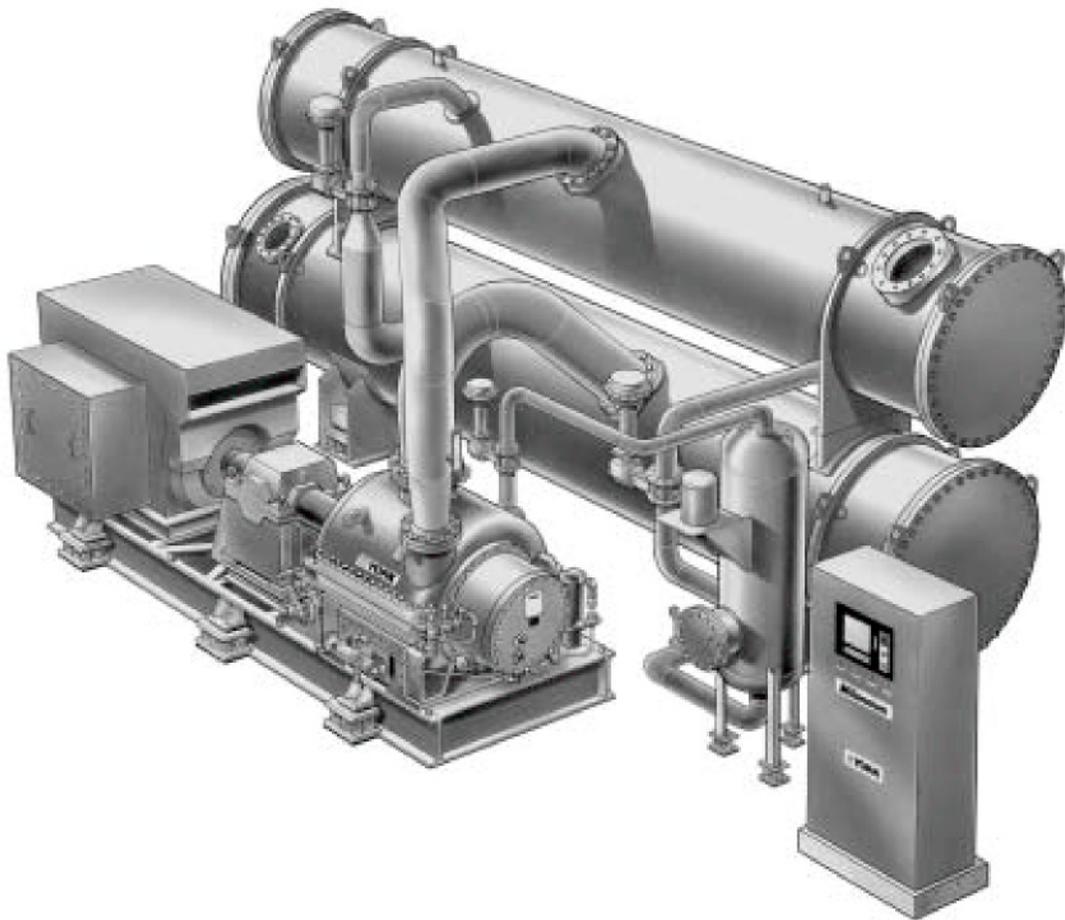




BY JOHNSON CONTROLS



28502A

Multistage Industrial Chillers

Up to 5,200 Tons (18,300 kW)



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Introduction

INTRODUCTION

YORK Titan™ Multistage Industrial Chillers offer a complete combination of features for total owner satisfaction – for district energy, central plant and similar demanding industrial chiller applications up to a capacity of 5,200 tons (18,300 kW) using HFC-134a refrigerant.

MATCHED COMPONENTS MAXIMIZE EFFICIENCY

Actual chiller efficiency cannot be determined by analyzing the theoretical efficiency of any one chiller component. It requires a specific combination of heat exchangers [evaporator, condenser, flash economizer (intercooler)], compressor, gear and motor performance to achieve the lowest system kW/Ton (kW/kWR). Titan chiller technology matches chiller system components to provide maximum chiller efficiency under actual – not just theoretical operating conditions.

APPLICATION FLEXIBILITY

Titan chillers can be applied in many ways and with many modifications to suit any application. These chillers are designed with such drivers as induction or synchronous electric motors, condensing and/or exhausting steam turbines, gas or diesel engines or gas turbines. They can be applied to a broad range of brine cooling requirements; for heat recovery or heat pumps; and for river or sea water, closed-water-circuit (radiator) or air-cooled condensing.

OPEN DRIVE DESIGN

Hermetic-motor burnout can cause catastrophic damage to the internal components of a chiller. The entire chiller must be cleaned thoroughly, and the refrigerant replaced. The Titan centrifugal chillers eliminate this risk by utilizing open-drive motors, engines and turbines. Refrigerant never comes in contact with the motor, preventing contamination of the rest of the chiller.

PRECISE CHILLED WATER TEMPERATURE SETTING TO 0.1°F (0.05°C)

A chiller is designed to produce chilled water at a given temperature. In the past, the setting of this crucial temperature involved laborious trial-and-error adjustments, often accurate to only $\pm 1^\circ\text{F}$ (0.5°C). And a setting of 1°F (0.5°C) below design can increase chiller energy consumption by as much as 3%, wasting thousands of kilowatt-hours per year.

The Titan Control Center eliminates this energy waste. Now you have the capability of setting chilled water temperature to a resolution of 0.1°F (0.05°C) – right at your fingertips. Energy savings through chiller control has never been easier – or more accurate.

HIGH-EFFICIENCY HEAT EXCHANGERS

Titan chiller heat exchangers offer the latest technology in heat-transfer-surface design to give you maximum effi-

ciency and compact design. Water-side and refrigerant-side design enhancements minimize both energy consumption and tube fouling.

CHOICE OF ENERGY SAVERS

Titan chillers are also available as an option with “Free Cooling” (cooling without the use of the unit’s compressor), operating at up to 60% design load. This modification is used during those periods of the year when the available condenser water temperature is lower than the required chilled water temperature. This mode of operation offered by Johnson Controls has almost doubled the capacity compared to competitive free cooling modes, and can save thousands of dollars in operating costs by eliminating the need to operate the compressor during these conditions.

Heat recovery, another energy saver, is available for the reclamation of heat from condenser water. A modified split-bundle shell and tube condenser is used for this application.

For those places of the world where water is scarce, the Titan Chiller can be applied with an air-cooled condenser, thereby eliminating the need for water in the condensing portion of the air-conditioning cycle. Contact your local Johnson Controls Sales Engineer for additional information.

INDUSTRIAL APPLICATIONS

The Titan chiller can also be selected and manufactured to meet many industrial applications, such as chemical and petrochemical processes, brine cooling, mine applications, etc. The uses are practically unlimited. Contact your local Johnson Controls Sales Engineer for additional information.

EQUIPMENT SELECTION OPTIMIZED

The Titan Chiller operates economically throughout the year and over the life of the equipment because of its highly flexible design. Each unit is optimized to suit each unique job requirement utilizing Johnson Controls’ experience with every type of application.

Titan Chillers are selected to suit each individual job application, physical area size, and location requirements. A full range of optimized components have been designed to meet every possible selection requirement through use of the Titan Chiller Computer Selection/Rating Program. All are equipped and rated in accordance with the requirements of ARI Standard 550 (latest revision).

LOWER POWER DEMAND AND OPERATING COSTS

The Titan Chiller is engineered to operate efficiently with the reduced entering condenser water temperatures usually available during most of the operating year. Power consumption falls as condenser water temperature drops,

thus lowering operating costs. The Titan unit's ability to operate down to approximately 55°F (13°C) entering condenser water temperature reduces power usage tremendously as shown in the curve, Fig. 1.

Steam turbine or gas engine drive capability adds further incremental energy savings as a result of the turbine/gas engine governor being able to automatically adjust compressor speed in response to required head to optimize unit performance, in conjunction with pre-rotation vane position.

PARTLOAD OPERATION

The ability of large tonnage chillers to operate at partload conditions is most important to economical operation. Titan chillers are equipped with effective fully automatic partload capacity controls. Automatic control of the hot-gas by-pass in conjunction with the compressor's prerotation vanes (and speed control with steam turbine or gas engine drive) coordinates their operation with the system head requirements (entering condenser water temperature) to minimize operating costs. The Johnson Controls multi-stage compressor with pre-rotation vanes is especially efficient in partload performance in the 50% to 100% capacity range which is most crucial to large tonnage units. Automatic safe control down to 10% partload conditions is incorporated in the overall unit/control system.

PARTLOAD PERFORMANCE

The versatility of the Johnson Controls TMaster Computerized Selection Program for Titan Chiller(s) allows in-depth studies for partload evaluations where energy is

of major concern. Typical partload performance is graphically shown in Fig. 1, Curve 1, depicting the reduction of compressor shaft horsepower (i.e. energy) as the required load is reduced, and the condenser water temperature falls. If a constant design water temperature is required (typically 85°F, 29°C), then Curve 2 is typical.

VARIABLE SPEED

The PLC incorporates Johnson Controls' patented algorithm for variable speed control, assuring stable operation while affording the maximum efficiency at any operating condition within the application envelope. This feature can be used for variable frequency drive (VFD) control on electrically powered chillers as well as governor control on turbine- and gas-engine-driven chillers.

The Johnson Controls method of variable speed control is superior to others. It incorporates the actual compressor operating limits, and determines the best combination of speed and inlet vane position, based on the process requirements and operating parameters. In this way, surge is eliminated, the process set point is always respected, and stable, efficient operation is assured.

STANDARD CHILLERS

Titan Chillers are offered in a broad range of sizes and component details to meet unique customer requirements. Chillers in a series of standard pre-selected increments up to 5,200 tons (18,300 kW) can be used to achieve significant savings in first cost and delivery time. Contact your Johnson Controls Sales Representative for performance, dimensions, and details.

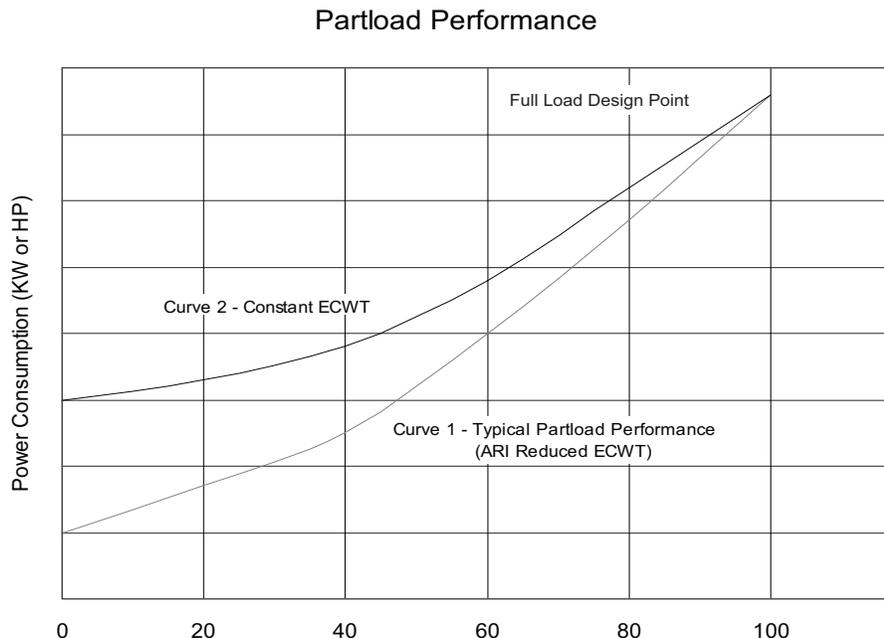


FIG. 1 – PARTLOAD PERFORMANCE

Mechanical Specifications

COMPRESSOR – INDUSTRIAL TYPE – 2 OR 3-STAGE

CASING – Rigid, close grain, high grade cast iron – horizontally split to provide access to rotor assembly – top vertical flanged suction and discharge connections – flanged interstage gas connection for flash economizer (intercooler) – design allows major wearing parts (journal and thrust bearings, shaft seal, and main oil pump) to be inspected or replaced without removing upper half of casing. Compressor casing designed and constructed in accordance with Design Working Pressures (DWP) detailed in Table 1 on page 10.

