. (See Figs. 4 & 7) Do not tighten the connection at charging valve until after the oil is forced out by pumping a few strokes of the oil pump. This fills the lines with oil and prevents air from being pumped into the system.
3. Open the oil charging valve and pump oil into the system until oil level in the compressor oil sump is about midway in the upper sight glass. Then close the charging valve and disconnect the hand oil pump.
4. As soon as oil charging is complete, close the power supply to the control center to energize the oil heater. (See Unit Operating Procedures, page 5.) This will keep the concentration of refrigerant in the oil to a minimum.

When the compressor is initially charged with oil, the oil pump should be started to fill the lines, passages, oil cooler and oil filter. This will lower the oil level in the sump. It will then be necessary to add oil to bring the level back to the center of the upper sight glass.

*WARNING – High Oil Level – If the oil level is too high, the compressor may lose some oil under starting conditions or conditions of a rapidly changing load. This is likely to happen if the oil level is above the top of the upper sight glass.*

*Low Oil Level – If the oil level is too low the oil pump may cavitate and cause a low oil supply pressure. When the oil pressure reduces to the setting of the COP – a unit shutdown will occur.*

*Prolonged Shutdown – Oil level will be above upper sight glass, this is normal.*

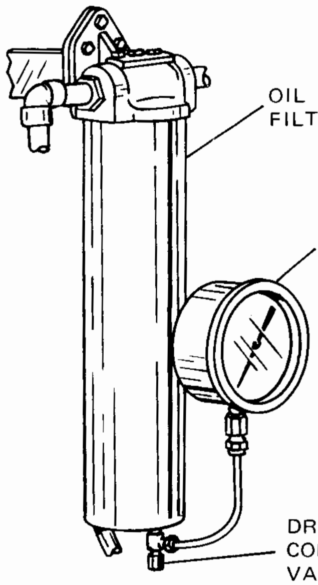



**FIG. 20** —CHECKING OIL PRESSURE DROP

### CHECKING OIL PRESSURE DROP ACROSS OIL FILTER (Refer to Fig. 20.)

The pressure drop across the oil filter should be checked if oil pressure drops to 80% of the normal oil pressure differential between sump and control center main oil pressure gauge. To check the oil filter pressure drop use the following procedure:

1. Connect a pressure gauge ( 0 to 200 psig) to the drain connection valve located on the bottom of the oil filter casing.
2. Open the drain connection valve.
3. Check the oil pressure drop by reading the difference between this gauge and the oil main pressure gauge on the control center. If the oil pressure difference is within 5 to 12 psi, the pressure drop is considered normal. If the pressure difference is more the oil filter should be replaced with a new cartridge.

### REPLACING OIL FILTER ELEMENT (See Fig. 19)

The oil filter of each compressor is equipped with a disposable filter element. Unless a steady decrease in main oil pump discharge pressure after the filter with increasing oil temperature indicates that the filter is becoming clogged, only annual replacement is necessary.

*THIS FILTER ELEMENT SHOULD NEVER BE CLEANED AND REINSTALLED; IT SHOULD ALWAYS BE REPLACED WITH A NEW ELEMENT.*

To replace a filter element shutdown unit, adjust valving, drain oil and then lower the filter bowl and lift out the filter element. Clean bowl and replace "O" rings and gaskets. To keep air out, pour oil in the bowl with the new element when reassembling.

## CHECKING THE UNIT FOR LEAKS

### LEAK TESTING DURING OPERATION

After the unit is in operation under load, all components should be carefully leak tested with a leak detector to be sure all joints are tight.

If any leaks are found, they must be repaired immediately. Usually, leaks can be stopped by tightening flare nuts or flange bolts. However, if it is necessary to repair a welded joint, the refrigerant charge must be removed. (See HANDLING REFRIGERANT FOR DISASSEMBLY AND REPAIR, see page 34.)

### CONDUCTING REFRIGERANT PRESSURE TEST

With all known leaks repaired, the unit should be charged with a small amount of refrigerant, and nitrogen, so that a halide torch or electronic halide leak detector can be used to detect any leaks too small to be found by the soap test.

To test with R-12 or R-22 or R-500, proceed as follows:

1. Charge approximately one quart of clean refrigerant oil into the shaft seal reservoir (through the 3/8″ pipe tap connection) located above the seal cavity in the bearing support.
2. With no pressure in the unit, charge refrigerant gas into the system until a pressure of 5 psig is produced.
3. Build up the unit pressure with nitrogen, to approximately 100 psi. To be sure that the concentration of refrigerant has reached all parts of the system, open the oil charging valve slightly (Fig. 7) and test for the presence of refrigerant with a leak detector.
4. Test around each joint, including all welds. It is important that this test be thoroughly and carefully done, spending as much time as necessary and using a good torch which is kept burning properly, or a good leak detector.
5. To check for refrigerant leaks in the cooler and condenser, open the vents in the cooler and condenser water boxes and test for the presence of refrigerant. If no refrigerant is present, the tubes and tube sheets may

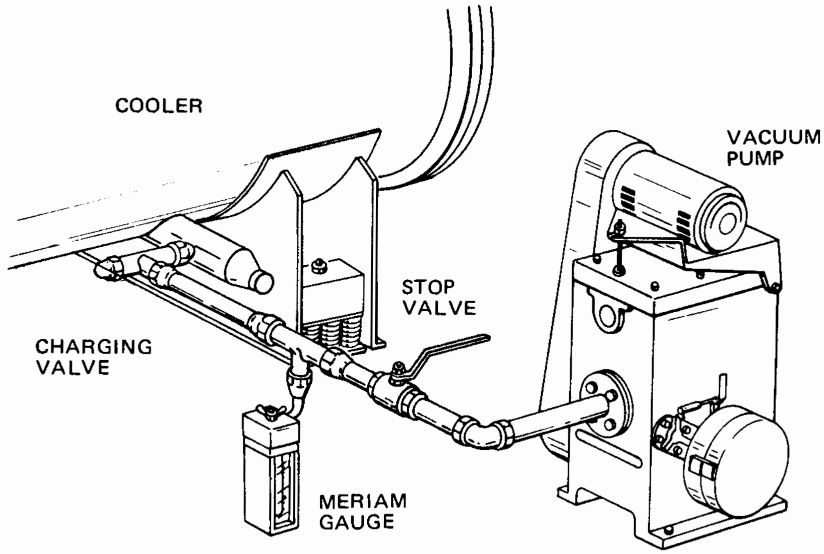



**FIG. 21**—EVACUATING THE SYSTEM

be considered tight. If refrigerant is detected at the vents, the cover plates must be removed, the leak located (by means of soap suds or test torch) and repaired.

6. When absolute tightness of the unit has been established, carefully exhaust the mixture of nitrogen and refrigerant to the atmosphere by opening the charging valve.

# EVACUATION AND DEHYDRATION OF UNIT

## Vacuum Testing

After the pressure test has been completed, the vacuum test should be conducted as follows:

1. Connect a high capacity vacuum pump, with indicator, to the system charging valve as shown in Fig. 21 and start the pump. (See VACUUM DEHYDRATION, page 32.)
2. Open all unit refrigerant valves fully, including the gauge valves. Be sure all valves to the atmosphere are closed.
3. Operate the vacuum pump in accordance with VACUUM DEHYDRATION until a wet bulb temperature of +35 F or 5 MM (Hg.) is reached. See Table 1 for corresponding values of pressure.
4. To improve evacuation, circulate hot water (not to exceed 125°F) through the cooler and condenser tubes to thoroughly dehydrate the shells. If a source of hot water is not available, a portable water heater should be employed. DO NOT USE STEAM. A suggested method is to connect a hose between the source of hot water under pressure and the cooler water box drain connection, out the cooler vent valve, into the condenser water box drain and out the condenser vent. To avoid the possibility of causing leaks, the temperature should be brought up slowly so that the tubes and shell are heated evenly.
5. Close the unit charging valve and the stop valve between the vacuum indicator and the vacuum pump. (See Fig. 21.) Then, disconnect the vacuum pump leaving the vacuum indicator in place.

**TABLE 1** — SYSTEM PRESSURES

| *Gauge | Absolute | | | | |
|---|---|---|---|---|---|
| Inches of Mercury (HG) Below One Standard Atmosphere | PSIA | Millimeters Of Mercury (HG) | Microns | Boiling Temperatures of Water °F | |
| 0 | 14.696 | 760 | 760,000 | 212 | |
| 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" | .968 | 50 | 50,000 | 101 | |
| 28.94" | .481 | 25 | 25,000 | 78 | |
| 29.53" | .192 | 10 | 10,000 | 52 | |
| 29.67" | .122 | 6.3 | 6,300 | 40 | |
| 29.72" | .099 | 5 | 5,000 | 35 | WATER |
| 29.842" | .039 | 2 | 2,000 | 15 | FREEZE |
| 29.882" | .019 | 1.0 | 1,000 | +1 | |
| 29.901" | .020 | .5 | 500 | –11 | |
| 29.917" | .002 | .1 | 100 | –38 | |
| 29.919" | .001 | .05 | 50 | –50 | |
| 29.9206" | .0002 | .01 | 10 | –70 | |
| 29.921" | 0 | 0 | 0 | | |

*One standard atmosphere = 14.696 Psia
= Atmospheric pressure at sea level
= 760 MM Hg. absolute pressure at 32°F
= 29.921 inches Hg.

