Number One Air Conditioning Maker
Carrier
Carrier Parkway • Syracuse, N.Y. 13221

Open-Drive Centrifugal Liquid Chillers

→

GENERAL

Carrier 17DA Open Drive Centrifugal Liquid Chillers are designed primarily for large capacity water chilling applications in the range from 2500 through 7000 tons. Various combinations of 17DA components also provide service in large tonnage brine chilling or industrial process cooling applications. The 17DA compressor is normally driven by steam turbine or by electric motor.

The auxiliary equipment used with 17DA chillers may vary widely from job to job. A purge unit and a pumpout unit, however, should be used in each installation. Usually, a single pumpout unit will suffice to service several machines on multiple-machine installations. The auxiliary oil pump is optional and is driven by an electric motor.

Because of the variety of drives and auxiliary equipment, the control systems described in this publication are basic and may not fully match those used on individual installations. Detailed control diagrams which include a sequence of operation are provided on all jobs.

17DA Controls – Three basic categories are described in this publication.

CAPACITY CONTROLS – These pneumatically operated controls vary the machine capacity in response to changes in load.

SAFETY CONTROLS (electric) shut down the drive equipment in the event of any machine malfunction.

AUXILIARY CONTROLS operate the purge pump, pumpdown unit and auxiliary oil pump(s).

CAPACITY CONTROLS

The capacity control system (Fig. 2) includes the pneumatic controls which move the guide vanes and the diffuser sleeve, and the turbine speed control system for partial load operation.

Guide Vane and Diffuser Sleeve Operation – As shown in Fig. 2, the temperature controller transmits a 3 to 15 psi air signal thru the auto.-manual loading panel to the positioner on the pneumatic actuator. The guide vanes and the diffuser sleeve are reset simultaneously to maintain the desired leaving chilled water temperature and to ensure optimum machine performance.

Refer to Fig. 1. The pneumatic actuator, in response to the temperature controller signal, rotates the coordinating ring which is mechanically linked to the inlet guide vanes by aircraft-type rod and bearing linkages. Three program cams in the coordinating ring, thru actuating rods, move diffuser sleeve across the impeller tip.

The cam programming is such that the diffuser sleeve does not move when the load is above 50%. Below 50%, the diffuser sleeve and guide vanes move simultaneously to provide optimum partial load performance down to about 10% load without the use of hot gas bypass.