ROTOR – Fabricated (furnace-brazed) aluminum alloy impellers, shrouded type with backward curved blades, dynamically balanced, and overspeed tested; designed and constructed to resist corrosion, erosion and pitting, and maintain initial balance and performance characteristics – hot rolled heat treated alloy steel main shaft designed to result in operation well below first critical speed, without vibration – rotor assembly dynamically balanced – balance piston on last stage impeller to minimize axial thrust load on thrust bearing.

BEARINGS – Precision machined aluminum alloy single piece tapered bore type journal bearings; aluminum alloy tilting pad type thrust bearing; aluminum alloy reverse thrust bearing. Bearings are accessible without removing the top half of casing.

LUBRICATION SYSTEM – Completely factory packaged, assembled and piped with oil sump reservoir as integral part of compressor. The sump is vented to compressor suction pressure.

- A main oil pump mounted directly on rotor shaft assures forced feed lubrication to all bearings and seals at all times, even under power failure coastdown conditions.
- An external auxiliary oil pump (CAOP) assures pressure lubrication prior to start-up during normal shutdown and at any time main oil pump does not maintain required pressure. The CAOP is a cast iron gear type pump, close coupled to a TEFC motor available for 200 thru 600 volts – 3 phase – 60/50 Hertz service: 2 HP (1.5 kW) for M__26 and M__38, and 3 HP (2.2 kW) for M__55 compressors.
- Dual Oil Filters with 15-micron replaceable pleated paper elements, and change-over valve permitting filter element replacement during unit operation.
- Oil cooler, external water cooled cleanable shell and copper tube type – for entering water temperatures up to 90°F (32°C) at .0005 Ft² °F hr/Btu(.000088m² °C/W) fouling factor.

- Thermostatic oil temperature control valve bypasses the oil cooler to maintain desired oil cooler leaving oil temperature.
- Oil heater(s), 1000 watt, 115 volt – 1 phase –60/50 Hertz thermostatically controlled immersion type – 1 heater for M__26, and 2 heaters for M__38 and M__55 compressor – to maintain 150°F (66°C) sump oil temperature during shutdown to minimize refrigerant accumulation in oil.
- Weld pad type oil level sight glass.
- Hard wired safety switches for High Thrust Bearing Oil Discharge Temperature and Low Oil (differential) Pressure.
- 100 ohm RTD with 4-20mA temperature transmitters (3) for: Refrigerant Discharge Gas; Thrust Oil Discharge; Shaft End Bearing Oil Outlet.
- Thermometers (dual scale °F/°C) industrial bimetallic element 5" (127 mm) dial adjustable angle type with stainless steel case, and 3/4" (19 mm) NPT S.Stl. Thermowells (5) for: Supply Bearing Oil; Thrust Bearing Discharge Oil; Oil Reservoir (sump); Shaft End Bearing Outlet; and Oil After Oil Cooler.
- Pressure gauges – Industrial 4-1/2" (114 mm) dial solid front phenolic case with brass socket and phosphor bronze bourdon tube, with dual English (psi) and metric (kPa) scale (5) for: Supply Bearing Oil After Filter; Oil Before Filter; Thrust Bearing Discharge Oil; Balance Piston; Oil Sump.
- Pressure taps for connection to Pressure Transmitters adjacent to above gauges.
- Automatic Sump Vent Valve to slowly equalize sump pressure to suction on start-up. Consists of ball-valve with pneumatic operator (80 PSIG / 55.5 kPa air required) with actuating air solenoid valve, filter, restrictor valve and gauges.
- Oil charging valve and oil drain valves

All electrical components for NEMA-1 application.

SHAFT SEAL – Rotating cast iron runner – stationary precision spring-loaded carbon ring, – small face area, low rubbing speed. The shaft seal is pressure lubricated in operation and oil flooded at all times by means of an upper gravity feed reservoir in the sump housing. The shaft seal is accessible without removing top half of casing.

CAPACITY REDUCTION – The bronze airfoil-shaped prerotation vanes (PRV) are radially arranged in the inlet to the first stage impeller. They regulate the volume of refrigerant suction gas handled by the compressor to provide highly efficient partload operation; and in conjunction with automatic hot-gas bypass provide

capacity reduction to 10% of design load under any extremes of operation conditions. The 10% of design load may be achieved with PRV alone, depending on such variables as condenser water flow, variation in condenser water temperature with reduction in cooling load, and individual compressor performance characteristics (and, if turbine or gas engine drive, whether speed control is being utilized).

HIGH SPEED COUPLING/DRIVE SHAFT – The YORK-FLEX drive shaft coupling, a light weight, non-lubricated threaded unit, with a flexible steel alloy threaded drive shaft, is designed to provide access to shaft seal and front journal bearing without disturbing main drive alignment. The high speed coupling guard is fabricated carbon steel with an aluminum liner.

GEAR – An external speed increaser gear is used to increase the 4-pole motor operating speed to the required compressor speed. The gear is of the double-helical type, and includes a gear type low speed flexible coupling and low speed coupling guard. The gear is furnished with wet sump, a low speed shaft driven main oil pump and auxiliary motor driven oil pump. A shell and tube oil cooler with thermostatic oil temperature control valve to by-pass oil cooler to maintain desired oil cooler leaving oil temperature (similar to compressor), dual oil filters with change-over valve, local oil pressure gauge, oil thermometer and oil level indicator are provided. Sensors as detailed by the Control Panel Input/Output list are provided on the gear as applicable. The gears comply to AGMA standards.

DRIVERS

TYPICAL STANDARD PRIME MOVER – Air-cooled ODP, WP II (LoNoise), or TEWAC (Totally Enclosed Water-To-Air-Cooled) induction motor with external speed increasing gear. Driver is sized to efficiently and continuously fulfill chiller unit compressor brake horsepower (including speed increaser) and speed requirements, and capable of sustained operation at 110% of that total BHP (kW). Motors are typically medium voltage 2300 to 6600 volt - 3 ph - 50/60 Hz. Motor drive units have a motor/starter combination to start the compressor (including speed increaser) and bring it up to speed without exceeding starting inrush limitations as may be project defined. Standard motor bearings are oil lubricated sleeve type (anti-friction bearings below 2000 HP/1491 kW). Where flood lube is dictated by the motor manufacturer (generally 4500 HP/3356 kW and larger), oil from the gear may be piped to the motor bearings and drained back to the gear sump. Motors typically comply to NEMA MG-1 standards.

STARTERS – Stand alone NEMA-1 enclosure, and may be across the line. Commonly a reduced voltage starter such as 65% tap auto-transformer is used to minimize inrush current as well as to reduce starting stress on the

driveline components. A microprocessor based motor protection relay and display is standard.

DRIVELINE/BASE ASSEMBLY

DRIVELINE BASE – Single base to mount compressor, speed increaser (if required) and driver – rigid design for controlled alignment – welded structural steel channel construction – steel mounting plates/pads for individual components – optical leveling pads – mounting brackets for spring type isolators (if ordered) or holes for anchor bolting and field grouting to concrete.

DRIVELINE ASSEMBLY – Components factory assembled, bolted, rough aligned on base – final alignment and doweling after installation prior to unit startup. Driveline components (compressor, speed increaser, driver), oil cooler water piping, factory assembled to common manifold at the end of the base – galvanized steel pipe and fittings with manual stop valves, and water solenoid valve and strainer.

PRESSURE VESSELS – ASME CODE

Pressure vessels (evaporator, condenser, flash economizer [intercooler], pumpout receiver and oil return unit) designed, constructed, tested and stamped (certified) on both the refrigerant (shell) and water (tube) sides in accordance with the requirements of the ASME Code for Unfired Pressure Vessels – Section VIII Div. 1, as applicable; and ANSI/ASHRAE Standard 15 Safety Code; for Design Working Pressures (DWP) detailed in Table 1 on page 10.

EVAPORATOR AND CONDENSER

SHELLS – Rolled from carbon steel plate – fusion welded seams – shells to accommodate tube lengths from 14 ft. (4267 mm) to 30 ft. (9144 mm) in 2 ft. (610 mm) increments. – 1" (25 mm) minimum thickness steel tube sheets welded to ends of shells – intermediate tube supports spaced on 48" (1219 mm) maximum centers – integral mounting stands to support condenser on evaporator, and evaporator support feet providing mounting brackets for level-adjusting, spring-type vibration isolators.

TUBES – 3/4" (19 mm) OD, copper heat exchanger tubes – externally enhanced and internally ribbed – spaced on 7/8" (22 mm) triangular pitch and roller expanded into tube sheets with sealant to insure refrigerant gas-tight joints – individually replaceable.

WATER BOXES – Marine type, integrally welded to the tube sheet, with removable covers to provide access to tubes without breaking water connections. Full round, fabricated steel construction with necessary removable steel pass baffles, and 150 PSIG (1034 kPa) radially oriented, weld-end water connections of fixed, pre-determined

sizes to suit maximum water flows, with a nitrogen holding charge. Suitable for flanged or direct welded pipe connections.

EVAPORATOR – Horizontal flooded shell and tube type – tubes are roller expanded into intermediate tube supports – liquid inlet with slotted duct distribution plate – evaporator designed to keep all the tubes wetted, even under varying load conditions, for maximum efficiency – upper portion of shell free of tubes to provide refrigerant liquid-gas separation space – steel suction gas baffle or mesh eliminators for even distribution of gas flow, and liquid droplet elimination – hot-gas bypass inlet baffle assures uniform gas distribution and prevents direct gas impingement on evaporator tubes – two 2" (51 mm) sight ports – high capacity relief valve(s) in accordance with ANSI/ASHRAE Standard 15 Safety Code in series with a metal type forward acting scored bursting disc(s) for leak tightness (for field piping). Refrigerant connections such as the liquid inlet, liquid transfer, suction (single suction on shells for 14' thru 20' (4262 mm thru 6096 mm) tube lengths and dual suction on shells for 22' thru 30' (6706 mm thru 9144 mm) tube lengths), hot-gas inlet, unit relief, gas charging, oil return unit supply and gas return, LP control and liquid temperatures.

CONDENSER – Horizontal shell and tube type – discharge gas inlet baffles provide for uniform gas distribution and prevent high velocity impingement on tubes – tube bundle configuration and baffling provide effective condensed refrigerant liquid drain off to maintain efficient condenser performance – and an integral axial-flow-refrigerant liquid sub-cooler, with refrigerant liquid level controller and pneumatically operated high-pressure liquid valve. Refrigerant connections: discharge gas inlet, liquid outlet, hot-gas outlet, pumpout gas, purge, and oil return unit gas supply.

FLASH ECONOMIZER (INTERCOOLER) – Single stage type, consisting of a vertical pressure vessel with internally mounted mesh eliminators and liquid spray pipe, an externally mounted (field installed) level transmitter located within a liquid level pipe assembly and an external, pneumatic control valve mounted in the liquid outlet to the evaporator. Refrigerant from the condenser, after expanding through the condenser subcooler level control valve, enters through the internal spray pipe, where flash gas is removed and channeled through the mesh eliminator, out the top and on to the compressor second stage. Remaining liquid feeds out of the economizer through the pneumatic-operated ball-valve to the evaporator. Eight sight glasses are provided, two above and two below mesh eliminators, two at the liquid spray pipe and two in the liquid line leaving the economizer. A thermometer well is furnished for checking liquid temperature. Connections are provided for the Johnson Controls furnished, field installed pressure transmitter and relief valve assemblies. Three support legs of structural steel tubing are provided

with mounting brackets for spring type isolators. A bracket for mounting the oil return unit is provided on side of economizer. Refrigerant connections: high pressure liquid inlet, interstage flash gas top outlet, low pressure liquid bottom outlet.