NOTES:
Psig = Lbs. per sq. in. gauge pressure
= Pressure above atmospheric
Psia = Lbs. per sq. in. absolute pressure
= Sum of gauge plus atmospheric pressure
Hg = Mercury

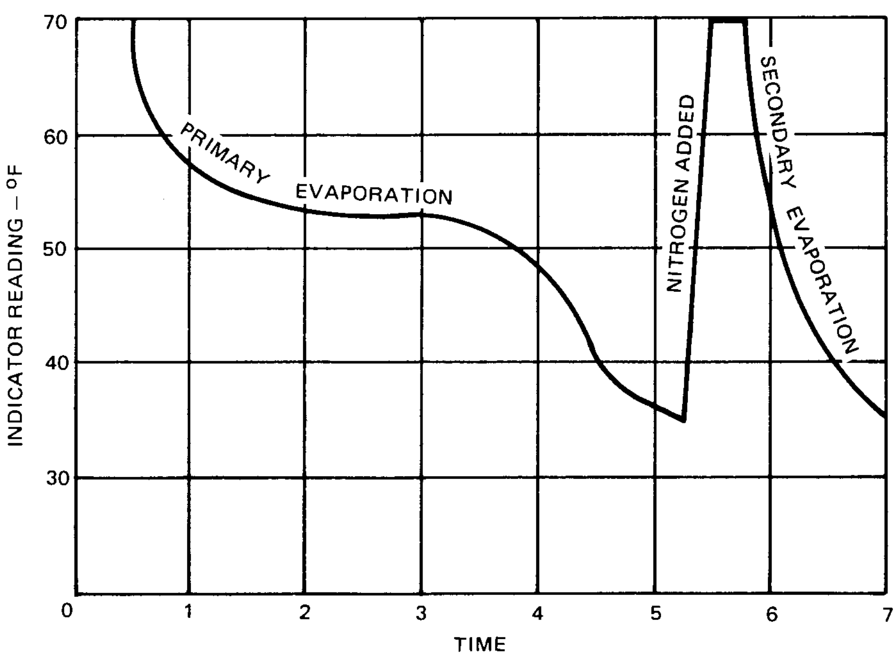



**FIG. 22** —SATURATION CURVE

6. Hold the vacuum obtained in Step 3 in the system for 2 hours; the slightest rise in pressure indicates a leak or the presence of moisture, or both. If, after 2 hours, the wet bulb temperature in the vacuum indicator has not risen above 40°F, the system may be considered tight.

*NOTE: Be sure the vacuum indicator is valved off while holding the system vacuum and be sure to open the valve between the vacuum indicator and the system when checking the vacuum after the 2 hour period.*

7. If the vacuum does not hold for 2 hours, within the limits specified in Step 6 above, the leak must be found and repaired.

## VACUUM DEHYDRATION

To obtain a dry system, the following instructions have been assembled to provide an effective method of evacuating and dehydrating a system in the field. Although there are several methods of dehydrating a system, we are recommending the following, as it produces the best results, and affords a means of obtaining accurate readings as to the extent of dehydration.

The equipment required to follow this method of dehydration consists of a vacuum indicator or Meriam Gauge, a chart showing the relation between dew point temperature and pressure in inches of mercury (vacuum), (see Table 1) and a vacuum pump capable of pumping a suitable vacuum on the system.

### Operation

Dehydration of a refrigeration system can be obtained by this method because the water present in the system reacts much as a refrigerant would. By pulling down the pressure in the system to a point where its saturation temperature is considerably below that of room temperature, heat will flow from the room through the walls of the system and vaporize the water, allowing a large percentage of it to be removed by the vacuum pump. The length of time necessary for the dehydration of a unit is dependent on the volume of the system, the capacity and efficiency of the vacuum pump, the room temperature and the quantity of water present in the system. By the use of the vacuum indicator as suggested, the test tube will be evacuated to the same pressure as the system and the distilled water will be maintained at the same saturation temperature as any free water in the system and this temperature can be observed on the thermometer.

If the system has been pressure tested and found to be tight prior to evacuation, then the saturation temperature recordings should follow a curve similar to the typical saturation curve shown as Fig. 22.

The temperature of the water in the test tube will drop as the pressure decreases until the boiling point is reached, at which point the temperature will level off and remain at this level until all the water in liquid form is vaporized. When this final vaporization has taken palce, the pressure and temperature will continue to drop until eventually the temperature reaches 35°F or 5 MM (hg.).

When this point is reached, practically all of the air has been evacuated from the sytem, but there is still a small amount of moisture left. In order to provide a medium for carrying this residual moisture to the vacuum pump, nitrogen should be introduced into the system to bring it to atmospheric pressure and the indicator temperature will return to approximately ambient temperature. Close off the system again and start the second evacuation.

The relatively small amount of moisture left will be carried out through the vacuum pump and the temperature shown by the indicator should drop uniformly until it reaches 35°F or 5 MM (Hg.).

When the vacuum indicator registers this temperature, it is a positive sign that the system is evacuated and dehydrated to the recommended limit. If the indicator temperature does not go below ambient temperature during the first pulldown, or permanently levels out at some other temperature, then it is evident that there is a leak somewhere in the system. Any leaks must be corrected before the indicator temperature can be pulled down to 35°F or 5 MM (Hg.) in the primary evacuation.

During the primary pulldown keep a careful watch on the wet bulb indicator temperature and do not let it fall below 35°F. If the temperature is allowed to fall to 32°F, the water in the test tube will freeze and the result will be a faulty temperature reading.

## REFRIGERANT CHARGING

To avoid the possibility of freezing the water within the cooler tubes when charging an evacuated unit, only refrigerant vapor from the top of the drum or cylinder shall be admitted to the unit until the unit pressure is raised above the point corresponding to the freezing point of the cooler liquid. For chilled water, the pressure corresponding to the freezing point (at sea level) is 30.1 psig for R-12, 37.9 psig for R-500, and 57.5 psig for R-22.

While charging, every precaution must be taken to prevent moisture laden air from entering the system. Make up a suitable charging connection from new copper tubing to fit between the system charging valve and the fitting on the charging cylinder. This connection should be as short as possible but long enough to permit sufficient flexibility for changing drums. The charging connection should be purged each time a full container of refrigerant is connected and changing containers should be done as quickly as possible to minimize the loss of refrigerant.

Refrigerant-12 or Refrigerant-500 may be furnished in cylinders containing either 145 or 2000 lbs of R-12 refrigerant or 125 or 1700 for R-500 or R-22. These cylinders are returnable.

Refer to unit nameplate for correct refrigerant charge.

# CHECKING AND TRIMMING REFRIGERANT CHARGE

The initial refrigerant charge is specified and furnished by YORK for each installation.

Final checking of the charge must be made under full load design conditions with the specified water flow through the condenser and secondary refrigerant flow through the cooler at design temperatures.

While charging, every precaution must be taken to prevent moisture laden air from entering the system. Make up a suitable charging connection from new copper tubing to fit between the system charging valve and the fitting on the charging drum. This connection should be as short as possible but long enough to permit sufficient flexibility for changing drums. The charging connection should be purged each time a full container of refrigerant is connected and changing containers should be done as quickly as possible to minimize the loss of refrigerant.

Start the unit as outlined under UNIT START-UP PROCEDURE. Open the charging valve and permit refrigerant to flow into the system. Normally, with the unit in operation, refrigerant will readily flow into the cooler. If the ambient temperature is too cold, the use of heat lamps applied to the refrigerant container will speed up the flow of refrigerant into the unit.

While charging, check the cooler pressure carefully to be sure it does not pull down below the point corresponding to the freezing point of the secondary refrigerant. Be sure the low water temperature cutout is set to open before the secondary refrigerant reaches its freezing point. The prerotation vanes may be manually adjusted as necessary to help maintain the desired cooler pressure.

While operating the system with partial charge, check the discharge temperature frequently to be sure it does not exceed 250°F. A thermometer is provided in the compressor discharge line for this purpose.

A sight glass is provided in the cooler shell opposite the suction connection to observe the tube wetting action within the cooler. The compressor suction connection is equipped with a thermometer well for checking suction superheat.

If the system is being charged under full load conditions, continue charging until the top row of cooler tubes is completely wetted as observed through the sight glass in the cooler.

If full load conditions are not available, do not exceed the calculated full load refrigerant charge until a thorough check can be made since the boiling action within the cooler is much less at partial loads than at full load. Checking the refrigerant charge for coverage of the tubes during pull-down will be approximately the same as at full load conditions.

When conducting an evaluation of the final charge requirements, reasonably steady load conditions should exist. Manual capacity control should be used. The following conditions should be carefully observed as a guide to establishing the proper charge:

1. Refrigerant Temperatures – Actual suction, discharge, and condensing temperatures will vary with specific application conditions. Typically, discharge gas superheat will be approximately 20 - 30 F, suction gas superheat 0 - 3 F, condensing temperature approximately 5 - 8 F above condenser water outlet temperature, evaporator temperature approximately 6 - 9 F below chilled water temperature.

2. Cooler Charge Action – As viewed through the sight port, evidence of wetting over most of the tube surface should be observed.

3. Evaporator Refrigerant Pressure – At a given combination of load and chilled water outlet temperature, a system is properly charged when refrigerant has been added to the extent of producing the highest possible pressure in the evaporator. This condition will generally result in best economy of operation at a given load, or maximum capacity from a given system. It can be determined by adding incremental amounts of refrigerant, while carefully noting any trend to higher refrigerant pressure and/or lower chilled water outlet temperature.

4. Power Requirements – While making the charge adjustment, effect to the power requirement should be carefully monitored. Overcharging will cause droplets of liquid refrigerant to be drawn into the compressor, resulting in an increase to power requirement without a corresponding increase in system capacity. This condition will be accompanied by a marked decrease in compressor discharge temperature, without appreciable change to other refrigerant temperature and pressure values.

If the refrigerant charge evaluation indicates the presence of an excessive amount, the charge should be reduced by completing the following procedures:

1. If the amount of refrigerant must be reduced, the charge of an operating unit can be readily reduced by first opening the receiver drain and vent circuits (open Valves I, J, N, M) to reduce the receiver pressure, then stopping the unit briefly to permit the increased system pressure to force liquid into the receiver. (See LIQUID TRANSFER OM TURBOMASTER TO RECEIVER, Form 160.71-NM3.) When operation is reestablished it will likely be necessary to restore some of the charge in accordance with the guide lines mentioned above.

## CHECKING REFRIGERANT CHARGE AT PARTIAL LOADS

Since full load conditions are not always available, they must be temporarily obtained for check purposes as outlined below. This procedure is not an accurate method of checking charge; but it will serve as a guide in checking the charge at partial loads.

1. Stop the compressor and permit the chilled water pumps to operate until the chilled water temperature rises 3 or 4 degrees above full load design temperature.

2. Start the compressor and when the chilled water temperature decreases to normal full load design conditions, check the charge by observing the compressor motor amperes, the discharge temperature and the wetting of the top row of cooler tubes as outlined under CHECKING AND TRIMMING THE REFRIGERANT CHARGE, page 33.