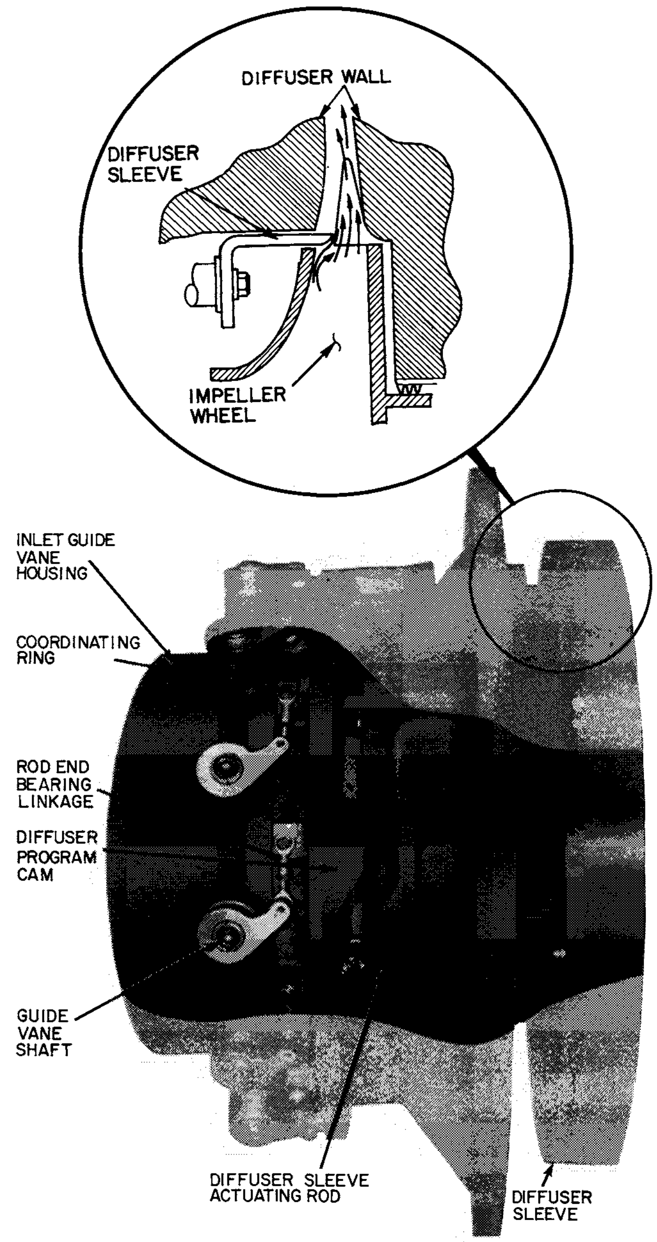
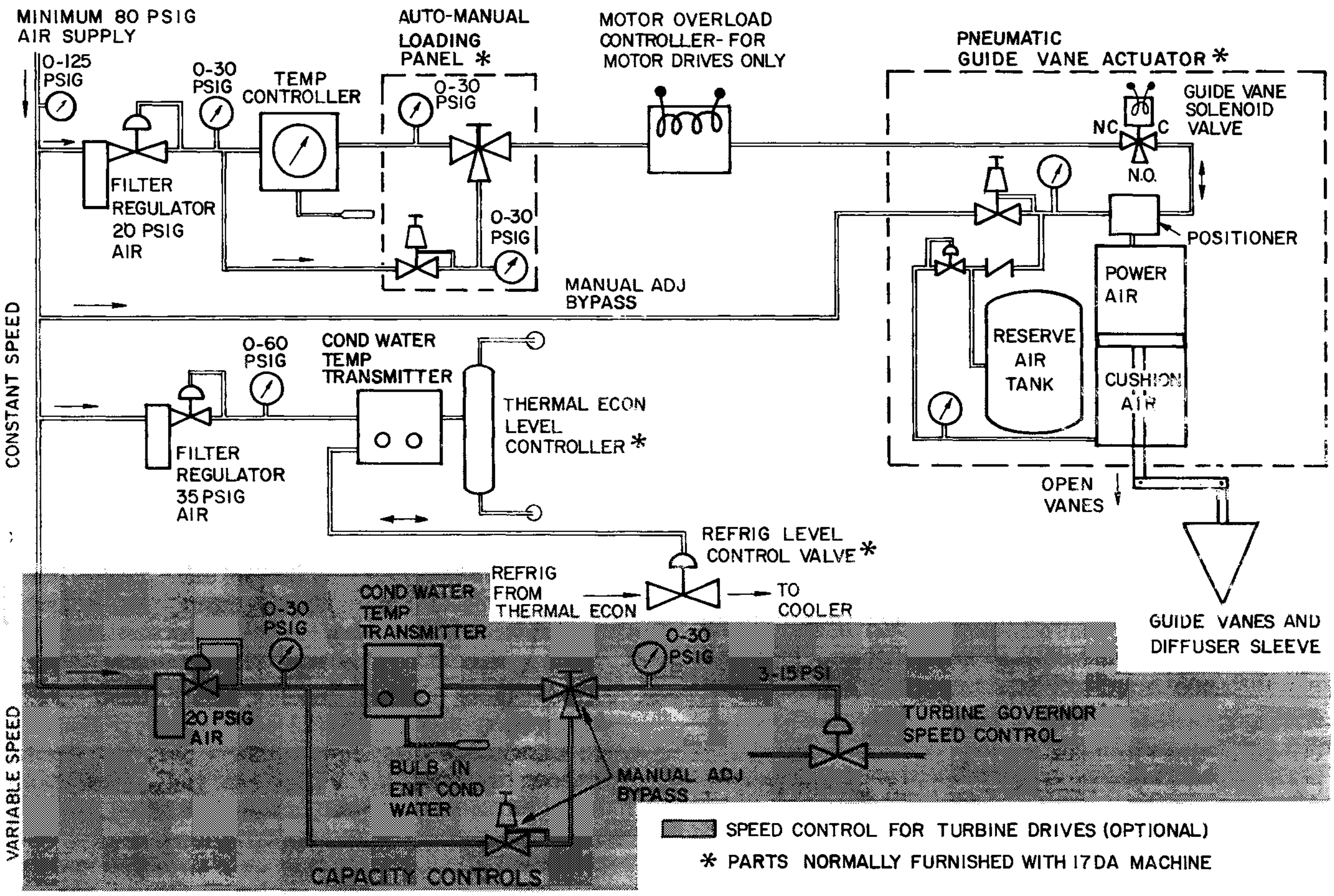


Fig. 1 – Guide Vane and Diffuser Sleeve

→ The purpose of the diffuser sleeve is to prevent aerodynamic instability thru the impeller. Aerodynamic instability is characterized by a high noise level and occurs at low loads when the gas velocity is relatively low. It differs from surge which is characterized by a series of deep roaring sounds and unstable operation.

→ As the load decreases, the diffuser sleeve begins to close off the impeller tip area, thus maintaining sufficient gas velocity thru the impeller to prevent aerodynamic instability, and also reducing the point at which compressor surge may occur.



→ **Fig. 2 — Capacity Control Diagram**

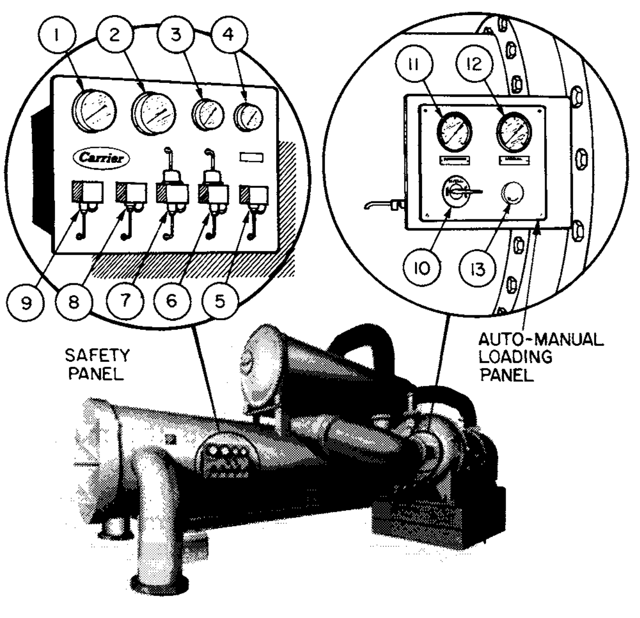
Table 1 — Capacity Control Diagram Components (Pneumatic)