REFRIGERANT PIPING

Necessary interconnecting refrigerant piping, valves and fittings for welded fabrication, in accordance with ANSIB31.5 Piping Code – Schedule 40 steel, or greater, thru 10" (254 mm), 0.375" (9.5 mm) wall, 12" (305 mm) and larger – flanged or butt weld above 2" (51 mm), and flanged, socket weld or threaded 2" (51 mm) and smaller, as necessary for fabrication and/or service accessibility – partially factory pre-fabricated to minimize installation labor costs, but allowing for (1) field cut and (1) weld in each plane to compensate for actual component alignment: suction line from evaporator to compressor, including dual connection header on evaporators of 22' (6706 mm) tube length and longer – discharge line from compressor to condenser – high pressure line from condenser to flash economizer (intercooler) including automatic pneumatic refrigerant level/flow control valve – low pressure liquid line from economizer to evaporator liquid connection – interstage gas line from economizer to compressor including automatic pneumatic interstage control valve – hot-gas line from condenser to evaporator, including automatic hot-gas valve and pneumatic operator – auxiliary high pressure liquid line to interstage gas and hot-gas line injectors, including stop valves; copper gauge and control tubing; oil return system piping to evaporator, condenser, economizer and compressor, including stop valves and replaceable element oil filter; purge valve; and pumpout liquid and gas lines from chiller unit to refrigerant transfer unit/receiver (located within 50' (15.2m) from chiller), shipped loose for field assembly. Straight lengths of pipe only and fittings furnished when required. Lifting lugs for suction and discharge lines furnished for field welding to facilitate handling.

OIL RETURN SYSTEM – Oil return unit – fusion welded steel shell (ASME Code); with one internal electric heater (1635 watts), solenoid valve, outlet oil float drainer, temperature control and thermometer, low level oil switch, and with single relief valve in accordance with ANSI/ASHRAE Standard 15 Safety Code – for field mounting on side of vertical economizer. Continuous automatic function during compressor operation to maintain minimum oil concentration in refrigerant for most efficient evaporator performance, and eliminate need for periodic oil additions to make up normal losses from compressor to refrigerant circuit.

CONTROL CENTERS – A broad range of microprocessor-based control centers, wall or stand-alone floor mounted, with color graphic TFT display of conditions and values,

Mechanical Specifications

are available to provide all necessary controls and control logic to provide fully automatic operation, pneumatic capacity control and safety protection of the chiller unit, as further detailed under CONTROL CENTERS.

MISCELLANEOUS

VIBRATION ISOLATORS

High efficiency – 1" (25 mm) deflection – level adjusting – vertically restrained – spring type isolators – coil springs in series with neoprene waffle pad isolation on base plate – furnished for: evaporator/condenser assembly, flash economizer (intercooler), and chiller unit driveline assembly.

THERMOMETERS – 5" (127 mm) dial type bimetal adjustable angle thermometer with stainless steel separable well are supplied for evaporator refrigerant liquid inlet and compressor discharge gas temperatures. Test thermometer wells are supplied for suction line and the interstage gas line at compressor.

TOOLS – Special wrenches for YORKFLEX high speed coupling, drive shaft and main shaft – snap ring pliers for seal and bearing retainer rings – special shaft socket wrench – guide pins for casing assembly – manual oil charging pump. A wall mountable lockable toolbox is provided for storage of the tools.

REFRIGERANT AND OIL CHARGES – Initial charge of refrigerant shipped separately by tank truck bulk delivery – initial charge of compressor and driveline component oil shipped separately.

REFRIGERANT TRANSFER (RECOVERY) SYSTEM – Certified per ARI Standard 740 as a Refrigerant Recovery Unit.

RP-4400 – RECIPROCATING COMPRESSOR - V-belt drive with belt guard; 10 HP (7.5 kW) TEFC motor 200 thru 600-3-60/50 voltage – fused combination starter with on-off pushbuttons – combination high and low pressure safety cutout and oil pressure failure switch – shell and tube type condenser, water cooled, steel shell and copper tubes 85°F (29.4°C) max. water, .0005 ft² °F hr/Btu (0.000088 m² °C/W) fouling – oil separator and float valve for complete oil return and compressor lubrication – unit factory assembled; mounted on and piped to pumpout receiver, with necessary liquid/gas transfer valving – ready for field piping to chiller unit. All electrical components for NEMA-1 application. For outdoor applications, when a belt drive unit is not suitable, Model RTU-10DD can be provided.

PUMPOUT RECEIVER – Horizontal, storage type, fabricated from steel plate with formed heads – fusion welded seams – float actuated, magnetic, dial type liquid level

gauge standard – integral supports for floor mounting and for factory top mounted refrigerant transfer unit – sized for full Titan Chiller(s) unit charge when 90% full at 90°F (32.2°C), and furnished with high capacity dual relief valves assembled in series with metal bursting discs for leak tightness (for field piping), in accordance with ANSI/ASHRAE Standard 15 Safety Code. Refrigerant connections: liquid transfer inlet/outlet, charging/drain, relief, other connections factory piped to transfer unit for condensed liquid drain, condenser equalizing and compressor suction/discharge gas. The receiver is provided with four lifting lugs for rigging into place.

PAINTING – All external surfaces cleaned and protected by one coat of Amerlock 2 high solids epoxy coating (dark blue), compatible with adhesives typically used in application of thermal insulation materials, and acoustic wrapping. Touch up and painting of the piping (which is field welded) is done by others. The control panel is factory painted ANSI 61 light gray outside and white inside.

SHIPMENT – All component connections securely closed to protect mating surfaces and keep out foreign matter – compressor and all shell refrigerant circuits charged with dry nitrogen under pressure and water circuits purged with nitrogen for added protection during shipment and prior to installation – compressor/ driveline/base assembly, evaporator, condenser, economizer, refrigerant transfer unit/receiver assembly, control center, refrigerant piping, refrigerant charge and miscellaneous material each shipped separately for field assembly. Skidding is not generally provided nor necessary.

SHOP DRAWINGS – Detailed unit, piping, controls and applicable subvendor drawings will be provided for construction purposes.

INSTALLATION INSTRUCTIONS – Five (5) sets of standard literature furnished prior to installation.

INSTALLATION, OPERATING AND MAINTENANCE (IOM) INSTRUCTIONS – Necessary sets of comprehensive IOM manuals including custom control descriptions, reduced folded Johnson Controls Construction drawings, standard Johnson Controls publications, and sub-vendor literature will be provided in hard cover binders prior to equipment start-up.

START-UP SUPERVISION AND INSTRUCTION – Services of a factory-trained Johnson Controls representative will be furnished for five consecutive normal working day (40 hours) to advise on evacuation, leak testing, charging, adjusting, initial start-up and operation of unit; and to concurrently instruct the owner's personnel in the proper operation of the unit – for multiple units, three additional days supervision will be furnished for each additional unit – expense allowance for one trip per unit included.

STANDARDS AND CODES

Titan Chiller(s) are designed, constructed and tested in accordance with the applicable portions of the latest revisions of the following nationally recognized Standards and Codes.

ARI 550 – Air Conditioning and Refrigeration Institute Standard for Centrifugal Water Chilling Packages (General Specifications, Testing and Rating).

ARI 575 – Air Conditioning and Refrigeration Institute Standard Method of Measuring Machinery Sound Within Equipment Rooms (Basis of all data presented or field testing of equipment, with relation to sound requirements.)

ARI 740 – Air Conditioning and Refrigeration Institute Standard for Refrigerant Recovery/Recycle Equipment.

ASME CODE – American Society of Mechanical Engineers Code for Unfired Pressure Vessels – Section VIII, Div. 1 (Design, construction, testing and certification of pressure vessels).

ANSI/ASHRAE 15 – American National Standards Institute / American Society of Heating, Refrigeration and Air-conditioning Engineers: Safety Code for Mechanical Refrigeration (Overall general safety requirements,

relief device sizing, etc.).

ANSI-B31.5 – American National Standards Institute Code for Refrigerant Piping.

ANSI/ASQC Q9001 – American National Standard – Quality Systems-Model for Quality Assurance in Design, Development, Production, Installation, and Servicing (US equivalent of ISO 9001)

NEC – National Electrical Code (Electrical components and wiring). Also identified as ANSI-C2 and NFPA-70.

NEMA MG-1 – National Electrical Manufacturer's Association standard for Motors and Generators (domestic U.S. motors).

OSHA – Occupational Safety and Health Administration – US Dept. HEW (Health, Education, and Welfare) – Titan Chiller(s) comply with safety requirements. Sound data will be furnished in accordance with ARI-575 as required to permit comprehensive analysis by others for compliance with sound requirements.

TABLE 1 – STANDARD DESIGN WORKING PRESSURES (DWP)

Standard DWPs for Titan Chiller components have been established by Johnson Controls in accordance with applicable codes for equipment and installation application requirements for the refrigerants used as follows:

COMPONENT DESCRIPTION	DWP - PSIG / (kPa)	
	WATER SIDE	REFRIG. SIDE
		HFC-134a
COMPRESSOR AND LUBE SYSTEM		
M226/M326	—	180 / (1241)
M238/M338	—	180 / (1241)
M255/M355	—	180 / (1241)
Oil Cooler	150 / (1034)	300 / (2069)
EVAPORATOR	*150 / (1034)	180 / (1241)
CONDENSER	*150 / (1034)	180 / (1241)
FLASH ECONOMIZER (INTERCOOLER)	—	180 / (1241)
OIL RETURN UNIT	—	300 / (2069)
REFRIGERANT TRANSFER UNIT		
RP-4400	250 / (1724)	300 / (2069)
PUMPOUT STORAGE RECEIVER	—	225 / (1531)
REFRIGERANT PIPING		
Suction, Discharge, Interstage & Hot-gas	—	180 / (1241)
Refrigerant Transfer	—	225 / (1531)
AUXILIARY WATER		
Gear Oil Cooler	150 / (1034)	—
Motor Cooling Coil	150 / (1034)	—
Aux. Water Piping	150 / (1034)	—

* Including ASME Code exemptions allowed.

Higher refrigerant side DWPs will be utilized as required by special application requirements such as unusually high ambient or condensing temperature (above 110°F / 43.3°C), heat recovery, outdoor installation, etc.

Higher water side DWPs (e.g. 200 PSIG / 1379 kPa; 300 PSIG / 2069 kPa, etc.) are available for specific job requirements.

STANDARD FACTORY TEST REQUIREMENTS

Titan Chillers are under the constant surveillance of the Johnson Controls Quality Control and Inspection program, conforming to ISO 9001 requirements, to insure compliance with Johnson Controls Engineering requirements, as well as the applicable Standards and Codes – assurance of the quality and performance expected of heavy duty industrial type equipment. The following listing outlines the primary testing and related procedures used by Johnson Controls (DWPs per Table 1).

A. Compressors are tested as follows:

1. Hydrostatic (water with rust inhibitors) strength test of machined compressor casing and sump (before internal assembly) at 1.5 x DWP, followed by cleaning and drying procedures.
2. Each impeller is individually balanced.
3. Overspeed test of individual impellers at 1080 FPS (approximately 2.0 x design RPM).
4. Rotor dimensions are checked and logged.
5. Mechanical and electrical shaft runout is checked at the location of any proximity probes (optional), while the rotor is on V-blocks.
6. Static and dynamic balance (at reduced speed) with the pair of impellers assembled on the rotor shaft to levels given on the compressor drawing.
7. Air run-in test of the complete compressor assembly for one-half hour at 1.0 x design RPM.

During the air-run test, data is measured and recorded for discharge pressure and temperature, balance piston interstage pressure, lube oil temperature and pressure, and vibration probe reading (if furnished). Oil leakage from the shaft seal is monitored and compared to established maximums.