## HANDLING REFRIGERANT FOR DISMANTLING AND REPAIRS

If it becomes necessary to open any part of the refrigerant system for repairs, see OPERATING PROCEDURE FOR REFRIGERANT TRANSFER AND PUMPOUT UNIT, (Refer to 160.71-NM3) to outline the procedure for handling the refrigerant before opening the unit.

Under atmospheric pressure, Refrigerant-12 boils at approximately –20°F, Refrigerant-22 boils at approximately –41°F and Refrigerant-500 boils at –28°F. It will be necessary to remove the charge before opening any part of the unit.

## COOLERS AND CONDENSERS

### GENERAL

Maintenance of condenser and cooler shells is important to provide trouble free operation of the unit. The water side of the tubes in the shell must be kept clean and free from scale. Proper system maintenance; such as water treating, tube cleaning and testing for leaks is covered on the following pages.

### CHEMICAL WATER TREATMENT

Since the mineral content of the water circulated through coolers and condensers varies with almost every source of supply, it is possible that the water being used may corrode the tubes or deposit heat resistant scale in them. Reliable water treatment companies are available in most larger cities to supply a water treating process which will greatly reduce the corrosive and scale forming properties of almost any type of water.

As a preventive measure against scale and corrosion and to prolong the life of cooler and condenser tubes, a chemical analysis of the water should be made preferably before the system is installed. A reliable local water treatment company can be consulted to determine whether water treatment is necessary, and if so, to furnish the proper treatment for the particular water condition.

The York Chemical Laboratory can make a water analysis in conjunction with maintenance contracts, and recommend type of treatment required.

### CLEANING COOLER AND CONDENSER TUBES

#### Cooler

It is difficult to determine, by any particular test, whether possible lack of performance of the water cooler is due to fouled tubes alone or due to a combination of troubles. Trouble, which may be due to fouled tubes, is indicated when, over a period of time, the cooling capacity decreases and the split (temperature difference between water leaving the cooler and the refrigerant temperature in the cooler) increases. A gradual drop-off in cooling capacity can also be caused by a gradual leak of refrigerant from the system or by a combination of fouled tubes and shortage of refrigerant charge. An excessive quantity of oil in the cooler can also contribute to erratic performance.

#### Condenser

In a condenser, trouble due to fouled tubes is usually indicated by a steady rise in head pressure, over a period of time, accompanied by a steady rise in condensing temperature.

#### Tube Fouling

Fouling of the tubes can be due to deposits of two types as follows:

1. Rust or sludge -- which finds its way into the tubes and accumulates there. This material usually does not build up on the inner tube surfaces as scale, but does interfere with heat transfer. Rust or sludge can generally be removed from the tubes by a thorough brushing process.

2. Scale -- due to mineral deposits. These deposits, even though very thin and scarcely detectable upon physical inspection, are highly resistant to heat transfer. They can be removed most effectively by circulating an acid solution through the tubes.

## TUBE CLEANING PROCEDURES

### Brush Cleaning of Tubes

If the tube fouling consists of dirt and sludge, it can usually be removed by means of the brushing process. Drain the water sides of the circuit to be cleaned (cooling water or chilled water), remove the heads and thoroughly clean each tube with a soft bristle bronze brush. DO NOT USE A STEEL BRISTLE BRUSH. A steel brush may damage the tubes.

Improved results can be obtained by admitting water into the tube during the cleaning process. This can be done by mounting the brush on a suitable length of 1/8" pipe with a few small holes at the brush end and connecting the other end by means of a hose to the water supply.

The tubes should always be brush cleaned before acid cleaning.

### Acid Cleaning of Tubes (Refer to Figs. 23 and 24.)

If the tubes are fouled with a hard scale deposit, they must be acid cleaned. It is important that before acid cleaning, the tubes be cleaned by the brushing process described above. If the relatively loose foreign material is removed before the acid cleaning, the acid solution will have less material to dissolve and flush from the tubes with the result that a more satisfactory cleaning job will be accomplished with a probable saving of time.

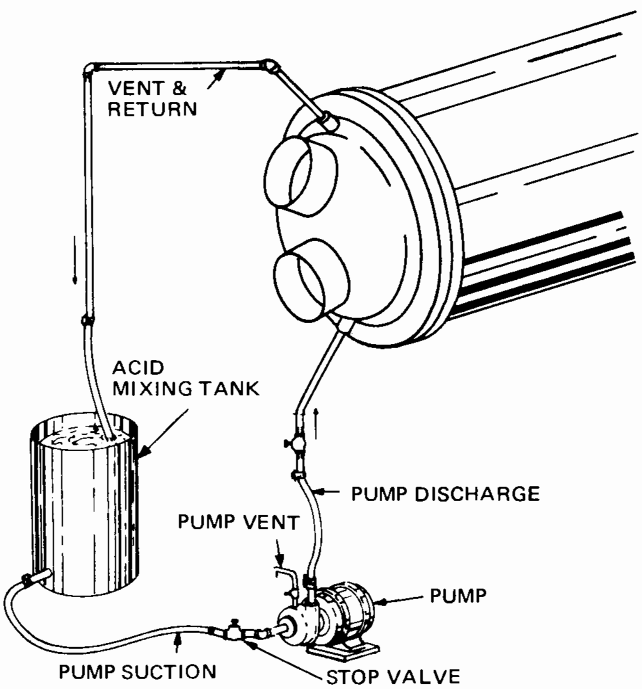



FIG. 23 – ACID CLEANING OF CONDENSER TUBES

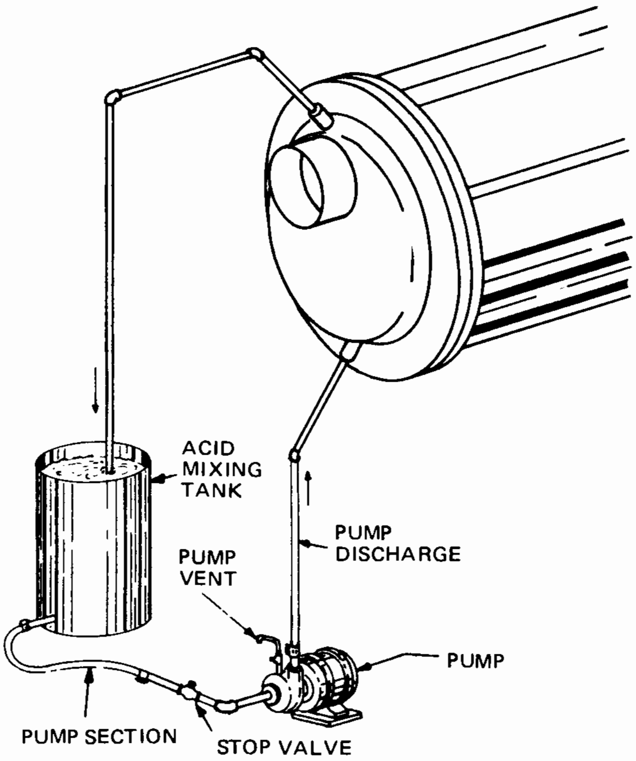



FIG. 24 –ACID CLEANING COOLER TUBES

### Commercial Acid Cleaning

In many major cities, commercial organizations now offer a specialized service of acid cleaning coolers and condensers. These organizations will analyze the type of dirt or scale to be removed and then use the proper cleaning solution for the individual job.

If it becomes necessary to clean the tubes (especially condenser tubes), it is sometimes difficult to detect the scale and to determine the proper cleaning solution unless a chemical analysis of the scale is made.

If it becomes necessary to acid clean shells or tubes, without the benefit of a local cleaning organization, follow the procedures outlined.

Figs. 23 and 24 show the material and connections required for acid cleaning of condenser and cooler tubes.

The pump is about 1/4 hp, all iron centrifugal, about 10 gpm against approximately 10 feet head. The air vent on top of the pump casing should be valved, with nipples and elbows so that the pump can be gas vented into a bucket and not to the floor.

The cooler, or condenser, should be isolated from the water circulating system before cleaning. If there are not two stop valves in the water lines near the shell, the inlet and outlet flanges should be opened and steel plates with rubber gaskets installed to isolate the cooler or condenser from the system piping.

The mixing tank should be clean, of wood or iron construction. A 55 gallon oil drum is commonly used. However, when the tank is not large enough to hold the entire charge, it will be necessary to mix several batches of clear solution.

The pump suction line should have a stop valve to prevent the solution from draining back when the pump is stopped. The pump should discharge into the drain connection in the bottom water nozzle of the cooler or condenser. The gas is vented and the solution is returned to the tank through a hose or piping from the vent connection in the top of the top water nozzle. (See Figs. 24 and 25 .) Do not use rusty or scaled pipe as the acid will loosen any particles and may cause a stoppage.

In some cases the scale may be coated with an oily film. This oily film will prevent or retard the penetration of acid cleaners. In order to remove the oil, the following procedures should be followed:

1. Obtain the necessary quantity of a good household grease cutting detergent such as "All Dishwashing Compound" or an industrial detergent such as "Oakite No. 62 or No. 162".

2. Mix the detergent solution in the recommended quantity of water in sufficient amount to fill the cooler or condenser and also the mixing tank which has been procured as previously recommended. One pound of "All" per 100 gallons of water or four oz/gallon is required with Oakite No. 62 or No. 162.

3. Heat this solution by any convenient method; such as, a steam pipe or nozzle opened into the acid mixing tank (Fig. 23 or 24) to 160°F to 180°F and circulate this solution for one hour.

4. Drain and refill with fresh water than drain completely.

5. Then, slowly add the necessary quantity of inhibited acid cleaner. The following inhibited acids have been found suitable:

   PENNSALT PM-90:

   Pennsylvania Salt Manufacturing Co.
   2 Penn Center Plaza
   Philadelphia, Pa. 19102

   Add one (1) part of Pennsalt PM-90 to four (4) parts of water by volume.

   OAKITE COMPOUND No. 32 sold by:

   Oakite Products, Inc.
   50 Valley Road
   Berkley Heights, N.J. 07922

   Add one (1) part Oakite No. 32 to four (4) parts of water by volume.

*CAUTION: ALWAYS POUR ACID INTO THE WATER, NEVER ADD WATER TO ACID.*

Pump the solution into the water sides of the shell (mixing as many batches as necessary) until solution begins to return to the tank through the vent line. If necessary, add enough solution to cover the end of the return hose or pipe and to seal the pump.