DESCRIPTION	LOCATION	REMARKS
Pneumatic Items By Carrier (Unless Otherwise Noted)		
Variable Guide Vane and Diffuser Sleeve Pneumatic Actuator, with Airlock System and DA Positioner	Compressor	Guide vanes fully open on 15 psig air signal, closed on 3 psig. Vanes close on loss of air pressure or electrical failure.
Auto.-Manual Loading Panel with Selector Valve, Manual Pressure Regulator and Gages	Compressor, or Control Console	Permits manual control of inlet guide vanes.
Chilled Water Temp Controller*	–	–
→ Thermal Economizer Liquid Level Controller with Filter Regulator, Level Gage, and Air Press. Gages	Condenser	Field set for 25% proportional band. Set level adjustment at 80%. Rising level decreases air output.
Refrigerant Control Valve	Refrig line from cond	N.O. valve fully open at 6 psig, closed at 30 psig.
Cond Water Temp Transmitter*	Located ent cond water line	–
Guide Vane Solenoid Valve	Compressor	Bleeds when de-energized.

*Not by Carrier.

→ **Auto.-Manual Loading Panel** (Fig. 2 and 3) – The panel allows either automatic or manual control of the leaving chilled water temperature. Manual control is useful for adjusting the guide vane actuator if any maintenance is required. On turbine driven machines, manual control is useful in limiting the initial horsepower requirements, and on motor driven machines without a load limit relay, it prevents motor overload during start-up and pull-down. Manual control is accomplished by adjusting the air pressure to the pneumatic guide vane actuator thru the manual pressure regulating valve knob (item 13, Fig. 3). Air pressure to the actuator is indicated on the manual loading pressure gage (item 12).

→ **Pneumatic Guide Vane Actuator** – A piston type pneumatic vane actuator (Fig. 2), requiring 80 – 100 psi air, is used to power the guide vane and diffuser sleeve mechanism. A constant pressure "cushion air" is maintained on the guide vane side of the piston. The positioner, in response to control air pressure, varies the air pressure above the piston, thus controlling the guide vane position. The reserve air tank on the pneumatic actuator has sufficient air reserve to close the guide vanes if air pressure fails. A 3-way solenoid in the signal air line actuates on shutdown, bleeding air from the positioner and allowing the guide vanes to close. This action prevents reverse compressor rotation.



LEGEND

- 1 – Cond Pressure Gage
- 2 – Cooler Pressure Gage
- 3 – Duplex Pressure Gage (Seal Oil Supply and Back of Seal Pressure)
- 4 – Bearing Oil Supply Pressure Gage
- 5 – Bearing Oil Low-Pressure Cutout
- 6 – Seal Oil Low-Pressure Cutout
- 7 – Aux Oil Pump Control
- 8 – Cooler Low-Pressure Cutout
- 9 – Cond High-Pressure Cutout
- 10 – Auto.-Manual Selector Switch
- 11 – Instrument Loading Pressure Gage
- 12 – Manual Loading Pressure Gage
- 13 – Manual Pressure Regulating Valve

Fig. 3 – 17DA Loading and Safety Panels (Typical)

→ **Thermal Economizer Liquid Level Controller** – A refrigerant level controller and control valve (Fig. 2) are used to maintain a liquid seal between the high and the low side of the machine.

HIGH SIDE – The controller maintains a liquid level above the thermal economizer deck in the condenser, thus assuring flooded thermal economizer tubes and providing optimum performance.

LOW SIDE – The refrigerant charge in the cooler is maintained at optimum level under all load conditions by proportional action of the thermal economizer liquid level controller.

The proportional band setting on the level controller is such that, as the load decreases, additional refrigerant is released to the cooler from the thermal economizer. This ensures that the cooler tubes are covered even though boiling action has decreased.

→ PARTIAL LOAD OPERATION

Centrifugal water chillers seldom operate at design conditions. Usually, condenser water is at a lower temperature than the specified design temperature, or the cooling load is less than design. These off-design conditions require a reduction in compressor head (temperature lift).

On constant speed machines, the reduction in compressor head and machine capacity is accomplished solely by adjustment of the inlet guide vanes and the diffuser sleeve as previously described. This combination of constant speed and guide vane adjustment can deliver stable operation down to 10% load as shown in Fig. 4. At the same time, however, there is little saving in partial load power regardless of reduction in entering condenser water temperature.