8. For turbine driven compressors, at the end of the run-in period, the compressor speed is brought up to the turbine trip speed (usually 110% of design) for a short period and then tripped at 115.5% of design for steam turbines and 110.3% of design for gas turbines.
 9. After the air run-in, the shaft seal, journal bearings (2), and thrust bearings are removed and visually inspected for unusual wear or deep scratches which might indicate a problem. The oil filter cores are also removed, and cut apart to inspect for metal shavings. If no problems are found, the bearings and seal are reassembled, and the compressor is given a brief re-run to prove the mechanical integrity of the assembly.
 10. Nitrogen and air mixture leak test of the assembled compressor and self-contained lubrication system at 1.0 x DWP.
 11. Evacuation of complete compressor/lube system assembly to 3 mm Hg absolute, followed by a 2 hour holding period. Pressure rise may not exceed 2.6 mm Hg over the 2 hours.
 12. Shipping closures are installed. Then the compressor is evacuated to 10-12" (254-305 mm) Hg vacuum, and charged with 5 to 7 PSIG (34.4 to 48.3 kPa) of dry nitrogen for protection.
- B. Shells (evaporator and condenser) are tested as follows:
1. Hydrostatic (water) strength test of shell side (before tubing) at 1.3 x shell side DWP, followed by cleaning and drying procedures.
 2. Pneumatic (air) pressure strength test of shell side (after tubing) at 1.1 x DWP.
 3. Air leak test of shell side at 1.0 x DWP after tubing.
 4. Air pressure strength test of tube side at 1.1 x DWP (hydrostatic test at 1.3 x DWP is used if tube side DWP is higher than shell side), followed by cleaning and drying procedures.
 5. Evacuation of shell side to 3 mm Hg absolute – followed by 30-minute holding period. Pressure rise may not exceed 0.35 mm Hg.
 7. Refrigerant sides of shells sealed, then charged with 5 - 7 PSIG (34.5 - 48.3 kPa) dry nitrogen for shipping. Water sides purged, dried, sealed for shipping and charged with 5 PSIG dry nitrogen.
- C. Flash Economizer, pumpout receiver, vertical/horizontal oil separator (return unit) – Shells
1. Hydrostatic test of shells at 1.3 DWP, followed by cleaning and drying.
 2. Air leak test shells at 1.0 DWP.
 3. Shell side is evacuated to 3 mm Hg Abs and held for 30 minutes during which time the pressure rise may not exceed 0.35 mm Hg.
 4. The shells are given a 5 - 7 PSIG (34.5 – 48.3 KPa) charge of dry nitrogen for shipment.
- D. Vertical Oil Separator (return unit) Assembly
1. Air leak test of oil return unit assembly and piping at 1.0 DWP.
 2. Air pressure pneumatic strength test of oil return unit piping at 1.1 DWP.
- E. Control Centers are tested as follows:
1. Calibration of pressure and temperature sensors which may be shipped loose with the panel (does not include compressor or driver mounted devices).
 2. Functional bench test of completed control assembly to confirm proper control settings, operation and sequence versus the Schematic Wiring diagram. Alarm and trip settings of all available safeties are checked. Function of the microprocessor programming is simulated and checked.
 3. Control center sealed for shipping.

Accessories and Modifications

The following accessories for, or modifications to, Titan Chillers are available at additional cost.

ALTERNATE DRIVERS – High voltage induction motors (11 kV to 13.8 kV), special motor enclosures such as TEWAC or WP11, and synchronous motors may be substituted. Direct driving condensing or non-condensing steam turbines may be applied. Gas turbines can be offered. Natural gas or diesel engines may be used with soft clutch/coupling and speed increasing gear. All such offerings require significant coordination and engineering effort. All drivers should be capable of sustained operation of at least 105% of the compressor design horsepower (kW), including speed increaser/decreaser gear, if applicable.

JOHNSON CONTROLS FREE COOLING FEATURE – Permits significant operating cost savings through use of unit to produce 30% to 60% design capacity without operating compressor during fall, winter, spring periods when available condenser water temperature is lower than chilled water temperature needed to meet co-existing cooling load requirements. Includes necessary component modifications and material for field piping of bypass line(s) to provide free flow of refrigerant gas/liquid between evaporator and condenser; with Normal/Free Cooling selector switch, simple manual bypass valve(s), and necessary changeover controls to prevent compressor start-up, and fully open compressor PRV and hot-gas valve for additional flow area. Automatic bypass valves available – pneumatically operated.

Free cooling feature does not require refrigerant pumps, special spray header arrangements, or additional refrigerant charge.

ALTERNATE OR DUAL COMPRESSOR OIL COOLERS – Factory mounted and piped to suit unusually high coolant temperatures, increased fouling, alternate tube materials or minimum tube diameters and/or higher water side DWP.

FIELD MOUNTED DRIVELINE – Provisions for mounting and alignment of driveline components and/or fabrication of oil cooler water piping at time of field installation.

CONCRETE DRIVE FOUNDATION (option) – Drive component soleplates and anchor bolt assemblies can be offered for systems on grade where preferred in lieu of the drive base assembly. The driveline concrete pad would have multiple elevations to suit compressor and driver height variations. Johnson Controls would provide basic outline and pad elevation drawings. Detailed foundation design, materials, re-bar and grouting are by others.

DRIVE BASE BOLTED (NO SPRINGS) – Provides standard structural base but without springs or mounting brackets. If desired, and adequate foundation details are

provided prior to bid, Johnson Controls can provide anchor bolt assemblies shipped loose in advance of the unit for embedding in the concrete. Shimming and grouting at assembly are by others.

SEISMIC REQUIREMENTS – Johnson Controls can offer seismic designs where specified for hold down reaction forces. Johnson Controls is not prepared to offer operability guarantees during or immediately after a seismic event. Where seismic concerns are anticipated, the chiller should be bolted to the foundation.

SOUND TREATMENT – Acoustic Insulation may be provided by others, or provided loose by Johnson Controls for field application. Alternate low noise motor, gear or turbine driver options may be available. Acoustic driveline or component enclosures are also available.

TUBE GAUGES – Alternate 22 BWG (.028 in. / .71 mm nom. wall) tube wall thickness in lieu of basic 20 BWG (.035 in. / .89 mm nom. wall) copper tubes for condenser and/or evaporator. Heavier tube wall thickness 19 BWG (.042 in. / 1.067 mm nom. wall, etc.) not recommended as they preclude use of cost-effective internal wall enhancements.

TUBE AND/OR TUBE SHEET MATERIALS AND/OR WATER BOX COATING – Special construction and materials can be provided on the water side for the condenser/evaporator to protect against corrosion in aggressive water conditions. Alternate 90/10 copper/nickel or titanium tubes can be provided in lieu of standard copper. Tube sheets can be supplied as clad-type, but must be used in conjunction with bolted on, epoxy coated water boxes. Standard epoxy coating is applied to water boxes after blast cleaning and coated with two coats of epoxy to a minimum total dry film thickness of 16 mils. Epoxy coating is a temporary protective coating and is not designed to last the life of the chiller. Stainless steel pass baffle, auxiliary couplings, zinc anodes, plus special grinding of welds are provided when epoxy coated water boxes are supplied. Water nozzles must use ANSI/AWWA C-606 couplings or factory mounted flanges when this option is ordered. Field welded connections are not allowed.

SACRIFICIAL ZINC ANODES with mounting hardware for condenser and/or evaporator corrosion protection.

BOLTED-TYPE MARINE WATER BOXES – Boxes which are bolted to the tube sheet (rather than welded) are available where needed due to tube sheet cladding requirements, or in some cases to meet strict rigging weight limitations. In such cases removal of the water boxes for shipment can be offered.

HIGHER WATER CIRCUIT DWP – Condenser and/or evaporator water circuit(s) DWP higher than the standard 150 PSIG (1034 kPa) DWP.

HINGED WATER BOX COVERS – Where overhead crane or other alternate lifting facilities are not available, hinges can be furnished on the evaporator and/or condenser water box end covers at one or both ends of the heat exchangers.

TWO PASS / ONE PASS EVAPORATOR – An extra nozzle can be added to the return end of an evaporator water box. Customer piping and valving can be arranged to double the water flow in one pass mode during off season when fewer plant chillers are running, but high flow is needed to meet the building load and circulation requirements.

ZERO LOAD HOT-GAS BYPASS – Sized for operation to 0% load for critical industrial or process application.

SPECIAL APPLICATIONS – Comparable OM Chiller(s) available for air cooled condensing, brine cooling, heat recovery or heat pump applications. These may involve use of a three stage compressor for higher head applications.

OUTDOOR AND/OR HAZARDOUS DUTY APPLICATIONS – Necessary unit, control and control center modifications for Outdoor (NEMA-3 & 4) application in lieu of standard NEMA-1 construction. Ameron Amersfield polyurethane top coat is available for outdoor applications.

VIBRATION MONITORING – Shaft sensing proximity type probes and proximitors on driveline components and monitoring equipment in the chiller panel. Allen-Bradley XM Condition Monitoring system on compressor and driver components.

EXTERNAL CONTROLS – (REQUIRED FOR NORMAL UNIT OPERATION) Available separately for field mounting, piping and/or wiring: evaporator and condenser water

flow switches or pressure differential switches. Water or steam flow measuring equipment of appropriate accuracy shipped loose for installation in an agreed upon straight run of piping connected to the chiller, for use as continuous control input parameter and/or for use in field testing.

BUILDING MANAGEMENT SYSTEMS – Johnson Controls can offer complete plant control systems. Assistance in interfacing the chiller microprocessor to existing customer control schemes may also be available at extra cost – contact Johnson Controls with specific requirements.

REFLEX REFRIGERANT LIQUID LEVEL GAUGE GLASS(ES) with ball check valves for evaporator, flash economizer (intercooler), and/ or pumpout receiver.

VENT AND DRAIN valves for water boxes.

MULTIPLE UNIT PUMPOUT RECEIVER – Pumpout receiver sized to hold the combined charges of two or more OM Chillers in multiple unit installations (common refrigerant).

USE OF EXISTING PUMPOUT UNIT – Where a customer has an existing pumpout unit available to serve the new chillers or new chillers with existing chillers utilizing the same Refrigerant.

FIELD PERFORMANCE TEST – Services of a factory engineer or independent consultant to supervise a field performance test. Various levels of instrumentation can be offered by Johnson Controls.

Application Data

The following discussion is a user guide in the application and installation of Titan chillers to ensure the reliable, trouble-free life for which this equipment was designed. While this guide is directed towards normal, water-chilling applications, your Johnson Controls sales representative can provide complete recommendations on other types of applications.

SCOPE

The Titan Chiller is a field-erected unit. Evaporator, condenser, flash economizer (intercooler), driveline/base assembly and chiller panel are shipped as separate components. Piping materials are supplied by Johnson Controls for interconnection of the components, but must be field cut/fit/welded/assembled by others in accordance with ANSI B31.5 Piping Code requirements using qualified welders. Interconnecting control wiring from chiller components to the free standing panel is by others. All high and medium voltage power wiring is also by others. Relief vent piping is by others. Water connections to the evaporator, condenser and to the oil cooler water header is by others, as is water box vent & drain piping.

LOCATION

Titan chillers are balanced to a very low level of vibration, and when installed on spring isolators may generally be located at any level in a building where the construction will support the total system operating weight. However, it is not recommended that the chillers be placed directly over any office or retail space. Chillers bolted and grouted to the foundation should be on grade or on a robust structure in a dedicated equipment room.

The unit site must be a floor, mounting pad or foundation which is level within 1/4" (6.4 mm) and capable of supporting the operating weight of the unit.

Sufficient clearance to permit normal service and maintenance work should be provided all around and above the unit. Additional space should be provided at one end of the unit to permit cleaning or replacement of evaporator and condenser tubes as required. A doorway or other properly located opening may be used.

The chiller should be installed in an indoor location where temperatures range from 50°F to 105°F (10°C to 40°C).