Recirculate the acid solution through the tubes for about 4 hours or until the foaming action has stopped. If the scale is calcium carbonate, the acid solution will continue to foam as long as scale is being dissolved. If the scale is calcium sulphate, little, if any, foaming will take place during the acid cleaning process. After a recirculation period of about 4 hours, the tubes should again be thoroughly checked for scale to determine whether the acid cleaning should be discontinued or repeated.

When the cleaning operation has been completed, drain the acid solution and wash it down with a water hose in order to further dilute it. Acid in the tank and lines should be thoroughly diluted with fresh water and pumped to the cooler and drained in order to wash these parts and prevent rusting.

Fill the cooler or condenser with fresh water and drain it. Then fill the tubes and water heads with sodium hydroxide solution, 1/2 or 1% of the hydroxide by weight. Allow this solution to remain in the cooler and condenser one hour, then drain it.

Fill the cooler or condenser with fresh water, then drain.

## TESTING FOR COOLER AND CONDENSER TUBE LEAKS

Cooler and condenser tube leaks in unit will result in either refrigerant leaking into the water circuit, or water leaking into the shell depending on the pressure levels. If refrigerant is leaking into the water it can be detected at the water box vents after a period of shutdown. If water is leaking into the refrigerant frequent purging will be necessary and system capacity and efficiency will drop off sharply. Sometimes water will be visible on the surface of the refrigerant in the cooler. If a tube is leaking and water has entered the unit, the cooler and condenser should be valved off from the rest of the water circuit and drained immediately to prevent severe rusting and corrosion. If a tube leak is indicated, the exact location of the leak may be determined as follows:

1. Allow the system to warm up until a substantial pressure is reached for testing. Remove the water box covers and listen at each section of tubes for a hissing sound that would indicate gas leakage. This will assist in locating the section of tubes to be further investigated. Once the probable location of the leaky tubes has been determined, treat that section in the following manner (if the location is not definite, all the tubes will require investigation).

2. Wash off both tube heads and the ends of all tubes with water.

*NOTE: Do not use carbon tetrachloride for this purpose since its fumes give the same flame discoloration that the refrigerant does.*

3. With nitrogen or dry air blow out the tubes to clear them of traces of refrigerant laden moisture from the circulating water. As soon as the tubes are clear, a cork should be driven into each end of the tube. Repeat this with all of the other tubes in the suspected section or, if necessary, with all the tubes in the cooler or condenser. Allow the cooler or condenser to remain corked from 12 to 24 hours before proceeding. Depending upon the amount of leakage, the corks may blow from the end of a tube, indicating the location of the leakage. If not, it will be necessary to make a very thorough test with the halide torch.

4. After the tubes have been corked up for 12 to 24 hours, it is recommended that two men working at both ends of the cooler carefully test each tube – one man removing corks at one end and the other at the opposite end to remove corks and handle the test torch. Start with the top row of tubes in the section being investigated, remove the corks at the ends of one tube simultaneously and insert the exporing tube for 5 seconds – this should be long enough to draw into the detector any refrigerant gas that might have leaked through the tube walls. A fan placed at the end of the cooler opposite the torch will assure that any leakage will travel through the tube to the torch.

5. Mark any leaking tubes for later identification.

6. If any of the tube sheet joints are leaking, the leak should be detected by the test torch. If a tube sheet leak is suspected, its exact location may be found by using a soap solution. A continuous buildup of bubbles around a tube indicates a tube sheet leak.

## RENEWAL PARTS

To order replacement parts refer to the drawings furnished for each OM Turbomaster Unit installation. All parts should be ordered through the Regional or District Offices. In some cases spare parts are furnished with the job.

# SECTION VIII
# TROUBLE SHOOTING
## OPERATIONAL ANALYSIS CHART

| RESULTS | POSSIBLE CAUSE | REMEDY |
|---|---|---|
| **1. SYMPTOM–ABNORMALLY HIGH DISCHARGE PRESSURE** | | |
| Temperature difference between liquid refrigerant out and water out of condenser higher than normal. | Air in condenser. | Purge condenser of air with manual purge valves. |
| High discharge pressure | Condenser tubes dirty or scaled. | Clean condenser tubes. Check water conditioning. |
| | High condensing water temperature | Reduce condensing water inlet temperature. (Check cooling tower and water circulation). |
| Temperature difference between condenser water on and water off higher than normal, with normal cooler pressure. | Insufficient condensing water supply . | Increase the quantity of water through the condenser. |
| **2. SYMPTOM–ABNORMALLY LOW SUCTION PRESSURE** | | |
| Temperature difference between leaving chilled water and refrigerant in cooler greater than normal with high discharge temperature. | Insufficient charge of refrigerant. | Check for leaks and charge refrigerant into unit. |
| Temperature difference between leaving chilled water and refrigerant in the cooler greater than normal with normal discharge temperature | Cooler tubes dirty or restricted. | Clean cooler tubes. |
| | Excessive oil in evap. refrig. | Check oil return system. |
| Temperature of chilled water too low with low motor amperes. | Insufficient load for system capacity. | Check prerotation vane motor operation and setting of low water temperature cutout. |
| **3. SYMPTOM–HIGH COOLER PRESSURE** | | |
| Low discharge temperature. | Liquid slugging. Unit overcharged with refrigerant. | Check the charge. Remove refrigerant if necessary. |
| High chilled water temperature | Prerotation vanes fail to open. | Check the prerotation vane motor positioning circuit. |
| | Unit overloaded. | Be sure the vanes are wide open (without overloading the motor) until the load decreases. |
| **4. SYMPTOM–UNIT OPERATION NOISY** | | |
| Unit surging or "hunting"–(suction and discharge pressures swinging widely). | Insufficient condensing water supply. | Increase quantity of water through condenser. |
| | Condensing water inlet temperature above max. design. | Check cooling tower fans or control. |
| | Condenser tubes dirty or scaled. | Clean condenser tubes – check water conditioning. |
| | Cooler tubes dirty or scaled<br>Air in condenser – (refrigerant side). | Clean cooler tubes – check water conditioning.<br>Purge condenser (refrigerant side). |
| | Unit operating below design cooler temperature | See remedys for #2 – abnormally low suction pressure. |
| Compressor Bearing. | Lack of lubrication or lubrication cooling. | Disassemble and inspect compressor (repair as necessary). |

# OPERATIONAL ANALYSIS CHART (CONT.)

| | | |
|---|---|---|
| **5. SYMPTOM–COMPRESSOR STARTS, NORMAL OIL PRESSURE DEVELOPS, FLUCTUATES FOR SHORT WHILE, THEN COMPRESSOR STOPS ON OIL PRESSURE CUTOUT** | | |
| Oil pressure gauge shows normal oil pressure, fluctuates then compressor stops on COP. | Unusual starting conditions exist, i.e. abnormal oil foaming in reservoir and piping due to lowered system pressure. | If after several attempts to start the compressor, this condition still exists, drain the oil from the compressor and charge new oil into the compressor. (Refer Charging The System With Oil.) |
| | Low voltage to heater or inoperative heater during shutdown. | Correct voltage or replace heater. |
| **6. SYMPTOM–UNUSUALLY HIGH OIL PRESSURE DEVELOPS WHEN OIL PUMP RUNS** | | |
| Unusually high oil pressure is noted on oil pressure gauge when oil pump is started. | Relief valve is misadjusted. | Adjust pressure regulating valve. |
| **RESULTS** | **PDSSIBLE CAUSE** | **REMEDY** |
| **7. SYMPTOM–AUX. OIL PUMP VIBRATES** | | |
| Oil pump vibrates excessively with some oil pressure showing on the gauge.<br>Note: When oil pump is run without an oil supply it will vibrate and become extremely noisy. | Misalignment of pump or piping<br>Mounting bolts loose.<br>Bent shaft.<br>Worn pump parts. | Correct condition or replace faulty part. |
| | Oil not reaching pump in sufficient quantity. | Check oil supply and oil piping to oil pump. |
| **8. SYMPTOM–OIL PRESSURE GRADUALLY DECREASES (NOTED BY OBSERVATION OF DAILY LOG SHEETS)** | | |
| Oil pressure (noted on oil pressure gauge) drops to 30 psi differential between compressor oil sump and oil pressure gauge on control panel. | Oil filter is dirty. | 1. Check filter pressure drop.<br>2. Change oil filter. |
| | Extreme bearing wear. | 1. Check oil filter for aluminum particles.<br>2. Inspect compressor. |
| **9. SYMPTOM–OIL RETURN SYSTEM CEASES TO RETURN AN OIL/REFRIGERANT SAMPLE** | | |
| Oil refrigerant return not functioning. | Filter-drier in oil return system dirty. | Replace oil filter drier with new. |
| **10. SYMPTOM AUX.–OIL PUMP FAILS TO DELIVER OIL PRESSURE** | | |
| No oil pressure registers on oil pressure gauge when oil pump runs. | Faulty oil pressure gauge. | Replace oil pressure gauge. |
| | Oil pump shaft not rotating. | Check oil pump for pump shaft rotation. May require internal inspection of oil pump. |
| | Oil pump rotation incorrect. | Correct rotation.<br>Check relief valve for correct assembly. |
| | Internal oil cooler leak. | Confirm leak by pressurizing circuit. Replace oil cooler. |
| **11. SYMPTOM LOW OIL PRESSURE** | | |
| No pressure indicated on oil pressure gauge on control panel; compressor will not start. | Aux. Oil pump running in wrong direction | Check rotation of Aux. oil pump. |
| | Oil pump not running. | Check electrical connections to oil pump and oil pump contactor in aux. control panel. |
| Oil pump pumping capacity low. | Excessive end clearance in pump. | Inspect and replace worn parts. |
| | Other worn pump parts. | |
| | Partially blocked oil supply line. | Check oil piping for blockage. |
| | Oil pressure regulating valve stuck in open position. | Inspect and clean. |