On the other hand, if variable compressor speed is added to inlet guide vane operation, a substantial saving in partial load power can be achieved at

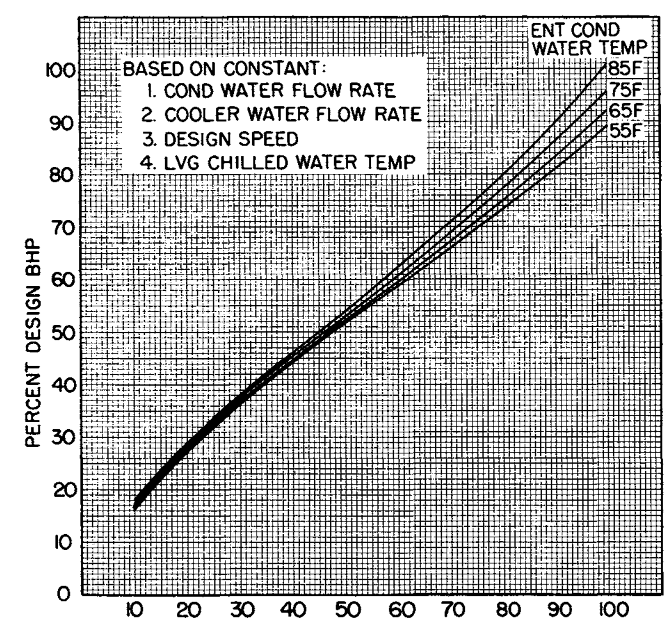


Fig. 4 – Typical 17DA Partial Load Performance with Constant Speed Driver

reduced entering condenser water temperatures. These savings are indicated in Fig. 5.

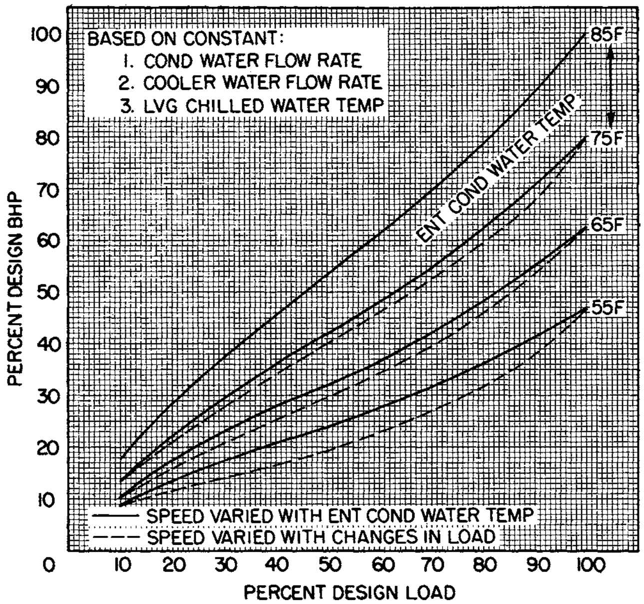


Fig. 5 — Typical 17DA Partial Load Performance with Variable Speed Driver

To illustrate, at constant speed and with 55 F entering condenser water, Fig. 4 shows a power requirement of 53% design bhp at 50% load. If, with the same 50% load and 55 F entering condenser water, the speed is reduced under the control of condenser water temperature, the bhp requirement is only 24% of design as shown in Fig. 5. This is a very substantial power saving over constant speed operation.

Figure 5 also indicates performance of a typical 17DA water chiller with speed reset in response to load changes. Ordinarily, the savings in power made by resetting speed on the basis of load changes do not warrant the complex and expensive controls required for such a system. Carrier, therefore, recommends that turbine speed be controlled from entering condenser water temperature. Experience has shown that this type of control provides most of the power advantages with minimum danger of hunting within the control system, and with the least likelihood of driving the machine into an unexpected surge condition.

To more fully explain the advantage of controlling speed on the basis of entering condenser water temperatures, a typical 17DA performance chart is provided in Fig. 6. Curves are shown for 3 different operating compressor speeds, 100%, 95% and 90%. A surge line has been drawn thru these 3 speed lines showing where the machine will surge if the guide vanes remain fully opened. At 100% speed, with no guide vane throttling, the machine can be expected to surge at approximately 90% load. With the guide vanes operating normally, controlled by leaving chilled water temperature, this surge line is lowered all the way to 5 or 10% load. Notice, however, that the percent head available on these surge lines is steadily reduced as the load falls off. Following the 100% speed line, approximately 92% head can be achieved without surging when at 50% load, and at 10% load, approximately 78% head can be achieved without surging. Similar head reductions also occur on the 95% speed line and 90% speed line.