WATER CIRCUITS

FLOW RATE – For normal water chilling duty, evaporator and condenser flow rates are permitted to any velocity level between 3-1/3 fps and 12 fps (1.0 mps and 3.7 mps). Practical pressure drop limitations (50 Ft. /149 kPa for two-pass) will generally limit flow before a 12 fps (3.7 mps) tube velocity is reached. Flow should ideally be maintained constant at all loads, however variable flows may be considered as discussed under Chilled Water and Condenser Water (pg 15).

TEMPERATURE RANGES – For normal water chilling duty, leaving chilled water temperatures may be selected between 40°F (4.4°C) and 50°F (10°C) for water temperature ranges between 3°F (1.6°C) and 20°F (11.1°C). Leaving water temperatures below 40°F (4.4°C) and down to 36°F (1.6°C) are offered, but may require extra precautions to protect against tube freeze-up.

WATER QUALITY – The practical and economical application of liquid chillers requires that the quality of the water supply for the condenser and evaporator be analyzed by a water treatment specialist. Water quality may affect the performance of any chiller through corrosion, deposition of heat-resistant scale, sedimentation or organic growth. These will adversely affect chiller performance, and increase operating and maintenance costs. Normally, performance may be maintained by corrective water treatment and periodic cleaning of tubes. If water conditions exist which can not be corrected by proper water treatment, it may be necessary to provide a larger allowance for fouling, and/ or to specify special materials of construction.

GENERAL PIPING – All chilled water and condenser water piping should be designed and installed in accordance with accepted piping practice. Chilled water and condenser water pumps should be located to discharge through the chiller to assure positive pressure and flow through the unit. Piping should include offsets to provide flexibility and should be arranged to prevent drainage of water from the evaporator and condenser when the pumps are shut down. Piping should be adequately supported and braced independent of the chiller to avoid the imposition of strain on chiller components. Hangers must allow for alignment of the pipe. Isolators in the piping and in the hangers are highly desirable in achieving sound and vibration control.

CONVENIENCE CONSIDERATIONS – With a view to facilitating the performance of routine maintenance work, some or all of the following steps may be taken by the purchaser. Evaporator and condenser water boxes are equipped with plugged vent and drain connections. If desired, vent and drain valves may be installed with or without piping to an open drain. Pressure gauges with stop cocks, and stop valves, may be installed in the inlets and outlets of the condenser and chilled water lines as close as possible to the chiller. An overhead monorail or beam crane may be used to facilitate servicing the shells and/or driveline, or hinged water box covers may be desirable.

CONNECTIONS – The standard chiller is designed for 150 PSIG (1034 kPa) design working pressure in both the chilled water and condenser water circuits. The connections (water nozzles) to these circuits are furnished as flanged pipe connections, (mating flanges not included). All water piping should be thoroughly cleaned of all dirt and debris before final connections are made to the chiller.

CHILLED WATER – The chilled water circuit should be designed for constant flow.

Variable chilled water flow in the range between minimum flow of 3-1/3 fps (1.0 mps) (4-3/4 (1.4 mps), preferred) to minimize possibility of freezing; and maximum flow at 50 ft. (149 kPa) pressure drop (2 pass); will normally have minimal effect on unit efficiency, as long as the rate of change does not adversely affect the ability of the chiller control system to maintain the desired leaving chilled water temperature.

A flow switch must be installed in the chilled water line of every unit. The switch must be located in the horizontal piping close to the unit, where the straight horizontal runs on each side of the flow switch are at least five pipe diameters in length. The switch must be electrically connected to the chilled water interlock position in the unit control center. Pressure differential type flow switches may alternatively be used. A water strainer of maximum 1/8" (3 mm) mesh must be field-installed in the chilled water inlet line as close as possible to the chiller. If located close enough to the chiller, the chilled water pump may be protected by the same strainer. The flow switch and strainer assure chilled water flow during unit operation. The loss or severe reduction of water flow could seriously impair the chiller performance or even result in tube freeze up.

CONDENSER WATER – The chiller is engineered for maximum efficiency at both design and part load operation by taking advantage of the colder cooling tower water temperatures which naturally occur during the winter months. Appreciable power savings are realized from these reduced heads. Variable (reduced) condenser water flow to minimize pumping costs is acceptable, but should be carefully evaluated against the increased chiller power requirements resulting from the increased temperature of water leaving the condenser (higher condensing temperature). Exacting control of condenser water temperature, requiring an expensive cooling tower bypass, is not necessary for most applications.

The expansion devices are sized to perform at full load capacity, with a minimum entering condenser water temperature of 65°F (18.3 °C) with a leaving chilled water temperature at design setting. The expansion devices can be oversized to support full load capacity at ECWT as low as 55°F (12.8°C).

At initial startup, entering condensing water temperature may be equal to the standby chilled water temperature. Cooling tower fan cycling will normally provide adequate control of entering condenser water temperature on most installations.

MULTIPLE UNITS

SELECTION – Many applications require multiple units to meet the total capacity requirements as well as to provide flexibility and some degree of protection against equipment shutdown. There are several common unit arrangements for this type of application. The Titan chiller has been designed to be readily adapted to the requirements of these various arrangements.

PARALLEL ARRANGEMENT (Refer to Fig. 2) – Chillers may be applied in multiples with chilled and condenser water circuits connected in parallel between the units. Assuming two

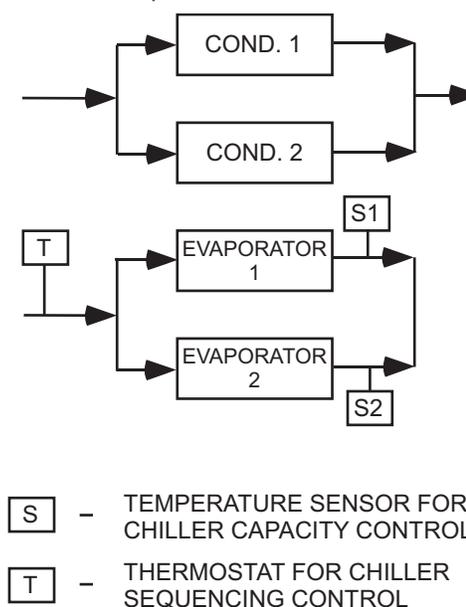


FIG. 2 – PARALLEL EVAPORATORS
PARALLEL CONDENSERS

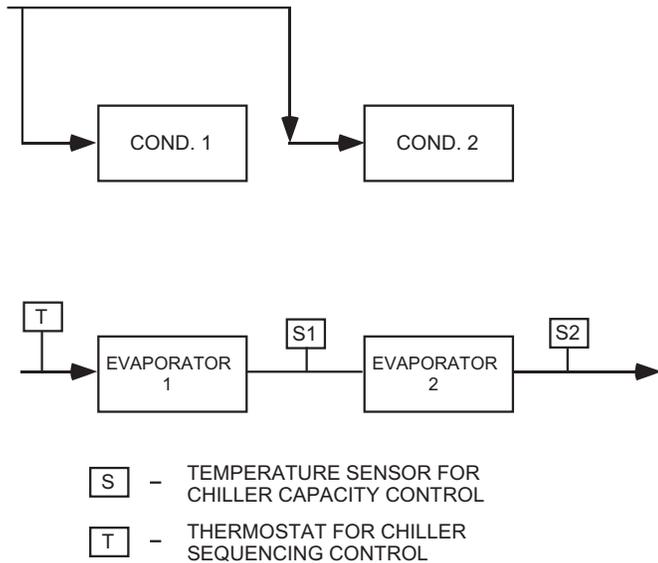
units of equal size, each will reduce in capacity as the load decreases to about 40% of the total capacity, at which point one of the units will be shut down by a sequence control.

Assuming chilled water flow to the inoperative unit is stopped by pump shutdown and/or a closed valve, the remaining unit will pick up the total remaining load and continue to reduce in capacity as the load decreases. The unit will cycle off on the low chilled water temperature control when the load reduces below minimum unit capacity. The controls can maintain constant ($\pm 1/2^\circ\text{F}/\pm 0.3^\circ\text{C}$) leaving chilled water temperature at all loads. If chilled water continues to flow through the non-operating unit, the chilled water flowing through the operating unit will mix with the water leaving the non-operating unit to produce a common water supply to the load. Since control of the operating unit is from its own leaving chiller water temperature, the common temperature to the load will rise above the full load design temperature. This higher chilled water temperature occurs below 40% load when the de-humidification load in normal air conditioning applications

is usually quite low. In such instances, this temperature rise will save additional energy.

The running time may be apportioned between both units by alternating the shutoff sequence.

SERIES ARRANGEMENT (Refer to Fig. 3) – Chillers may be applied in multiples with chilled water circuits connected in series and condenser water circuits connected in parallel. All of the chilled water flows through both evaporators with each unit handling approximately one-half of the total



**FIG. 3 – SERIES EVAPORATORS
PARALLEL CONDENSERS**

load. When the load decreases to about 40% of the total capacity, one of the units will be shut down by a sequence control. Since all water is flowing through the operating unit, that unit will cool the water to the desired temperature.

REFRIGERANT RELIEF PIPING

Each chiller is equipped with a pressure relief valve assembly, with high capacity relief valve(s) and upstream non-fragmenting metal rupture disk(s). The purpose of the relief valve is to quickly relieve excess pressure of the refrigerant charge to the atmosphere, as a safety precaution in the event of an emergency such as a fire. They are set to relieve at an internal pressure of 1.0 x shell side DWP, are located on the evaporator and are provided in accordance with ANSI/ASHRAE Standard 15 Safety Code and ASME Boiler and Pressure Vessel Code. Auxiliary relief valves are also provided on the Oil Return Unit, Refrigerant Transfer Unit, and RTU Condenser (when furnished). On special applications other relief valves may be provided.

Sized to the requirements of applicable codes (ANSI/

ASHRAE 15 and local codes), vent line(s) must run from the relief device(s) to the outside of the building. This refrigerant relief piping must include a cleanable, vertical leg dirt trap to catch vent-stack condensation. Vent piping must be arranged to avoid imposing a strain on the relief connection and should include one flexible connection.

Relief valves must be provided in the customer piping for ASME code water box pressure relief.

SOUND AND VIBRATION CONSIDERATIONS

A Titan chiller has high-speed rotating equipment and high energy added to the gas flow which may contribute to airborne noise in an equipment room. There are available options to reduce the chiller noise levels.

- Acoustic insulation treatment applied to the condenser shell surface, compressor discharge line, and the compressor top half.
- Low noise driver options.
- Use of refrigerant liquid injection to the compressor last stage reduces noise levels, but lowers cycle efficiency and adds to compressor horsepower requirement.
- Partial or complete driveline sound enclosure. Rigid models with doors and ventilation, or models with sliding side “sound curtains”.

Titan chiller sound pressure level ratings will be furnished on request.

Titan chiller vibration levels are generally very low. Johnson Controls standard 1” (25 mm) spring isolator mounting is recommended for upper-floor installation.

Control of sound and vibration transmission must be taken into account in the equipment room construction as well as in the selection and installation of the equipment.

THERMAL INSULATION

No appreciable operating economy can be achieved by thermally insulating the chiller. However, the chiller’s cold surfaces should be insulated with a vapor-barrier insulation sufficient to prevent condensation. Thermal insulation using an appropriate material is field applied by others. The evaporator, suction-line, flash economizer (intercooler), interstage line and certain other refrigerant lines have cold surface temperatures which should be insulated. The oil return unit should be insulated to retain warmth. If insulation is applied to the water boxes, the water box cover insulation must be readily removable to permit access to the tubes for routine cleaning and maintenance.

If the free cooling capability of a chiller is being utilized, anti-condensation insulation of the refrigerant condenser and water boxes should also be considered.

VENTILATION

The ANSI/ASHRAE Standard 15 Safety Code for Mechanical Refrigeration requires that all machinery rooms be vented to the outdoors utilizing mechanical ventilation by one or more power-driven fans. This standard, plus National Fire Protection Association Standard 90A, state, local and any other codes should be checked for specific requirements. Since the Titan chiller motors are air-cooled, ventilation must allow for the removal of heat from the motor.