# COMPRESSOR TROUBLE SHOOTING CHART

| | |
|---|---|
| **1. Compressor Surging:** | A. Insufficient load.<br>B. Cooling water temperature too high.<br>C. Low condensing water flow.<br>D. Dirty condenser or evaporator tubes.<br>E. Low refrigerant charge.<br>F. Foul gas in system.<br>G. Low driver speed.<br>H. Excessive oil in the refrigerant.<br>I. PRV closed from malfunction.<br>J. Improper float or intercooler operation.<br>K. Recheck controls system.<br>L. Hot gas by-pass valve not operating |
| **2. Fluctuation or loss of oil pressure during startup:** | A. Oil sump heaters not energized prior to startup. Sump temperature should be 150F. In cold ambients, sump should be 90F above ambient prior to starting.<br>B. When excessive oil foaming occurs, renew oil charge, prior to re-starting.<br>C. Insufficient water flow thru lube oil cooler.<br>D. Refrigerant condensed in casing, by running hot water thru cooler, while outdoor compressor is npressor is shutdown.<br>E. Outdoor oil lines and lube oil cooler absorbed refrigerant. Remedy: Circulate hot sump oil, thru lines with auxiliary oil pump for 15 minutes, to move refrigerant laden oil back to sump heaters, prior to startup. |
| **3. Low Oil Pressure:** | A. Dirty oil filter.<br>B. Obstructed jet nozzle.<br>C. Excessive oil foaming, due to refrigerant absorbed in the oil.<br>D. Worn pump volute, seal ring.<br>E. Worn journal bearings.<br>F. Worn thrust bearing. The thrust oil outlet pressure should exceed the oil supply pressure.<br>G. Improperly installed pump housing gaskets.<br>H. Low driver speed.<br>I. Valves improperly set on auxiliary oil pump.<br>J. Low oil level. |
| **4. High oil temperatures: (Max. off thrust bearing 185F) (Max. at filter - 140F)** | A. Dirty oil cooler.<br>B. Reduced water (or refrigerant) flow.<br>C. Extremely high discharge temperature.<br>D. Thrust bearing failure, if temperature range across the thrust bearing increases (nominal is 30F). Check balance piston pressure, (see item 5), and oil supply temperature.<br>E. Low oil flow, indicated by reduced oil pressure differential across the thrust bearing. |
| **5. High Balance Piston Pressure: Note: - Pressure should be 2 to 8 psig above the pressure at equalized stage** | A. Balance piston seal ring worn.<br>B. Seal ring seized to balance piston and rotating with it.<br>C. Compression seal ring on oil sump stuck, broken or otherwise damaged.<br>D. Exceptionally high discharge pressure. |
| **6. Compressor loses oil into system:** | A. Oil foaming, heaters not working prior to startup, insufficient cooling water to lube oil cooler, or liquid slopover.<br>B. Balance piston seal ring worn.<br>C. Porous casting at suction end.<br>D. Porous casting or leaking plugs on oil sump.<br>E. Equalizing tubes improperly installed.<br>F. Excessive shaft gas seal leakage, worn gas seals, Check seal end first.<br>G. Too high oil level, above sight glass.<br>H. Faulty oil return system. |
| **7. Compressor vibrates:** | A. Check and eliminate surging unbalance. Check gear & motor induced vibrations.<br>B. Check and correct coupling alignment and spacing. |
| **8. Shaft seal oil leakage:** | A. Check oil pressure at shaft seal.<br>B. Check oil temperature.<br>C. Check alignment.<br>D. Check thrust bearing axial clearance.<br>E. Replace shaft seal as necessary. |

TABLE 2 – CAUSES OF NORMAL AND SAFETY SHUT DOWNS

| SHUTDOWN CAUSE DESCRIPTION | GOVERNING CONTROL | | | CONTROL CENTER LIGHTS–OR GAUGES– | START-UP OF SYSTEM AFTER SHUT-DOWN | PROBABLE CAUSE AND SERVICE REQUIRED |
|---|---|---|---|---|---|---|
| | DESCRIPTION | SETTING | | | | |
| | | ON RISE | ON FALL | | | |
| High Pressure– (Condenser Pressure) | High Pressure Cutout (HP) | See A on Table 3 | | See Condenser Pressure Gauge - High Pressure - Red Light - ON | Push "RESET" to clear lights. Permits re-starting "ON" via the "START" button on control Center. | See Operation Analysis Chart - Sympton 1. (See Table 3 "ON FALL". |
| Low Pressure (Cooler Pressure) | Low Pressure Cutout (LP) | See B on Table 3 | | See Cooler Pressure Gauge - Low Pressure Red Light - ON | Push "RESET" to clear lights. Permits re-starting On Rise psig via the "START" button. | See Operation Analysis Chart - Symptom 2. |
| Low Water Temperature Leaving Cooler | Low Water Thermostat (LWT) | See C on Table 3 | | Low Water Temperature Amber Light - ON | Automatically starts unit when the water reaches 45°F | System load is so small as to be less than the min. capacity with prerotation vanes closed. |
| High Oil Temperature | Compressor Oil Temperature Thermostat (CHOT) | See D on Table 3 | | Oil/Motor Temp. Red Light - ON | Push "RESET" to clear lights. Can be started via the "START" button when oil temperature decreases to—See Table 3—"ON FALL". | Dirty oil filter or restricted oil cooler line, change oil filter. Refer to Operational Analysis Chart for other causes. |
| High Compressor Discharge Temperature | High Discharge Temperature (HDT) | See E on Table 3 | | Oil/Motor/Disch. Temperature Red Light - ON | Push "RESET" to clear lights. Can be started via the "START" button when discharge temperature decreases. See Table 3 "ON FALL". | Condenser tubes dirty or scaled. High condensing w water temperature. |
| Low Oil Pressure (Differential) | Oil Pressure Cutout (COP) | See F on Table 3 | | Low Oil Pressure Red Light - ON | Push "RESET" to clear lights. Can be started via the "START" button. | Refer to Operational Analysis Chart - symptoms 4, 5, 6. 7, 9, 10, 11, 12 (pages 28 & 29). |

**TABLE 3** — CONTROL SETTINGS

| | SETTING | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R–12 | | | | R–500 | | | | R–22 | | | |
| | A–Compr. | | B–Compr. | | A–Compr. | | B–Compr. | | A–Compr. | | B–Compr. | |
| | On Rise | On Fall | On Rise | On Fall | On Rise | On Fall | On Rise | On Fall | On Rise | On Fall | On Rise | On Fall |
| **A** | 150psig | 133psig | 150psig | 133psig | 180psig | 163psig | 180psig | 163psig | 250psig | 233psig | 250psig | 233psig |
| **B** | 36psig | 30psig | 36psig | 30psig | 44psig | 38psig | 44psig | 38psig | 64psig | 58psig | 64psig | 58psig |
| **C** | 45°F | 38°F | 45°F | 38°F | 45°F | 38°F | 45°F | 38°F | 45°F | 38°F | 45°F | 38°F |
| **D** | 185°F | 184°F | 185°F | 184°F | 185°F | 184°F | 185°F | 184°F | 185°F | 184°F | 185°F | 184°F |
| **E** | 250°F | 249°F | 250°F | 249°F | 250°F | 249°F | 250°F | 249°F | 250°F | 249°F | 250°F | 249°F |
| **F** | 30–32psi | 27psi | 43–45psi | 40psi | 30–32psi | 27psi | 43–45psi | 40psi | 30–32psi | 27psi | 43–45psi | 40psi |

# SECTION IX

# WATER PRESSURE DROPS

Pressure drop information is available relating pressure drop across the cooler and condenser to the rate of flow in GPM. If a pressure gauge is used to determine pressure drop, it should be calibrated so that maximum accuracy is obtained. Only one gauge should be used for both readings. Also, if the gauge connections are not located at the same level, a correction must be made for static head difference. The conversion from psi to ft water is 2.3 ft for 1 psi.

*NOTE: For GPM and pressure drop for condensers and coolers, computer printouts are provided for your specific job.*

In order to determine the flow: measure the pressure drop using water taps provided in the water heads: then, refer to the data for the particular unit size provided for the unit.

# SECTION X
# REFRIGERANT PRESSURE/TEMPERATURE & TEMPERATURE/PRESSURE CONVERSION TABLES

**TABLE 4** — REFRIGERANT-12 (ENGLISH)

| PRESSURE / TEMPERATURE | | | |
|---|---|---|---|
| VACUUM IN. HG. | DEGREES F. | PRESSURE PSIG | DEGREES F. |
| 27 | −99.9 | 34 | 36.7 |
| 26 | −91.8 | 36 | 38.9 |
| 25 | −85.2 | 38 | 41.1 |
| 24 | −80.7 | 40 | 43.3 |
| 23 | −74.9 | 42 | 45.3 |
| 22 | −70.6 | 44 | 47.4 |
| 21 | −66.7 | 46 | 49.3 |
| 20 | −63.2 | 48 | 51.3 |
| 19 | −59.9 | 50 | 53.1 |
| 18 | −56.9 | 52 | 55.0 |
| 17 | −54.1 | 54 | 56.8 |
| 16 | −51.4 | 56 | 58.5 |
| 15 | −48.9 | 58 | 60.2 |
| 14 | −46.5 | 60 | 61.9 |
| 13 | −44.3 | 62 | 63.6 |
| 12 | −42.1 | 64 | 65.2 |
| 11 | −40.0 | 66 | 66.8 |
| 10 | −38.1 | 68 | 68.3 |
| 9 | −36.2 | 70 | 69.9 |
| 8 | −34.3 | 72 | 71.4 |
| 7 | −32.5 | 74 | 72.8 |
| 6 | −30.8 | 76 | 74.3 |
| 5 | −29.2 | 78 | 75.7 |
| 4 | −27.6 | 80 | 77.1 |
| 3 | −26.0 | 85 | 80.6 |
| 2 | −24.5 | 90 | 83.9 |
| 1 | −23.0 | 95 | 87.1 |
| PRESSURE PSIG | | 100 | 90.1 |
| | | 105 | 93.1 |
| | | 110 | 96.0 |
| 0 | −21.6 | 115 | 98.8 |
| 2 | −16.1 | 120 | 102. |
| 4 | −11.2 | 125 | 104. |
| 6 | −6.6 | 130 | 107. |
| 8 | −2.3 | 135 | 109. |
| 10 | 1.7 | 140 | 112. |
| 12 | 5.4 | 145 | 114. |
| 14 | 8.9 | 150 | 117. |
| 16 | 12.3 | 160 | 121. |
| 18 | 15.4 | 170 | 125. |
| 20 | 18.5 | 180 | 130. |
| 22 | 21.4 | 190 | 134. |
| 24 | 24.2 | 200 | 138. |
| 26 | 26.9 | 210 | 141. |
| 28 | 29.4 | 220 | 145. |
| 30 | 31.9 | 230 | 148. |
| 32 | 34.3 | 240 | 152. |