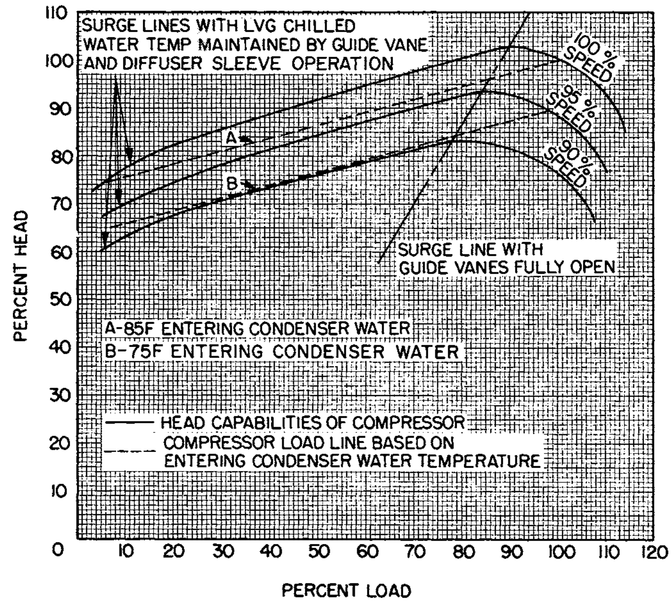


Fig. 6 — Typical 17DA Variable Speed Map with Compressor Load Lines

Two additional lines A and B have been drawn on Fig. 6 to show typical 17DA system head requirements at various loads and at 85 F and 75 F entering condenser water temperatures respectively. Both lines A and B are based on design entering condenser water flow at all load conditions. This is the normal mode of operation.

To ensure stable operation, without surging, the available compressor head (speed lines in Fig. 6) must always exceed the required head lines (dashed lines A and B, Fig. 6). Assuming a 50% load with 85 F entering condenser water temperature, the intersection of the 50% load line with line A indicates an ideal speed just over the 95% speed line, or approximately 96%. In normal 17DA operation, the actual speed will be kept at 100% as long as the entering condenser water temperature is 85 F or above. This is only 4% higher than the ideal speed of 96% at 50% load, and represents an additional head "cushion" to keep the machine away from a surge condition. Furthermore, at 50% load, the compressor will produce 92% head at 100% speed and the system will require 86.5% head (a 5.5% cushion). This slight difference between required head and available head will cause the inlet guide vanes to throttle slightly to reach a stable operating point.

The pneumatic controls for automatic speed reset, based as recommended, on entering condenser water temperatures, are shown in Fig. 2. A signal which is proportional to entering condenser water temperature is sent by a temperature transmitter to the air head of a turbine speed governor. The turbine speed varies as the water temperature changes.

It is important when controlling speed on the basis of entering condenser water temperature that the design condenser water flow be maintained.

SAFETY CONTROLS

Figure 7 schematically shows basic control function wiring for a turbine driven 17DA machine. Actual machine controls and/or wiring may differ from this in some respects; refer to individual job wiring diagrams.

To start machine, place all switches in "Auto." position except pumpout circuit switch (line 24), and compressor motor-driven auxiliary oil pump switch (line 14) if supplied.

Start cooler and condenser water pumps (not shown), and compressor main oil pump (line 11). Close shutdown seal bleed valve on compressor; seal movement switch (line 4) will close and seal ready light (line 6) will go on. All machine safeties (line 4) should now be satisfied.

Push machine start button (line 4). Run relay RR (line 4) locks in start circuit, and energizes solenoid trip (line 8) and run light (line 7). 17DA motor driven machines start immediately when start button is pushed. On turbine driven machines, the turbine trip handle switch (line 9) must be manually set and a steam valve opened to warm up and start the turbine.

To stop machine, push machine stop button (line 4). Run relay RR drops out, de-energizing turbine solenoid trip and guide vane bleed solenoid. The de-energized bleed solenoid allows air pressure to drop in the guide vane operator piston and the guide vanes close. This action prevents the pressure differential between cooler and condenser from forcing the compressor into reverse rotation.