OXYGEN DEPLETION DETECTION

As with any modern refrigeration system, provisions for oxygen depletion detection should be provided in the overall project.

ELECTRICAL CONSIDERATIONS

MOTOR VOLTAGE – Medium (2300-6600 volt) and high (11 kV-13.8 kV) voltage standard motors are furnished with three leads. Six leads can be brought out when specified, for differential protection or for testing purposes. Motor circuit conductor size must be in accordance with the National Electrical Code, or other applicable codes, for the motor full load amperes (FLA). Flexible conduit should be used for the last several feet to the chiller in order to provide vibration isolation. Motor horsepower, service factor, voltage, frequency, FLA, LRA and other information is stamped on the motor nameplate in accord with NEMA MG-1 requirements. Running voltage variation is ± 10 percent. A maximum 10% dip in supply voltage on starting will be assumed, unless otherwise specified.

STARTERS – The Titan chillers are available for use with standalone electro-mechanical starters. Reduced voltage primary reactor and auto-transformer starters are commonly utilized, to reduce starting line current and provide longer drivetrain life due to lower starting stress. Across-the-line starters may be used if the power system is sufficiently “stiff”. Reduced voltage starters must be coordinated with the motor driver. Microprocessor based motor protective relays are offered in a standard starter. Control interface must be coordinated with the Johnson Controls chiller control panel per Johnson Controls Standard R-787.

POWER STUDY – Large motor systems have a major impact on a plant electrical system. An Electrical Power System Coordination and Relay Setting study should be performed by others to ensure a reliable and safe system. The study should analyze coordination of motor protection relay, starter power fuses, and upstream fuses and safeties. The study would recommend safety settings of the motor protection relay. Also, the study should examine short circuit fault conditions and voltage dip at the utility and at the motor terminals. Johnson Controls will provide relevant motor information, and other relevant data within our scope for use in this study by others.

JOHNSON CONTROLS

COMPRESSOR MOTOR POWER SUPPLY – Electrical power wire size to the chiller is based on the minimum unit ampacity. The National Electrical Code defines the calculation of ampacity, as summarized below. More specific information on actual amperage ratings will be supplied with the submittal drawings.

- Three-lead type of starting: (Across-the-Line, Autotransformer and Primary Reactor)
- Minimum circuit ampacity per conductor (1 of 3):

$$\text{Ampacity} = 1.25 \times \text{compressor motor amps.}$$

Power fuses are sized by the starter manufacturer, based on motor full load amps, service factor and locked rotor amps. Changes to fuse size can be coordinated based on upstream fuses, at the approval stage, by those undertaking the Power Study advising Johnson Controls in writing.

CONTROLS – A 115 volt, single phase, 60 or 50 Hertz, 5 kVA power supply must be furnished to the chiller. This may be included as part of the electro-mechanical starter, or from separate source. If specified, the microprocessor based component power can be separated from the heaters for power by a 15 amp UPS system.

A clean filtered dry pneumatic air supply of 4 to 5 SCFM (1887 to 2359 cc/s) at 80 to 100 PSIG (312 to 390 kPa) is required for the control actuators. This is to be piped to a common 1/2” (13 mm) connection point near the compressor Pre-rotation Vane Actuator. Copper tubing and regulators for other pressures are furnished by Johnson Controls, loose for field installation.

COPPER CONDUCTORS – Only copper conductors should be connected to compressor motors and starters. Aluminum conductors have proven to be unsatisfactory when connected to copper lugs. Aluminum oxide, and as a result of the difference in thermal conductivity between copper and aluminum, cannot guarantee the required tight connection over a long period of time.

CAPACITORS – Capacitors can be applied to a chiller for the purpose of power factor correction. The capacitors should be located on the load-side of the starter. The capacitors must be sized and installed to meet the National Electrical Code and be verified by Johnson Controls. Motor no-load kVA must not be exceeded. Capacitors should not be installed at the motor terminals when zone differential protection (6 CT method) is used.

OIL PUMP POWER SUPPLY – A separate 3-phase power supply is required for the field mounted separate compressor and gear auxiliary oil pump starters (standard fused combination starter, NEMA-1 enclosure). Auxiliary starters can alternatively be by the customer from a Motor Control Center, with local disconnect installed within sight of the pump motors.

FIELD PERFORMANCE TESTING

The field erected Titan Chiller does not fall within the scope of the ARI 550 Certification program. Some customers may wish to conduct a field performance test of the chiller in the spirit of ARI 550 procedures to verify the agreed upon full load and/or part load design performance. Acceptance tests, if required, must be run prior to "Beneficial Use" of the chiller. Where Johnson Controls has been contracted to perform the test, the Johnson Controls Performance Test Group will provide the necessary test instrumentation and will review and recommend appropriate locations for the equipment in the customer's installation. All Johnson Controls pressure and temperature test instrumentation

will be traceable to the National Institutes of Standards and Technology (NIST). The customer is responsible for providing permanently installed flow measurement devices in their piping. These flow measurement devices must be flow tested and installed in accordance with the manufacturer's specifications with adequate upstream and downstream straight pipe run. The customer is further responsible to ensure that adequate steady state load is available at design conditions and agrees to provide the necessary operating utilities during the test. Contact Johnson Controls for more details on Field Performance Testing. Johnson Controls Performance Test Group should be involved in all planning and execution of the performance testing in the field.

STANDARD CONTROL CENTER FEATURES

Titan Chillers are available with a broad range of microprocessor-based control centers to meet every level of need.

FLOOR-MOUNTED, PLC-BASED CONTROL CENTER

– Features Allen-Bradley CompactLogix Programmable Logic Controller (PLC) with PanelView PLUS color graphic display of all data and operating conditions. The panel is capable of communicating with the Ethernet Industrial Protocol, DF-1 Protocol or Modbus RTU over RS-232 and with protocol translators. The panel is available in a free-standing, floor-mounted front-access enclosure.

Each of this spectrum of control centers listed above provides display of all operating and protective parameters, factory mounted and wired, in upright, rugged steel, NEMA-1 enclosures, with locked full-height access door(s). Panels are finish painted with ANSI 61 light gray exterior and white enamel inside.

The control centers contain all necessary controls and control logic to provide stand-alone automatic start-up, fail-safe fully automatic operation, electronic capacity control and safety protection of the chiller unit, speed increaser gear/electric motor drive. They also provide for automatic pre-lube and post-lube operation of the speed increaser gear and compressor auxiliary oil pumps (AOP); and operation of the AOPs during any low pressure lube condition. Controls are also included for automatic control of compressor capacity to limit maximum motor power consumption, manually adjustable 100% to 40% of chiller capacity.

Control centers are 100% electronic/electric, with all values displayed on the face of the panel. Refrigerant, oil and bearing temperatures and/or pressures, and control air pressures, are all to be electronically monitored from locally mounted RTDs with transmitters and pressure transducers. Also to be monitored are pre-rotation vane, high pressure liquid valve, interstage gas valve, and hot-gas valve signals; drive motor power requirements; and chilled and condenser water flows and temperatures.

The control centers also include an Emergency Stop button, bypassing all controls, mounted on the front of the panel, together with the data display, and Start, Stop and Power Failure/Reset buttons. A separate hard wired high pressure cutout, remotely mounted at the compressor, will be provided in accordance with ASHRAE/ANSI Std 15 Safety Code requirements.

All controls are to be arranged for easy access – internally wired to clearly marked terminal strips for external (field) wiring connections; wiring color coded black (control), white (neutral), and green (ground), with each wire numerically identified at both ends. All low voltage discrete and analog input wiring to the panels shall be #18 AWG/2-conductor shielded cable, color coded red and black. A copy of the unit wiring diagram is to be provided in a pocket inside the enclosure door.

The control center is to be supplied a 5 kVA 120 volt single phase 60 or 50 Hertz power supply (by others). The panel is to be all electric. The pre-rotation vanes, high pressure liquid valve, interstage gas valve, and hot-gas valve are all to be electronically controlled and pneumatically actuated, and are to be supplied a total of 4-5 SCFM (1887 to 2359 cc/s) of clean dry filtered instrument air at 80 to 100 PSIG (312 to 390 kPa) pressure (by others). All displays are to be in English or (Metric) units of measure.

CUSTOM CONTROL CENTERS

Custom-designed control centers can be furnished to meet the unique requirements of individual projects.

OPTIONAL VIBRATION MONITORING – Proximity vibration monitoring of driveline components (compressor/gear/motor) based on Allen-Bradley XM Series Condition Monitor can be provided in any of the control centers. The Allen-Bradley based panel will utilize the customized Allen-Bradley XM system, incorporating the vibration monitoring as an additional color-graphic display screen.

In all cases, necessary proximity probes, cables and proximitors must be provided as part of each of the driveline components to be monitored.

¹Control Centers are described for electric motor drive. Comparable Control Centers detailed to the unique requirements of steam turbine, and natural gas engines or gas turbine drives are also available.

TABLE 2 - INPUT LIST

Device Tag#	Description	Signal	Remarks
ANALOG INPUTS:			
FT-100	Chilled Water Flow rate	4-20 mA DC ^{1,6}	Flow Element & Transmitter by Others
FT-102	Condenser Water Flow rate	4-20 mA DC ^{1,6}	Flow Element & Transmitter by Others
JT-160	Motor Power (Kilowatts) 0-125% FL	4-20 mA DC ⁵	from Starter
LT-114	Subcooler Refrig. Liquid Level	4-20 mA DC	
LT-116	Flash Economizer (Intercooler) Refrig. Liquid Level	4-20 mA DC	
PT-111	Evaporator Refrigerant Pressure	4-20 mA DC	
PT-113	Condenser (Compr. Disch.) Pressure	4-20 mA DC	
PT-116	Flash Economizer (Intercooler) Refrigerant Pressure	4-20 mA DC	
PT-140	Compressor Supply Oil Pressure	4-20 mA DC	
PT-143	Compressor Sump Pressure	4-20 mA DC	
PT-144	Compressor Shaft Pump Oil Pressure	4-20 mA DC	
PT-146	Compressor Balance Piston Pressure	4-20 mA DC	
PT-150	Gear Supply Oil Pressure	4-20 mA DC	
PT-156	Gear Shaft Pump Oil Pressure	4-20 mA DC	
PT-180	Control Supply Air Pressure	4-20 mA DC	
TT-100	Chilled Water Out Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-101	Chilled Water In Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-102	Condenser Water In Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-103	Condenser Water Out Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-111	Evaporator Refrig. Liquid Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-113	Compressor Refrig. Discharge Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-114	Condenser Refrig. Liquid Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-120	Oil Separator Temp	4-20 mA DC	100 OHM RTD with Transmitter
TT-115	Subcooled Refrig. Liquid Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-142	Compressor Shaft End Brg. Oil Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-147	Compressor Thrust Brg. Oil Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-150	Gear Supply Oil Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-151	Gear H.S. Shaft End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-152	Gear H.S. Blind End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-153	Gear L.S. Blind End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-154	Gear L.S. Shaft End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-161	Motor Shaft End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-162	Motor Blind End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter

TABLE 2 - INPUT LIST - CONTINUED

Device Tag#	Description	Signal	Remarks
DISCRETE INPUTS:			
M1R	Compr. Motor Starter "Run" Interlock	120 VAC	from starter
M2	Compr. AOP Starter Run Interlock	120 VAC	from starter
M3	Gear AOP Starter Run Interlock	120 VAC	from starter
MPDA	Starter Motor Protective Relay Trip	120 VAC	from starter
LSL-120	Oil Separator Low Level Switch	120 VAC	
LSL-143	Compressor Oil Sump Low Level Switch	120 VAC	
PSHH-113A	Cond. Refrig. High Press. Switch	120 VAC ²	
PDSLL-140A	Comp. Oil Low Diff. Press. Cutout	120 VAC ²	
PDSLL-101A	Chilled Water Low Diff. Flow Press. Sw.	120 VAC ²	
PDSLL-102A	Cond. Water Low Diff Flow Press. Sw.	120 VAC ²	
TSHH-147A	Comp. Thrust Bearing High Temp Sw.	120 VAC ²	
	Chiller Start Push-button	120 VAC	
	Chiller Stop Push-button	120 VAC	
	Emergency Stop Push-button	120 VAC ^{2,3}	
	Reset Push-button	120 VAC	