| TEMPERATURE / PRESSURE | | | |
|---|---|---|---|
| DEGREES F. | VACUUM IN. HG. | DEGREES F. | PRESSURE PSIG |
| −100 | 27.0 | 52 | 48.8 |
| −95 | 26.4 | 54 | 50.9 |
| −90 | 25.7 | 56 | 53.1 |
| −85 | 25.0 | 58 | 55.4 |
| −80 | 24.0 | 60 | 57.7 |
| −75 | 23.0 | 62 | 60.1 |
| −70 | 21.9 | 64 | 62.5 |
| −65 | 20.5 | 66 | 65.0 |
| −60 | 19.0 | 68 | 67.6 |
| −55 | 17.3 | 70 | 70.2 |
| −50 | 15.4 | 72 | 72.8 |
| −45 | 13.3 | 74 | 75.6 |
| −40 | 11.0 | 76 | 78.4 |
| −35 | 8.4 | 78 | 81.2 |
| −30 | 5.5 | 80 | 84.2 |
| −25 | 2.3 | 82 | 87.1 |
| | PRESSURE PSIG | 84 | 90.2 |
| | | 86 | 93.3 |
| | | 88 | 96.5 |
| −20 | 0.6 | 90 | 99.8 |
| −15 | 2.4 | 92 | 103. |
| −10 | 4.5 | 94 | 107. |
| −5 | 6.7 | 96 | 110. |
| 0 | 9.1 | 98 | 114. |
| 2 | 10.2 | 100 | 117. |
| 4 | 11.2 | 102 | 121. |
| 6 | 12.3 | 104 | 125. |
| 8 | 13.5 | 106 | 129. |
| 10 | 14.6 | 108 | 132. |
| 12 | 15.8 | 110 | 136. |
| 14 | 17.1 | 112 | 141. |
| 16 | 18.4 | 114 | 145. |
| 18 | 19.7 | 116 | 149. |
| 20 | 21.0 | 118 | 153. |
| 22 | 22.4 | 120 | 158. |
| 24 | 23.9 | 122 | 162. |
| 26 | 25.4 | 124 | 168. |
| 28 | 26.9 | 126 | 171. |
| 30 | 28.4 | 128 | 176. |
| 32 | 30.1 | 130 | 181. |
| 34 | 31.7 | 132 | 186. |
| 36 | 33.4 | 134 | 191. |
| 38 | 35.2 | 136 | 196. |
| 40 | 37.0 | 138 | 201. |
| 42 | 38.8 | 140 | 207. |
| 44 | 40.7 | 142 | 212. |
| 46 | 42.6 | 144 | 218. |
| 48 | 44.6 | 146 | 223. |
| 50 | 46.7 | 148 | 229. |
| | | 150 | 234. |

**TABLE 5** — REFRIGERANT-12 (METRIC)

| PRESSURE / TEMPERATURE | | | |
|---|---|---|---|
| VACUUM CM. HG. | DEGREES C. | PRESSURE k Pa | DEGREES C. |
| 70.0 | −76.4 | 3.6 | 12.3 |
| 67.5 | −71.2 | 3.8 | 13.7 |
| 65.0 | −67.2 | 4.0 | 15.1 |
| 62.5 | −63.9 | 4.2 | 16.4 |
| 60.0 | −61.0 | 4.4 | 17.8 |
| 57.5 | −58.5 | 4.6 | 19.0 |
| 55.0 | −56.2 | 4.8 | 20.3 |
| 52.5 | −54.2 | 5.0 | 21.5 |
| 50.0 | −52.3 | 5.2 | 22.6 |
| 47.5 | −50.6 | 5.4 | 23.8 |
| 45.0 | −48.9 | 5.6 | 24.9 |
| 42.5 | −47.4 | 5.8 | 26.0 |
| 40.0 | −46.0 | 6.0 | 27.1 |
| 37.5 | −44.6 | 6.2 | 28.1 |
| 35.0 | −43.4 | 6.4 | 29.1 |
| 32.5 | −42.1 | 6.6 | 30.1 |
| 30.0 | −41.0 | 6.8 | 31.1 |
| 27.5 | −39.8 | 7.0 | 32.1 |
| 25.0 | −38.8 | 7.2 | 33.1 |
| 22.5 | −37.7 | 7.4 | 34.0 |
| 20.0 | −36.7 | 7.6 | 34.9 |
| 17.5 | −35.8 | 7.8 | 35.8 |
| 15.0 | −34.8 | 8.0 | 36.7 |
| 12.5 | −33.9 | 8.2 | 37.6 |
| 10.0 | −33.0 | 8.4 | 38.4 |
| 7.5 | −32.2 | 8.6 | 39.3 |
| 5.0 | −31.4 | 8.8 | 40.1 |
| 2.5 | −30.6 | 9.0 | 40.9 |
| PRESSURE k Pa | | 9.2 | 41.7 |
| | | 9.4 | 42.5 |
| | | 9.6 | 43.3 |
| 0.0 | −29.8 | 9.8 | 44.1 |
| 0.2 | −25.5 | 10.0 | 44.9 |
| 0.4 | −21.8 | 10.2 | 45.6 |
| 0.6 | −18.4 | 10.4 | 46.4 |
| 0.8 | −15.4 | 10.6 | 47.1 |
| 1.0 | −12.6 | 10.8 | 47.8 |
| 1.2 | −10.0 | 11.0 | 48.5 |
| 1.4 | −7.5 | 11.5 | 50.3 |
| 1.6 | −5.3 | 12.0 | 52.0 |
| 1.8 | −3.1 | 12.5 | 53.7 |
| 2.0 | −1.1 | 13.0 | 55.3 |
| 2.2 | 0.8 | 13.5 | 56.8 |
| 2.4 | 2.6 | 14.0 | 58.4 |
| 2.6 | 4.4 | 14.5 | 59.9 |
| 2.8 | 6.1 | 15.0 | 61.3 |
| 3.0 | 7.7 | 15.5 | 62.8 |
| 3.2 | 9.3 | 16.0 | 64.2 |
| 3.4 | 10.8 | 16.5 | 65.5 |
| | | 17.0 | 66.9 |

| TEMPERATURE / PRESSURE | | | |
|---|---|---|---|
| DEGREES C. | VACUUM CM. HG. | DEGREES C. | PRESSURE k Pa |
| −74 | 68.9 | −6 | 1.54 |
| −72 | 67.9 | −4 | 1.72 |
| −70 | 66.8 | −2 | 1.91 |
| −68 | 65.5 | 0 | 2.11 |
| −66 | 64.2 | 2 | 2.32 |
| −64 | 62.6 | 4 | 2.55 |
| −62 | 60.9 | 6 | 2.78 |
| −60 | 59.0 | 8 | 3.03 |
| −58 | 57.0 | 10 | 3.28 |
| −56 | 54.7 | 12 | 3.55 |
| −54 | 52.3 | 14 | 3.83 |
| −52 | 49.6 | 16 | 4.12 |
| −50 | 46.6 | 18 | 4.43 |
| −48 | 43.5 | 20 | 4.75 |
| −46 | 40.0 | 22 | 5.08 |
| −44 | 36.3 | 24 | 5.43 |
| −42 | 32.2 | 26 | 5.79 |
| −40 | 27.9 | 28 | 6.17 |
| −38 | 23.2 | 30 | 6.56 |
| −36 | 18.1 | 32 | 6.97 |
| −34 | 12.7 | 34 | 7.39 |
| −32 | 6.9 | 36 | 7.83 |
| −30 | 0.7 | 38 | 8.29 |
| | PRESSURE k Pa | 40 | 8.76 |
| | | 42 | 9.25 |
| | | 44 | 9.76 |
| −28 | 0.08 | 46 | 10.3 |
| −26 | 0.17 | 48 | 10.8 |
| −24 | 0.28 | 50 | 11.4 |
| −22 | 0.39 | 52 | 12.0 |
| −20 | 0.51 | 54 | 12.6 |
| −18 | 0.63 | 56 | 13.2 |
| −16 | 0.76 | 58 | 13.9 |
| −14 | 0.90 | 60 | 14.5 |
| −12 | 1.05 | 62 | 15.2 |
| −10 | 1.20 | 64 | 15.9 |
| −8 | 1.36 | 66 | 16.7 |

Metric R-12 Refrigerant Conversion Tables, Form EM68-3294B, Pressure Sensitive Label available from York.

**TABLE 6** — REFRIGERANT-500 (ENGLISH)

| PRESSURE / TEMPERATURE | | | |
|---|---|---|---|
| VACUUM IN. HG. | DEGREES F. | PRESSURE PSIG | DEGREES F. |
| 27 | −105.0 | 36 | 30.0 |
| 26 | −97.1 | 38 | 32.1 |
| 25 | −90.6 | 40 | 34.1 |
| 24 | −85.2 | 42 | 36.1 |
| 23 | −80.4 | 44 | 38.1 |
| 22 | −76.2 | 46 | 39.9 |
| 21 | −72.4 | 48 | 41.8 |
| 20 | −68.9 | 50 | 43.6 |
| 19 | −65.7 | 52 | 45.3 |
| 18 | −62.7 | 54 | 47.0 |
| 17 | −60.0 | 56 | 48.7 |
| 16 | −57.4 | 58 | 50.4 |
| 15 | −54.9 | 60 | 52.0 |
| 14 | −52.6 | 62 | 53.5 |
| 13 | −50.4 | 64 | 55.1 |
| 12 | −48.3 | 66 | 56.6 |
| 11 | −46.2 | 68 | 58.1 |
| 10 | −44.3 | 70 | 59.5 |
| 9 | −42.4 | 72 | 61.0 |
| 8 | −40.7 | 74 | 62.4 |
| 7 | −38.9 | 76 | 63.8 |
| 6 | −37.3 | 78 | 65.1 |
| 5 | −35.7 | 80 | 66.5 |
| 4 | −34.1 | 82 | 67.8 |
| 3 | −32.6 | 84 | 69.1 |
| 2 | −31.1 | 86 | 70.4 |
| 1 | −29.7 | 88 | 71.6 |
| | | 90 | 72.9 |
| PRESSURE PSIG | | 95 | 75.9 |
| | | 100 | 78.9 |
| 0 | −28.3 | 105 | 81.7 |
| 2 | −23.0 | 110 | 84.4 |
| 4 | −18.2 | 115 | 87.1 |
| 6 | −13.7 | 120 | 89.7 |
| 8 | −9.6 | 125 | 92.2 |
| 10 | −5.8 | 130 | 94.7 |
| 12 | −2.2 | 135 | 97.1 |
| 14 | 1.2 | 140 | 99.4 |
| 16 | 4.4 | 145 | 102. |
| 18 | 7.5 | 150 | 104. |
| 20 | 10.4 | 160 | 108. |
| 22 | 13.2 | 170 | 112. |
| 24 | 15.9 | 180 | 116. |
| 26 | 18.4 | 190 | 120. |
| 28 | 20.9 | 200 | 124. |
| 30 | 23.3 | 210 | 127. |
| 32 | 25.6 | 220 | 131. |
| 34 | 27.8 | 230 | 134. |