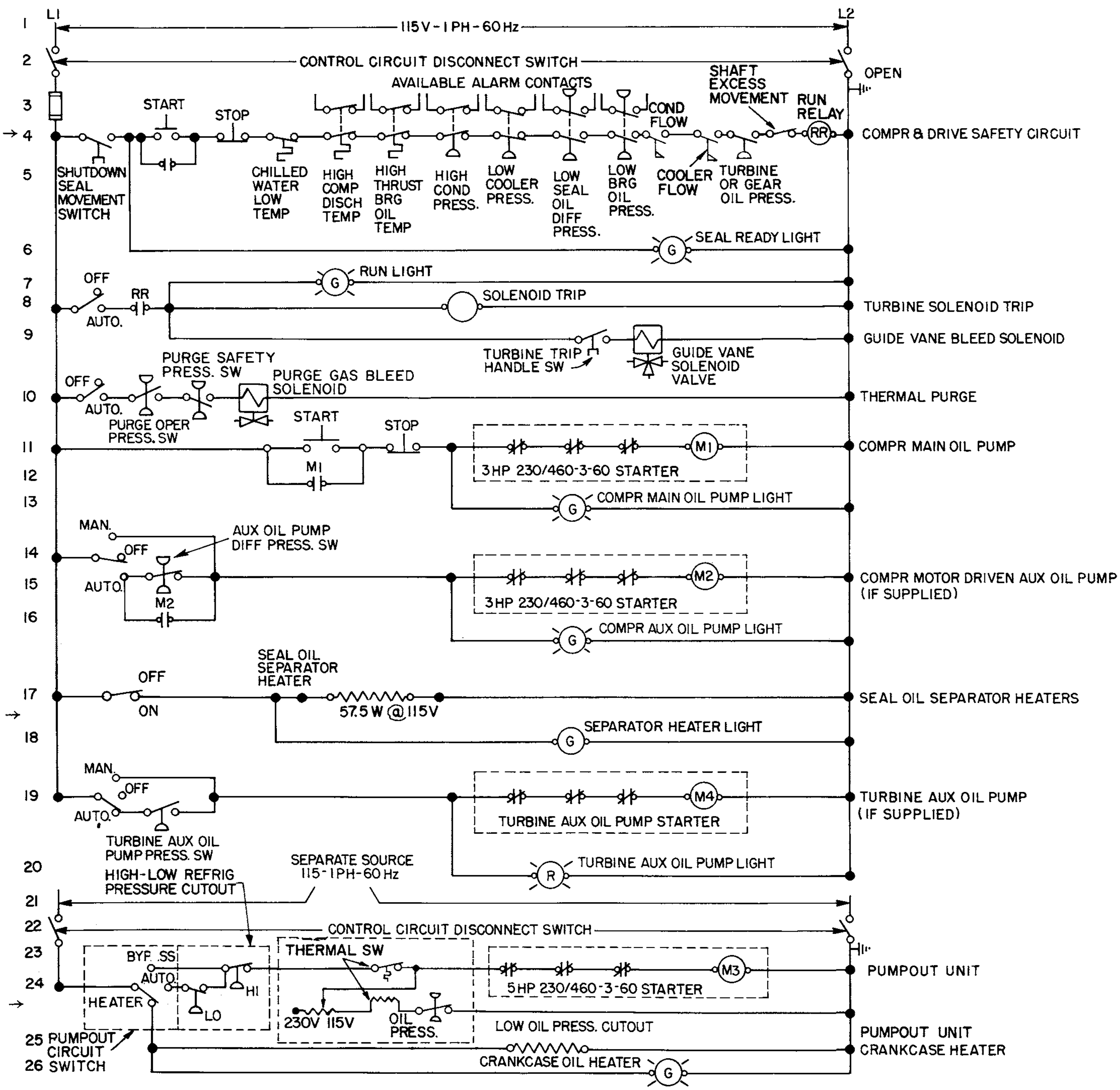


Fig. 7 — Basic Operating Control Function Schematic

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Table 2 — Operating Control Diagram Components (Electrical)

DESCRIPTION	LOCATION	CONTACTS Setting Opens At	CONTACTS Setting Closes At	CONTACTS Reset	RATED AT 115 VOLTS
Electrical Items By Carrier (Unless Otherwise Noted)					
Guide Vane Solenoid Valve	Compressor	Bleeds when de-energized	—	—	—
High Disch Temp Switch	Compressor	240 F	—	Manual	20 amps
High Thrust Bearing Oil Temp Gage and Safety Cutout	Compressor	180 F	—	Auto.	10 amps
Shutdown Seal Movement Limit Switch	Compressor	When shutdown seal is seated	When shutdown seal is in running position	Reset by opening or closing manual valve	15 amps
Seal Oil Separator Heater	Seal Oil Separator	Energize whenever machine is shut down.		Manual	57.5 watts at 115 v
Low Chilled Water Temp Cutout	Cooler	38 F or 5 F below leaving brine temp	15 F above opening point	Auto.	10.2 amps
Low Oil Press. Cutout	Pumpout Unit	16 psid	11 psid	Auto.	6.5 amps
High-Low Refrigerant Press. CFC-12, HFC-134a, CFC-500 Cutout	Pumpout Unit	High — 161 psig Low — 32 psig	High — 130 psig Low — 17 psig	Auto.	16 amps (both)
High-Low Refrigerant Press. HCFC-22 Cutout	Pumpout Unit	High — 220 psig Low — 61 psig	High — 185 psig Low — 73 psig	Auto.	16 amps (both)
Crankcase Oil Heater	Pumpout Unit	Energize when pumpout is not operating		—	100 watts
Purge Gas Bleed Solenoid	Purge	Bleeds when energized	—	—	12 watts
Purge Operating Press. Switch	Purge	16 psid	8 psid	Auto.	15 amps
Purge Safety Press. Switch	Purge	16 psid	24 psid	Auto.	15 amps
High Condenser Press. Cutout	Safety Panel	167 psig	25 psi† below cuout point	Manual	20 amps
Low Cooler Press. Cutout	Safety Panel	Field set 1-2 psi below design suction pressure	10 psi† above cutout point	Manual	20 amps
Low Seal Oil Diff Press. Cutout	Safety Panel	11 psid	16 psid†	Manual	7 amps
Low Bearing Oil Press. Cutout	Safety Panel	8 psig	13 psig†	Manual	20 amps
Aux Oil Pump Diff Press. Switch	Safety Panel	27 psid	22 psid	Manual	13.9 amps
Turbine or Gear Oil Press. Switch* (if required)	Turbine or Gear	Per job requirement		—	—
Turbine Trip Handle Switch*	Turbine	—		Manual	—
Turbine AOP Press. Switch*	Turbine	Per job requirement		—	—
Motor Overload Controller (for motor drives only)	—	Per job requirement		—	—

*Not by Carrier.
†"Closes At" setting is condition at which mechanical portion of cutout will automatically reset. Electrical portion of cutout cannot be manually reset until these conditions are attained.