TABLE 3 – OUTPUT LIST

ANALOG OUTPUTS			
Device Tag #	Description	Signal	Remarks
LY-114	Subcooler Level Control Valve	4-20 ma	
LY-116	Flash Economizer (Intercooler) Level Control Valve	4-20 ma	
PDY-116	Interstage Control Valve	4-20 ma	
TY-100A	Compressor Pre-rotation Vanes	4-20 ma	
TY-100B	Hot-gas Bypass Control Valve	4-20 ma	
DISCRETE OUTPUTS:			
CR	Compressor Motor Starter Control Relay	120 VAC	Interposing relay in motor starter
FCV-105	Aux. Cooling Water Solenoid Valve	120 VAC	
FCV-114	Liquid Injection Solenoid Valve	120 VAC	
FCV-120	Oil Return (Jet Pump) Solenoid Valve	120 VAC	
M2	Comp. AOP Motor Starter Coil	120 VAC	
M3	Gear AOP Motor Starter Coil	120 VAC	
M5	Oil Separator Heater Contactor A	120 VAC	
M6	Oil Separator Heater Contactor B	120 VAC	
PCV-143B	Comp. Auto. Sump Vent Valve	120 VAC	
R1	Hardwired Trip Relay	120 VAC	
R2	Compressor Oil Heater Control Relay	120 VAC	
R3	Start-up Bypass Relay	120 VAC	
R4	Chilled Water Pump "Emergency" Start Relay	120 VAC ⁴	
	Chiller Run to DCS	Dry contact	
	Remote Alarm dry contact open on alarm	Dry contact	

FOOT NOTES:

- 1 Installation methods must comply with industry and manufacturer's requirements (particularly straight lengths up and downstream, coordinated pipe wall thickness).
- 2 This input will also be hardwired to trip the chiller independent of the Allen-Bradley PLC trip output.
- 3 An Emergency stop pushbutton is provided on the front of the control panel which when pulled will stop the chiller, even in the event of a failure of the Allen-Bradley PLC output.
- 4 This contact output is energized by an evaporator low pressure condition. ***The customer must establish chilled water flow through the chiller when this contact is closed to prevent tube freeze-up. It is recommended that this contact be hardwired into the chilled water pump motor starter control circuit.***
- 5 Isolated Input
6. Optional Input (not necessarily a control or safety point)

Guide Specifications

OVERVIEW

Large tonnage centrifugal liquid chilling units (above 2000 tons / 7032 kW), such as Titan Turbomaster, and comparable competitive units, as well as their major drive components (speed increaser gears, motors, starters, steam turbines, steam condensers, gas engines, gas turbines, etc.), are based on standardized designs that are custom tailored to the unique requirements of each project.

Due to the size and weight of these large tonnage units, they are not available as factory packaged units, but rather must be shipped as a number of coordinated individual components, which must be field erected, piped, wired, evacuated and charged, insulated, painted, etc, at the job-site. It is essential that overall project specifications reflect all of the materials and services required for a complete installation, and assign responsibilities for providing all of these materials and services.

The Guide Specifications which follow are generic in overall nature, detailing the basic chiller unit materials and services to be provided by the chiller manufacturer, as well as the additional related materials and services required, for which responsibility must be assigned as part of the overall project.

These specifications are based on :

- Unit for water cooling duty, with cooling tower water cooled condenser.
- Unit to be installed in indoor, heated, NEMA-1 environment.
- Driver to be induction motor with open drip-proof (ODP), lower sound (WP II), or totally enclosed water-to-air cooled (TEWAC), enclosure.
- Power supply to be 2400 or 4160 volts-3 phase-60 Hertz, or 3300 or 6600 volts-3 phase-50 Hertz.
- Compressor, speed increaser gear, and motor to be factory mounted and rough aligned on heavy duty welded structural steel driveline base.
- Main motor starter to be equipped with microprocessor based motor protective system.
- Chiller control system to be Titan Allen-Bradley CompactLogix 1769, 1756 or ControlLogix (Programmable Logic Controller) based with A-B PanelView color graphic TFT, displaying all operating, monitoring and safety functions, in a free-standing, floor-mounted enclosure. For further information, see the section on Control Centers.
- Pneumatic operation of pre-rotation vanes, high pressure liquid valve, interstage gas valve, and hot-gas valve.

Additional or alternative requirements affecting components of these specifications may require changes to other interrelated portions of the specifications – please consult your Johnson Controls representative. The following alternative requirements require special attention:

- Unit for glycol cooling duty, other than tower water cooled (sea, river, well, radiator), air cooled condensing, heat recovery, or heat pump application.
- Outdoor and/or unheated location, and other than NEMA-1 environment.
- Power supply to be 13,800 V (13.8kV)-3-60; or 11,000 V (11kV)-3-50.
- Driver to be synchronous motor, steam turbine, gas turbine, gas engine, diesel engine, etc.
- Drive components to be individually mounted on multilevel reinforced concrete foundation.
- Main motor starter to have individual protective relays for each function, not microprocessor based protective unit.
- Switchgear (circuit breakers) acting as main motor starter.
- Chiller control system other than A-B PLC PanelView based; or requiring electro-pneumatic type with multiple individual gauges, lights, switches, monitors, annunciators, controllers, etc.
- Electric operation for pre-rotation vanes, hot-gas valve, and interstage valve.
- Driveline component vibration monitoring system.

Following are detailed Guide Specifications for large tonnage unit(s) based on an induction motor drive. To complete a comprehensive specification, it is essential that the specific requirements of each project be reflected by entering appropriate data in each of the spaces (blanks), and that in the case of each OPTION, a decision be made as to whether or not the requirements of that option should be included in the specification.

Copies of this Guide Specification, as well as those for alternative drives, are available from your Johnson Controls sales representative:

Guide Specifications

1. **Induction Motor Drive** – including Gear, Motor and Starter
 - 1.1 **Standard Unit** – Induction Motor Drive – including Gear, Motor and Starter
2. **Synchronous Motor Drive** – including Gear, Motor and Starter
3. **Condensing Steam Turbine Drive** – including Condensing Steam Turbine and Steam Surface Condenser
4. **Non-condensing Steam Turbine Drive** – including Non-condensing Steam Turbine
5. **Gas Engine Drive** – including Gear, Clutch/ Coupling and Gas Engine

GUIDE SPECIFICATIONS - INDUCTION MOTOR DRIVE-JOBSITE/OPERATING CONDITIONS* (ENGLISH UNITS OF MEASURE)

Furnish and install where indicated on the plans (quantity) open centrifugal liquid chilling unit(s) as manufactured by Johnson Controls (Titan). Unit(s) will utilize refrigerant and will be equipped and rated in accordance with ARI Standard 550 (latest revision).

Each unit shall produce a capacity of _____ tons of refrigeration, cooling _____ GPM of _____ (**water**) from _____ °F to _____ °F when supplied with GPM of condenser water at _____ °F. Equipment to be located _____ (**indoors**), _____ (**NEMA-1**), with ambient conditions of _____ °F (**50**) minimum, to _____ °F (**105**) maximum, altitude _____ ft. _____ (**above**) sea level.

Chiller maximum power consumption, including motor and speed increaser gear losses, not to exceed _____ kW (_____ kW/ton) at full load design conditions.

Electric power shall be supplied to the centrifugal compressor drive motor at _____ (2400) (4160) volts-3 phase-60 Hertz, or _____ (3300)(6600) volts-3 phase-50 Hertz, for _____ (**reduced**) (full) voltage starting (inrush not to exceed _____ amps); with _____ (**10%**) voltage dip on starting. Motor speed shall be _____ (**1800**) (3600) RPM/60 Hz, or _____ (**1500**)(3000) RPM/50 Hz, synchronous. Motor enclosure shall be _____ (ODP)(**WP II**)(TEWAC); and if

TEWAC, cooling water to be supplied at _____ °F (**85**), _____ PSIG (**150**) DWP with _____ (.0005)ft²/F hr/Btu fouling factor. Motor to develop 93% (Min) full load power factor.

Main motor starter shall be _____ (**reduced**) (full) voltage type in a free-standing floor-mounted NEMA _____ (**1**) enclosure.

Electric power shall be supplied to all auxiliary motors at _____ (**460**) volts-3 phase-60 Hertz; or _____ (**380**) volts-3 phase-50 Hertz; control power at 120 volts-1 phase-(60)(50) Hertz; and control air at 80 to 100 PSIG.

The evaporator tubes shall be _____ (**20**) BWG (_____ [.035] inches nominal wall thickness) _____ (**copper**). The maximum water velocity at any point in the tubes shall not exceed _____ ft. per second. Pressure drop shall not exceed _____ ft.

of water. Selection shall be based on _____ (.00025) Ft² °F hr/Btu fouling factor. Water side shall be _____ (**150**) PSIG Design Working Pressure.

The refrigerant condenser tubes shall be _____ (**20**) BWG (_____ [.035] inches nominal wall thickness) _____ (**copper**). The maximum water velocity at any point in tubes shall not exceed _____ ft. per second. Pressure drop shall not exceed _____ ft. of water. Selection shall be based on _____ (.00025) Ft² °F hr/Btu fouling factor. Water side shall be _____ (**150**) PSIG Design Working Pressure.

Oil coolers (compressor and speed increaser); and motor cooler (if TEWAC); shall be furnished with _____ (**condenser**) (chilled) (city) water at _____ °F (**85**) maximum temperature and _____ (**150**) PSIG Design Working Pressure based on _____ (.0005) Ft² °F hr/Btu fouling factor. Water pressure drop shall not exceed _____ ft. of water. (If condenser water is used, total auxiliary water circuit pressure drop, including all interconnecting piping, must be less than refrigerant condenser water pressure drop.)

Refrigerant transfer unit water cooled condenser shall be furnished with _____ (**city**) (chilled) (condenser) water at _____ °F (**85**) maximum temperature and _____ (**150**) PSIG Design Working Pressure based on _____ (.0005) Ft² °F hr/Btu fouling factor. Water pressure drop shall not

* Data shown in parentheses () indicates "typical" or "standard" response for data. The **bold** response is the "standard" input.

exceed _____ ft. of water. Refrigerant high-pressure receiver shall be sized for _____ (the full refrigerant charge of _____ [1] unit), or (lbs. of refrigerant, minimum) when 90% full at 90°F, per ANSI/ASHRAE Standard 15.

Unit shall fit an overall space _____ ft. long (including tube pulling space), _____ ft. wide, _____ ft. high, but not including housekeeping or foundation pad. Necessary additional space shall be provided around the chiller for maintenance/service access (4' front, 3' rear and 5-6' ends); and as required for the chiller control panel, main motor starter, and for the refrigerant transfer unit storage receiver.

- or -

JOBSITE/OPERATING CONDITIONS* (METRIC UNITS OF MEASURE)

Furnish and install where indicated on the plans _____ (quantity) open centrifugal liquid chilling unit(s) as manufactured by Johnson Controls (Titan). Unit(s) will utilize _____ refrigerant and will be equipped and rated in accordance with ARI Standard 550 (latest revision).

Each unit shall produce a capacity of _____ kW of refrigeration, cooling _____ L/s of _____ (water) from _____ °C to _____ °C when supplied with _____ L/s of condenser water at _____ °C. Equipment to be located _____ (indoors), _____ (NEMA-1), with ambient conditions of _____ °C (10), minimum, to _____ °C (40.5) maximum, altitude _____ km _____ (above) sea level.

Chiller maximum power consumption, including motor and speed increaser gear losses, not to exceed _____ kW (_____ kW/kWR) at full load design conditions.