| TEMPERATURE / PRESSURE | | | |
|---|---|---|---|
| DEGREES F. | VACUUM IN. HG. | DEGREES F. | PRESSURE PSIG |
| −100 | **26.4** | 52 | 60.0 |
| −95 | **25.7** | 54 | 62.6 |
| −90 | **24.9** | 56 | 65.2 |
| −85 | **24.0** | 58 | 67.9 |
| −80 | **22.9** | 60 | 70.6 |
| −75 | **21.7** | 62 | 73.4 |
| −70 | **20.3** | 64 | 76.3 |
| −65 | **18.8** | 66 | 79.3 |
| −60 | **17.0** | 68 | 82.3 |
| −55 | **15.0** | 70 | 85.4 |
| −50 | **12.8** | 72 | 88.6 |
| −45 | **10.4** | 74 | 91.8 |
| −40 | **7.6** | 76 | 95.1 |
| −35 | **4.6** | 78 | 98.5 |
| −30 | **1.2** | 80 | 102. |
| | PRESSURE PSIG | 82 | 106. |
| | | 84 | 109. |
| | | 86 | 113. |
| −25 | 1.2 | 88 | 117. |
| −20 | 3.2 | 90 | 121. |
| −15 | 5.4 | 92 | 125. |
| −10 | 7.8 | 94 | 129. |
| −5 | 10.4 | 96 | 133. |
| 0 | 13.3 | 98 | 137. |
| 2 | 14.5 | 100 | 141. |
| 4 | 15.7 | 102 | 146. |
| 6 | 17.0 | 104 | 150. |
| 8 | 18.4 | 106 | 155. |
| 10 | 19.7 | 108 | 159. |
| 12 | 21.1 | 110 | 164. |
| 14 | 22.6 | 112 | 169. |
| 16 | 24.1 | 114 | 174. |
| 18 | 25.7 | 116 | 179. |
| 20 | 27.3 | 118 | 184. |
| 22 | 28.9 | 120 | 189. |
| 24 | 30.6 | 122 | 195. |
| 26 | 32.4 | 124 | 200. |
| 28 | 34.1 | 126 | 206. |
| 30 | 36.0 | 128 | 211. |
| 32 | 37.9 | 130 | 217. |
| 34 | 39.9 | 132 | 223. |
| 36 | 41.9 | 134 | 229. |
| 38 | 43.9 | 136 | 235. |
| 40 | 46.1 | 138 | 241. |
| 42 | 48.2 | 140 | 248. |
| 44 | 50.5 | 142 | 254. |
| 46 | 52.8 | 144 | 261. |
| 48 | 55.1 | 146 | 267. |
| 50 | 57.6 | 148 | 274. |
| | | 150 | 281. |

## TABLE 7 — REFRIGERANT-500 (METRIC)

| PRESSURE / TEMPERATURE | | | |
|---|---|---|---|
| VACUUM CM. HG. | DEGREES C. | PRESSURE k Pa | DEGREES C. |
| 67.5 | −74.2 | 3.8 | 8.3 |
| 65.0 | −70.2 | 4.0 | 9.6 |
| 62.5 | −66.9 | 4.2 | 10.9 |
| 60.0 | −64.0 | 4.4 | 12.2 |
| 57.5 | −61.6 | 4.6 | 13.4 |
| 55.0 | −59.3 | 4.8 | 14.6 |
| 52.5 | −57.3 | 5.0 | 15.7 |
| 50.0 | −55.5 | 5.2 | 16.8 |
| 47.5 | −53.8 | 5.4 | 17.9 |
| 45.0 | −52.2 | 5.6 | 19.0 |
| 42.5 | −50.7 | 5.8 | 20.0 |
| 40.0 | −49.3 | 6.0 | 21.0 |
| 37.5 | −48.0 | 6.2 | 22.0 |
| 35.0 | −46.7 | 6.4 | 23.0 |
| 32.5 | −45.5 | 6.6 | 24.0 |
| 30.0 | −44.4 | 6.8 | 24.9 |
| 27.5 | −43.3 | 7.0 | 25.8 |
| 25.0 | −42.2 | 7.5 | 28.1 |
| 22.5 | −41.2 | 8.0 | 30.2 |
| 20.0 | −40.2 | 8.5 | 32.3 |
| 17.5 | −39.3 | 9.0 | 34.2 |
| 15.0 | −38.4 | 9.5 | 36.1 |
| 12.5 | −37.5 | 10.0 | 38.0 |
| 10.0 | −36.7 | 10.5 | 39.8 |
| 7.5 | −35.8 | 11.0 | 41.5 |
| 5.0 | −35.0 | 11.5 | 43.2 |
| 2.5 | −34.3 | 12.0 | 44.8 |
| | | 12.5 | 46.4 |
| PRESSURE k Pa | | 13.0 | 47.9 |
| | | 13.5 | 49.4 |
| 0.0 | −33.5 | 14.0 | 50.8 |
| 0.2 | −29.3 | 14.5 | 52.3 |
| 0.4 | −25.7 | 15.0 | 53.7 |
| 0.6 | −22.5 | 15.5 | 55.0 |
| 0.8 | −19.6 | 16.0 | 56.3 |
| 1.0 | −16.9 | 16.5 | 57.6 |
| 1.2 | −14.4 | 17.0 | 58.9 |
| 1.4 | −12.0 | 17.5 | 60.2 |
| 1.6 | −9.8 | 18.0 | 61.4 |
| 1.8 | −7.8 | 18.5 | 62.6 |
| 2.0 | 5.8 | 19.0 | 63.8 |
| 2.2 | −4.0 | 19.5 | 64.9 |
| 2.4 | −2.2 | 20.0 | 66.0 |
| 2.6 | −0.5 | | |
| 2.8 | 1.0 | | |
| 3.0 | 2.6 | | |
| 3.2 | 4.1 | | |
| 3.4 | 5.6 | | |
| 3.6 | 7.0 | | |

| TEMPERATURE / PRESSURE | | | |
|---|---|---|---|
| DEGREES C. | VACUUM CM. HG. | DEGREES C. | PRESSURE k Pa |
| −74 | 67.4 | −6 | 2.0 |
| −72 | 66.2 | −4 | 2.2 |
| −70 | 64.9 | −2 | 2.4 |
| −68 | 63.4 | 0 | 2.7 |
| −66 | 61.8 | 2 | 2.9 |
| −64 | 60.0 | 4 | 3.2 |
| −62 | 58.0 | 6 | 3.5 |
| −60 | 55.8 | 8 | 3.7 |
| −58 | 53.4 | 10 | 4.0 |
| −56 | 50.7 | 12 | 4.4 |
| −54 | 47.8 | 14 | 4.7 |
| −52 | 44.7 | 16 | 5.0 |
| −50 | 41.3 | 18 | 5.4 |
| −48 | 37.6 | 20 | 5.8 |
| −46 | 33.5 | 22 | 6.2 |
| −44 | 29.2 | 24 | 6.6 |
| −42 | 24.4 | 26 | 7.0 |
| −40 | 19.4 | 28 | 7.5 |
| −38 | 13.9 | 30 | 7.9 |
| −36 | 8.0 | 32 | 8.4 |
| −34 | 1.6 | 34 | 8.9 |
| | PRESSURE k Pa | 36 | 9.4 |
| | | 38 | 10.0 |
| | | 40 | 10.6 |
| −32 | 0.1 | 42 | 11.1 |
| −30 | 0.2 | 44 | 11.7 |
| −28 | 0.3 | 46 | 12.4 |
| −26 | 0.4 | 48 | 13.0 |
| −24 | 0.5 | 50 | 13.7 |
| −22 | 0.6 | 52 | 14.4 |
| −20 | 0.8 | 54 | 15.1 |
| −18 | 0.9 | 56 | 15.9 |
| −16 | 1.1 | 58 | 16.6 |
| −14 | 1.2 | 60 | 17.4 |
| −12 | 1.4 | 62 | 18.2 |
| −10 | 1.6 | 64 | 19.1 |
| −8 | 1.8 | 66 | 20.0 |

Metric R-800 Refrigerant Tables Form MS-479 pressure sensitive label available from York.