Shutdown Seal — All 17DA machines have an iso-carbon seal that prevents refrigerant leakage during operation. In addition, there is a separate and unique shutdown seal arrangement.

At shutdown, the impeller shaft moves approximately 1/16-in. axially and contacts a Teflon seat to provide a positive shutdown seal. At the same time, a shutdown seal movement switch (line 4, Fig. 7) prevents compressor start-up with the shaft in this position. Starting the main oil pump and closing the seal oil bleed valve causes the shaft to move away from the Teflon seat and closes the seal movement switch. A seal ready light (line 6, Fig. 7) is recommended to indicate when the shaft is in the run position.

Chilled Water and Condenser Water Interlocks are required to prevent machine operation if water flow is interrupted. The interlocks may be flow or differential pressure switches, or auxiliary contacts in the water pump starting circuits.

Turbine Trip Handle Switch is furnished by the turbine manufacturer. It is mounted near the solenoid trip lever so that it closes when the solenoid is energized and the arm mechanism is set. If the turbine is intentionally shut down by manually tripping the trip handle, the switch opens and de-energizes the guide vane solenoid (line 9, Fig. 7). This ensures that the guide vanes close, preventing reverse rotation of the compressor shaft and impeller.

Motor Overload Control — Motor driven machines must have a load limit relay or other control to prevent motor overload during start-up and pull-down conditions. A commercial grade load limiting control is normally used. This relay, located in the air signal line to the guide vane positioner, responds to excessive motor current by overriding the signal from the leaving chilled water thermostat and preventing the guide vanes from opening fully. This reduces compressor horsepower requirements during start-up and pulldown.

A special industrial grade load limiting control can also be supplied at a higher initial cost. For further information on this special control, contact

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Motor used with 17DA centrifugal machines must be limited to a given number of starts per hour to prevent overheating. To accomplish this, or to prevent rapid recycling on any safety control, a timer is recommended.

Safety Panel, illustrated in Fig. 3, is supplied as standard on 17DA machines.

→**Alarm Circuit** — If a custom control panel is not ordered, an alarm circuit can be built using double pole, single-throw (DPST) safety switches. See Fig. 8a and 8b.

AUXILIARY CONTROLS

Pumpout Unit and Storage Tank are usually supplied with 17DA machines. The pumpout unit transfers refrigerant between the machine cooler and the storage tank. The pumpout compressor is protected by a low oil pressure safety switch and a refrigerant high-low pressure switch (line 24, Fig. 7). The low oil pressure safety switch contains a thermal time delay which bypasses this safety for a few seconds during pumpout start-up. The normally closed pressure switch allows the thermal element to heat up. If oil pressure is not present within a very short time, the heat of the thermal element will cause the thermostat to open and stop the pumpout compressor.

An Auto.-Heater-Bypass switch (line 24, Fig. 7) is suggested for use with the pumpout unit. In the "Bypass" position, the switch bypasses the refrigerant low pressure cutout (line 24, Fig. 7) and allows nearly complete machine evacuation. When evacuating, make sure there is no brine in the system or freeze-up damage may result.

To prevent oil dilution in the pumpout compressor crankcase, the crankcase oil heater (line 25, Fig. 7) should be energized when the pumpout unit is not operating.

Special Control Console (Fig. 9) can be supplied on a per job basis, at extra cost. Standard panel items (see Fig. 3), lights, relays, controllers, gages, switches and other job specified controls are included.

Purge removes water vapor and noncondensables from the system. When the noncondensable pressure level in the purge condensing chamber approaches machine condensing level, the purge operating switch (line 10, Fig. 7) closes, opening a solenoid valve and bleeding off noncondensables.

To prevent the operating switch from opening the solenoid valve at machine shutdown when vessel pressures equalize, a purge safety switch remains open until an operating pressure difference exists between cooler and condenser.

Auxiliary Oil Pump — Because the bearings of the 17DA compressor are designed to retain sufficient oil for proper lubrication during machine coastdown, even after power failure with the oil pump not running, an auxiliary oil pump is not normally required. To ensure against extended coastdown time, however, turbine driven machines must be