**TABLE 8** — REFRIGERANT-22 ( ENGLISH)

| PRESSURE / TEMPERATURE | | | |
|---|---|---|---|
| VACUUM IN. HG. | DEGREES F. | PRESSURE PSIG | DEGREES F. |
| 28 | −124. | 40 | 17.2 |
| 27 | −113. | 42 | 19.1 |
| 26 | −106. | 44 | 20.9 |
| 25 | −99.8 | 46 | 22.6 |
| 24 | −94.7 | 48 | 24.4 |
| 23 | −90.2 | 50 | 26.0 |
| 22 | −86.2 | 52 | 27.7 |
| 21 | −82.7 | 54 | 29.3 |
| 20 | −79.4 | 56 | 30.9 |
| 19 | −76.4 | 58 | 32.4 |
| 18 | −73.6 | 60 | 33.9 |
| 17 | −71.0 | 62 | 35.4 |
| 16 | −68.6 | 64 | 36.8 |
| 15 | −66.3 | 66 | 38.3 |
| 14 | −64.1 | 68 | 39.6 |
| 13 | −62.0 | 70 | 41.0 |
| 12 | −60.1 | 72 | 42.4 |
| 11 | −58.2 | 74 | 43.7 |
| 10 | −56.4 | 76 | 45.0 |
| 9 | −54.6 | 78 | 46.3 |
| 8 | −52.9 | 80 | 47.5 |
| 7 | −51.3 | 90 | 53.5 |
| 6 | −49.8 | 100 | 59.1 |
| 5 | −48.3 | 110 | 64.4 |
| 4 | −46.8 | 120 | 69.3 |
| 3 | −45.4 | 130 | 74.0 |
| 2 | −44.0 | 140 | 78.4 |
| 1 | −42.7 | 150 | 82.7 |
| PRESSURE PSIG | | 160 | 86.7 |
| | | 170 | 90.6 |
| | | 180 | 94.3 |
| 0 | −41.4 | 190 | 97.9 |
| 2 | −36.4 | 200 | 101. |
| 4 | −31.9 | 210 | 105. |
| 6 | −27.7 | 220 | 108. |
| 8 | −23.9 | 230 | 111. |
| 10 | −20.3 | 240 | 114. |
| 12 | −16.9 | 250 | 117. |
| 14 | −13.7 | 260 | 120. |
| 16 | −10.7 | 270 | 123. |
| 18 | −7.8 | 280 | 126. |
| 20 | −5.1 | 290 | 128. |
| 22 | −2.5 | 300 | 131. |
| 24 | 0.0 | 310 | 133. |
| 26 | 2.5 | 320 | 136. |
| 28 | 4.8 | 330 | 138. |
| 30 | 7.0 | 340 | 141. |
| 32 | 9.2 | 350 | 143. |
| 34 | 11.3 | 360 | 145. |
| 36 | 13.3 | 370 | 147. |
| 38 | 15.3 | 380 | 150. |

| TEMPERATURE / PRESSURE | | | |
|---|---|---|---|
| DEGREES F. | VACUUM IN. HG. | DEGREES F. | PRESSURE PSIG |
| −120 | 27.7 | 48 | 80.8 |
| −115 | 27.2 | 50 | 84.0 |
| −110 | 26.6 | 52 | 87.4 |
| −105 | 25.9 | 54 | 90.8 |
| −100 | 25.0 | 56 | 94.3 |
| −95 | 24.1 | 58 | 97.9 |
| −90 | 23.0 | 60 | 102. |
| −85 | 21.7 | 62 | 105. |
| −80 | 20.2 | 64 | 109. |
| −75 | 18.5 | 66 | 113. |
| −70 | 16.6 | 68 | 117. |
| −65 | 14.4 | 70 | 121. |
| −60 | 12.0 | 72 | 126. |
| −55 | 9.2 | 74 | 130. |
| −50 | 6.2 | 76 | 134. |
| −45 | 2.7 | 78 | 139. |
| | PRESSURE PSIG | 80 | 144. |
| | | 82 | 148. |
| | | 84 | 153. |
| −40 | 0.5 | 86 | 158. |
| −35 | 2.6 | 88 | 163. |
| −30 | 4.9 | 90 | 168. |
| −25 | 7.4 | 92 | 174. |
| −20 | 10.1 | 94 | 179. |
| −15 | 13.2 | 96 | 185. |
| −10 | 16.5 | 98 | 190. |
| −5 | 20.1 | 100 | 196. |
| 0 | 24.0 | 102 | 202. |
| 2 | 25.6 | 104 | 208. |
| 4 | 27.3 | 106 | 214. |
| 6 | 29.1 | 108 | 220. |
| 8 | 30.7 | 110 | 226. |
| 10 | 32.8 | 112 | 233. |
| 12 | 34.7 | 114 | 239. |
| 14 | 36.7 | 116 | 246. |
| 16 | 38.7 | 118 | 253. |
| 18 | 40.9 | 120 | 260. |
| 20 | 43.0 | 122 | 267. |
| 22 | 45.3 | 124 | 274. |
| 24 | 47.6 | 126 | 282. |
| 26 | 49.9 | 128 | 289. |
| 28 | 52.4 | 130 | 297. |
| 30 | 54.9 | 132 | 305. |
| 32 | 57.5 | 134 | 313. |
| 34 | 60.1 | 136 | 321. |
| 36 | 62.8 | 138 | 329. |
| 38 | 65.6 | 140 | 337. |
| 40 | 68.5 | 142 | 346. |
| 42 | 71.5 | 144 | 354. |
| 44 | 74.5 | 146 | 363. |
| 46 | 77.6 | 148 | 372. |
| | | 150 | 381. |

## TABLE 9 — REFRIGERANT-22 (METRIC)

**PRESSURE / TEMPERATURE**

| VACUUM CM. HG. | DEGREES C. | PRESSURE k Pa | DEGREES C. |
|---|---|---|---|
| **65.0** | −75.1 | 4.6 | 3.2 |
| **62.5** | −72.0 | 4.8 | 4.3 |
| **60.0** | −69.4 | 5.0 | 5.4 |
| **57.5** | −67.1 | 5.2 | 6.4 |
| **55.0** | −65.0 | 5.4 | 7.5 |
| **52.5** | −63.1 | 5.6 | 8.5 |
| **50.0** | −61.4 | 5.8 | 9.4 |
| **47.5** | −59.8 | 6.0 | 10.4 |
| **45.0** | −58.3 | 6.2 | 11.3 |
| **42.5** | −56.9 | 6.4 | 12.2 |
| **40.0** | −55.6 | 6.6 | 13.1 |
| **37.5** | −54.3 | 6.8 | 14.0 |
| **35.0** | −53.1 | 7.0 | 14.9 |
| **32.5** | −52.0 | 7.5 | 17.0 |
| **30.0** | −50.9 | 8.0 | 19.0 |
| **27.5** | −49.9 | 8.5 | 20.9 |
| **25.0** | −48.9 | 9.0 | 22.8 |
| **22.5** | −48.0 | 9.5 | 24.6 |
| **20.0** | −47.1 | 10.0 | 26.3 |
| **17.5** | −46.2 | 10.5 | 28.0 |
| **15.0** | −45.3 | 11.0 | 29.6 |
| **12.5** | −44.5 | 11.5 | 31.1 |
| **10.0** | −43.7 | 12.0 | 32.7 |
| **7.5** | −42.9 | 12.5 | 34.1 |
| **5.0** | −42.2 | 13.0 | 35.6 |
| **2.5** | −41.5 | 13.5 | 37.0 |
| PRESSURE k Pa | | 14.0 | 38.3 |
| | | 14.5 | 39.7 |
| | | 15.0 | 41.0 |
| 0.0 | −40.7 | 15.5 | 42.3 |
| 0.2 | −36.9 | 16.0 | 43.5 |
| 0.4 | −33.5 | 16.5 | 44.7 |
| 0.6 | −30.4 | 17.0 | 45.9 |
| 0.8 | −27.7 | 17.5 | 47.1 |
| 1.0 | −25.1 | 18.0 | 48.2 |
| 1.2 | −22.8 | 18.5 | 49.3 |
| 1.4 | −20.6 | 19.0 | 50.4 |
| 1.6 | −18.6 | 19.5 | 51.5 |
| 1.8 | −16.6 | 20.0 | 52.6 |
| 2.0 | −14.8 | 20.5 | 53.6 |
| 2.2 | −13.0 | 21.0 | 54.7 |
| 2.4 | −11.4 | 21.5 | 55.7 |
| 2.6 | −9.8 | 22.0 | 56.7 |
| 2.8 | −8.3 | 22.5 | 57.6 |
| 3.0 | −6.8 | 23.0 | 58.6 |
| 3.2 | −5.4 | 23.5 | 59.6 |
| 3.4 | −4.0 | 24.0 | 60.5 |
| 3.6 | −2.7 | 24.5 | 61.4 |
| 3.8 | −1.4 | 25.0 | 62.3 |
| 4.0 | −0.2 | 25.5 | 63.2 |
| 4.2 | 0.9 | 26.0 | 64.1 |
| 4.4 | 2.1 | 26.5 | 65.0 |
| | | 27.0 | 65.8 |

**TEMPERATURE / PRESSURE**

| DEGREES C. | VACUUM CM. HG. | DEGREES C. | PRESSURE k Pa |
|---|---|---|---|
| −86 | 71.0 | −12 | 2.33 |
| −84 | 70.1 | −10 | 2.58 |
| −82 | 69.2 | −8 | 2.84 |
| −80 | 68.2 | −6 | 3.12 |
| −78 | 67.0 | −4 | 3.41 |
| −76 | 65.6 | −2 | 3.72 |
| −74 | 64.1 | 0 | 4.04 |
| −72 | 62.5 | 2 | 4.38 |
| −70 | 60.6 | 4 | 4.74 |
| −68 | 58.5 | 6 | 5.11 |
| −66 | 56.3 | 8 | 5.50 |
| −64 | 53.7 | 10 | 5.91 |
| −62 | 50.9 | 12 | 6.34 |
| −60 | 47.9 | 14 | 6.78 |
| −58 | 44.5 | 16 | 7.25 |
| −56 | 40.9 | 18 | 7.74 |
| −54 | 36.8 | 20 | 8.25 |
| −52 | 32.5 | 22 | 8.78 |
| −50 | 27.7 | 24 | 9.33 |
| −48 | 22.5 | 26 | 9.90 |
| −46 | 16.9 | 28 | 10.5 |
| −44 | 10.9 | 30 | 11.1 |
| −42 | 4.3 | 32 | 11.8 |
| | | 34 | 12.4 |
| | PRESSURE k Pa | 36 | 13.1 |
| | | 38 | 13.9 |
| −40 | 0.04 | 40 | 14.6 |
| −38 | 0.14 | 42 | 15.4 |
| −36 | 0.25 | 44 | 16.2 |
| −34 | 0.37 | 46 | 17.0 |
| −32 | 0.50 | 48 | 17.9 |
| −30 | 0.63 | 50 | 18.8 |
| −28 | 0.78 | 52 | 19.7 |
| −26 | 0.93 | 54 | 20.7 |
| −24 | 1.10 | 56 | 21.6 |
| −22 | 1.28 | 58 | 22.7 |
| −20 | 1.46 | 60 | 23.7 |
| −18 | 1.66 | 62 | 24.8 |
| −16 | 1.87 | 64 | 25.9 |
| −14 | 2.10 | 66 | 27.1 |

Metric R-22 Conversion Tables, Form EM68-3294C, Pressure Sensitive Label available from York.

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