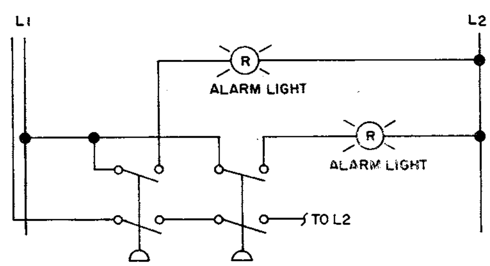

Fig. 8a — Typical Alarm Circuit

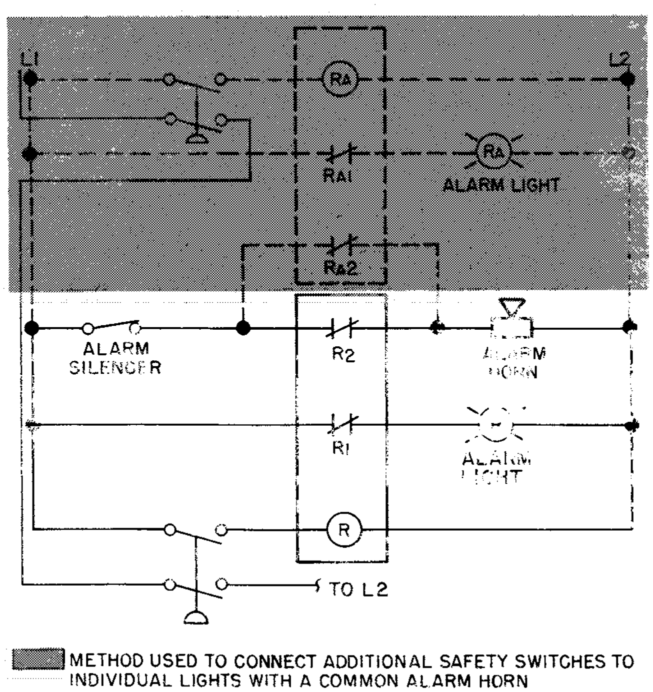

Fig. 8b — Alternate Alarm Circuit

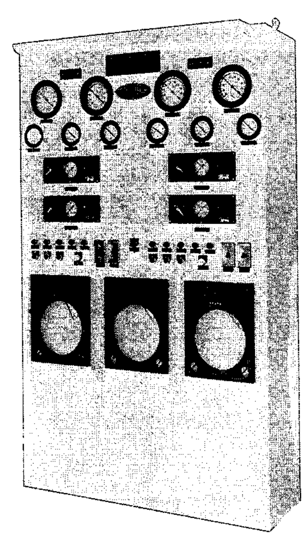

Fig. 9 — Representative Special Control Console

furnished with a condenser vacuum breaker and a high quality automatic turbine shutoff valve must be installed in the steam inlet line.

Normally, the auxiliary oil pump is driven by an electric motor. For special applications, auxiliary oil pumps driven by other means can be provided.

Hot Gas Bypass is not normally required on 17DA machines since the variable inlet guide vane and diffuser sleeve system permits stable operation down to 10% load.

17DA Free Cooling Cycle — 17DA water chillers may be modified to provide free cooling on customer request.

The term "free cooling" is applied to the cooling of recirculated chilled water in the machine cooler without operating the machine compressor. Free cooling is normally used in the winter season when both the cooling load and the entering condenser water temperatures are low. It is practical where:

1. There is a source of cold condensing water.
2. Required chilled water temperatures are 5 to 10 F higher than entering condenser water.
3. Anticipated loads are not more than 40% of full load.

Free cooling requires:

1. An efficient method of maintaining a flooded cooler tube bundle.
2. Large refrigerant gas and liquid passages between cooler and condenser.

The built-in thermal economizer of the 17DA water chiller makes the 17DA machine particularly suitable for free cooling applications, because the liquid refrigerant can easily be drained into the cooler to flood the tubes.

During colder seasons, when condensing water of 5 to 10 F lower temperature than the required leaving chilled water is available, the compressor can be shut down and the evaporating refrigerant is then piped directly from cooler to condenser.

The refrigerant charge of the thermal economizer (approximately 20% of the total charge) is drained thru a valved bypass line into the cooler. This additional refrigerant keeps the cooler tube bundle flooded for efficient heat transfer throughout the free cooling operation.

A large extra gas connection permits the free flow of evaporated refrigerant from cooler to condenser. This passage is valved off during normal operation of the compressor.

The 17DA system eliminates the need for refrigerant pumps and spray headers required by other methods of free cooling.

The necessary connections and valve for the thermal economizer-to-cooler liquid drain, and the connections and valve for the free cooling gas bypass from cooler to condenser are available as special order items when free cooling provisions are required with 17DA machines. The liquid drain line and valve vary in size from 6 to 8 in., and the gas bypass pipe and valve vary from 10 to 16 in. in diameter, depending upon machine size and design tonnage.

→ TURBINE GOVERNORS

Do not use NEMA (National Electrical Manufacturers Association) Class A or B governors for centrifugal compressor duty. See Table 3. The maximum speed rise and regulation values may allow compressor overspeed and nuisance tripping, particularly in high lift or HCFC-22 applications.

A NEMA Class C or D governor is recommended. Large horsepower machines (more than 2,000 hp) require NEMA Class D governors. Most applications require automatic speed modulation between 80% and 105%. The 80% speed modulation is normally at a 3 psi signal.

Table 3 — Governor Characteristics

EXPRESSION	DESCRIPTION	NEMA CLASS*			
		A	B	C	D
Variation	Percent change in speed at a steady load condition (dead band).	.75%	.50%	.25%	.25%
Regulation	Percent speed change from full load to no load (throttling range).	10%	6%	4%	0.5%
Maximum Speed Rise	Sudden speed increase due to instantaneous change of turbine load from full load to no load.	13%	7%	7%	7%
Maximum Trip Speed	Percent above rated speed.	15%	10%	10%	10%

*Class A is least expensive; Class D is most expensive.

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