Electric power shall be supplied to the centrifugal compressor drive motor at _____ (2400) (4160) volts-3 phase-60 Hertz, or _____ (3300)(6600) volts-3 phase-50 Hertz, for _____ (reduced) (full) voltage starting (inrush not to exceed _____ amps); with _____ (10%) voltage dip on starting. Motor speed shall be _____ (1800) (3600) RPM/60 Hz, or _____ (1500)(3000) RPM/50 Hz, synchronous. Motor enclosure shall be _____ (ODP) (WP II)(TEWAC); and if TEWAC, cooling water to be supplied at _____ °C (29.4), _____ kPa (1034) DWP with _____ (.000088) m² °C/W fouling factor. Motor to develop 93% (Min) full load power factor.

Main motor starter shall be _____ (reduced) (full) voltage type in a free-standing floor-mounted NEMA _____ (1) enclosure.

Electric power shall be supplied to all auxiliary motors at _____ (460) volts-3 phase-60 Hertz; or _____ (380) volts-3 phase-50 Hertz; control power at 120 volts-1 phase

60 Hertz; and control air at 312 to 390 kPa.

The evaporator tubes shall be _____ (20) BWG (_____ [0.89] mm nominal wall thickness) _____ (copper). The maximum water velocity at any point in the tubes shall not exceed _____ m/s. Pressure drop shall not exceed _____ kPa. Selection shall be based on _____ (.000044) m² °C/W fouling factor. Water side shall be _____ (1034) kPa Design Working Pressure.

The refrigerant condenser tubes shall be _____ (20) BWG (_____ [0.89] mm nominal wall thickness) _____ (copper). The maximum water velocity at any point in tubes shall not exceed _____ m/s. Pressure drop shall not exceed _____ kPa of water. Selection shall be based on _____ (.000044 m² °C/W) fouling factor. Water side shall be _____ (1034) kPa Design Working Pressure.

Oil coolers (compressor and speed increaser); and motor cooler (if TEWAC); shall be furnished with _____ (condenser) (city) (chilled) water at _____ (29.4) °C maximum temperature and _____ (1034) kPa Design Working Pressure based on _____ (.000088) m² °C/W fouling factor. Water pressure drop shall not exceed _____ kPa of water. (If condenser water is used, total auxiliary water circuit pressure drop, including all interconnecting piping, must be less than refrigerant condenser water pressure drop.)

Refrigerant transfer unit water cooled condenser shall be furnished with _____ (city) (chilled) (condenser) water at _____ °C (29.4) maximum temperature and _____ (1034) kPa Design Working Pressure based on _____ (.000088) m² °C/W fouling factor. Water pressure drop shall not exceed _____ kPa of water. Refrigerant high-pressure receiver shall be sized for _____ (the full refrigerant charge of _____ [1] unit), or (kg of refrigerant, minimum) when 90% full at 32.2°C, per ANSI/ASHRAE Standard 15.

Unit shall fit an overall space _____ mm long (including tube pulling space), _____ mm wide, _____ mm high, but not including housekeeping or foundation pad. Necessary additional space shall be provided around the chiller for maintenance/service access (1220 mm front, 915 mm rear and 1675 ends); and as required for the chiller control panel, main motor starter, and for the refrigerant transfer unit/storage receiver.

EXTENDED OPERATING RANGE (OPTIONAL)

Unit shall be specially equipped as required to produce full rated capacity at full flow entering condenser water temperatures down to 55°F (12.8°C) without the use of condenser water flow control or bypass, or cooling tower fan cycling; so as to provide maximum unit operating economies.

Guide Specifications

FREE COOLING (OPTIONAL)

The chiller units shall be provided with a Free Cooling system for the purpose of obtaining chilled water without operation of the main driver during those periods of the year when available condenser water temperature is lower than the coexisting required chilled water temperature.

Chiller units shall include all necessary component modifications, and material for field piping of refrigerant gas/liquid bypasses, including automatic valves, control center NORMAL OPERATION/FREE COOLING selector switch and indicating light, interlock to prevent compressor start-up during Free Cooling operation; and additional refrigerant charge, storage receiver, piping, valves and controls; as may be required for single point automatic operation and changeover between Normal and Free Cooling modes of operation.

GENERAL

Each unit shall consist of a steel driveline base assembly that includes the compressor, speed increaser gear (if required), and motor, factory mounted and rough aligned on a steel driveline base; liquid evaporator; refrigerant condenser with liquid sub-cooler; flash economizer (inter-cooler); refrigerant transfer unit and receiver; necessary interconnecting refrigerant pipe, valves and fittings; level adjusting spring isolators for complete unit; and floor mounted microprocessor-based, or Programmable Logic Controller (PLC) based, control panel with full multicolor graphic display CRT and membrane keypad, for use with an electric induction motor driven chilling system, all suitable for NEMA-1 application. All major components (compressor, evaporator, condenser, economizer and pumpout receiver) shall be factory leak tested, evacuated and protectively charged with nitrogen before shipment. It shall be the responsibility of the installing contractor to furnish all of the necessary labor and material to complete the installation in accordance with instructions and drawings furnished by the manufacturer.

Compressor motor starter shall be furnished for separate field mounting.

DRIVELINE BASE/ASSEMBLY

The driveline components noted above are specified in detail below, and shall be supplied factory mounted and rough aligned on a single, rigid fabricated structural steel base, with optical leveling points, to be furnished by the chiller unit manufacturer for controlled alignment. The base shall include provision for level-adjusting, limited rise, spring-type isolators as hereinafter specified; and necessary factory assembled galvanized steel auxiliary cooling water piping and manual valves within confines of base connecting all driveline components to a common manifold, including water solenoid valve and strainer.

Individual compressor and gear auxiliary oil pump motor starters with fused disconnect switches shall be furnished for field mounting and wiring on or near the driveline base.

COMPRESSOR

Compressor shall be of the open drive, single or multi-stage centrifugal type. The casing shall be of industrial construction, horizontally split to allow access to the rotor assembly. Casing design shall be such that major wearing parts (main bearings, thrust bearings, seals, and shaft oil pump) are accessible for inspection or replacement without removing upper half of the casing or disturbing compressor drive alignment. Casing shall have necessary suction, discharge and interstage flash gas connections.

Compressor impeller shaft shall be designed with sufficient rigidity to prevent vibration at any required operating speed and this operating speed shall be below the first lateral critical speed. The shaft shall be manufactured of heat treated alloy steel. Impellers shall be statically and dynamically balanced and made of material which will resist erosion, corrosion and pitting; and preserve initial impeller balance and performance characteristics. Multi-stage compressors shall include a balance piston on the last stage impeller to minimize axial thrust load on the thrust bearing.

Compressor shall include accessible precision bored aluminum alloy, or steel backed babbitt, journal bearings, and a tilting pad type thrust bearing to axially position the rotor and absorb any unbalanced thrust which may be encountered.

Compressor lubrication system shall be of the self-contained force feed type with a pump supplying oil under pressure to journal bearings and thrust bearing, and shall include dual replaceable element 15 micron oil filters with change-over valve, a water cooled oil cooler, and a thermostatically controlled oil valve to by-pass oil cooler, maintaining desired minimum oil temperature.

Complete lubrication system shall be factory packaged. Compressor shall include a main oil pump, and an auxiliary pump, including provisions to ensure positive lubrication at all operating speeds, on start-up or shutdown, and under power failure coast-down conditions. The oil reservoir shall include heaters to minimize accumulation of refrigerant in the oil during long idle periods. Sight ports, thermometers and pressure gauges shall be supplied. Provide 3-lead, 100 ohm platinum Resistance Temperature Detectors (RTD), and junction boxes with 4-20mA transmitters,

An automatic capacity reduction control of the pre-rotation vane type shall be provided to efficiently regulate the capacity by varying the volume of refrigeration suction gas handled by the compressor, together with a suitable pneumatic operator to automatically position the

pre-rotation vanes in response to a temperature control system sensing the leaving chilled water temperature. An automatic hot-gas bypass with pneumatic operator shall also be furnished to assure stable performance, even under extreme or abnormal operating conditions, down to 10% capacity.

OPTIONAL – A non-contacting proximity vibration monitoring system shall be provided as detailed below following Control Center.

COUPLINGS/COUPLING GUARDS

A lightweight, non-lubricated type of high speed coupling and guard shall be furnished between the compressor and the speed increaser gear, or motor. Coupling and guard shall be accessible and easily disassembled without disturbing the compressor drive alignment.

A limited end-float, lubricated, gear type low speed coupling and guard shall be furnished between speed increaser gear (if required), and motor.

SPEED INCREASER GEAR (IF REQUIRED)

External speed increaser shall be sized with a 1.3 (min.) gear service factor applied to the maximum continuous power output of the motor, (Motor Nameplate HP x Motor Service Factor – NEMA Rated, or Motor Nameplate kW-IEC Rated).

High speed increasers shall be totally enclosed, double helical and be manufactured in accordance with AGMA 421.06 standard for application of 1800 or 3600 rpm motors or 5,000 feet (1,524 m) per minute pitch line velocity.

Housing shall be ruggedly designed to insure maximum rigidity, made of high tensile alloy cast iron or fabricated steel, stress relieved and machined to match the precision of the gears. Housing to have machined leveling pads, vertical jacking screws, inspection cover and oversize drain port. All housing interior surfaces to be thoroughly cleaned, shot blasted and painted prior to assembly.

Gears shall be double helical design, heat treated by through hardening or case carburizing. Gears shall be precision hobbled and shaved, or have end relief and tip relief to eliminate edge loading. AGMA minimum quality level 10 shall be checked and qualified with certification available upon request. Gears shall be designed for life expectancy of 100,000 hours based on Figure 20 and 21 in AGMA 218.01. A pressure angle of 20° is required to reduce scoring and sound.

Journal bearings shall be tapered land, split-sleeve, babbit lined, steel backed, with thrust collars for axial loads. Bearings to be selected to meet specific speed and design load characteristics. (NOTE: Thrust loads on the high-speed shaft are normally handled by the compressor

thrust bearing.)

The lubrication system shall consist of a positive displacement shaft driven pump, auxiliary oil pump, heat exchanger with thermostatically controlled oil valve to bypass oil cooler, maintaining desired minimum oil temperature, dual replaceable element 25-micron (max.) oil filters with change-over valve, supply oil pressure gauge, oil temperature gauge and wet oil sump. Piping to be external of housing for ease of maintenance. Oil temperature 3-lead, 100 ohm platinum RTD/transmitter, and pressure transmitters, shall be furnished as detailed by the Control Center Input/Output List.

Seals are to be labyrinth type on both high speed and low speed shaft extensions and split horizontally for ease of maintenance. Gear lubrication system shall supply oil to the motor as required.

OPTIONAL – A non-contacting proximity vibration monitoring system shall be provided as detailed below following Control Center.

Speed increaser gears as manufactured by Lufkin, Nuttall, Philadelphia, or pre-approved equal.

COMPRESSOR MOTOR

The prime mover shall be a squirrel cage induction motor sized to efficiently and continuously fulfill the chiller unit compressor brake horsepower (including speed increaser, if required) and speed requirements without exceeding the motor nameplate HP (kW) rating, and the motor shall be specifically capable of continuous operation at 110% (min.) of the total chiller unit power requirements.

All equipment provided shall be manufactured in accordance with the applicable requirements established by the following codes or standards (latest revision), unless otherwise specified: "NEMA Publication No. MG-1, "Motors and Generators" ANSI C50.2, as a supplementary standard for motors. IEEE Publications temperature limits on insulating materials, rating methods, testing (IEEE112), etc." All material and equipment furnished shall be new free from defects of any character.

Motor shall be a horizontal, continuous duty, squirrel cage induction machine. Rating shall be for voltage and speed as previously specified; and carry a 1.15 service factor rating. Direction of rotation shall be as required by driven load and shall be prominently indicated on motor on both front and shaft sides, and be permanently affixed to each end of enclosure. Motor shall be connected to driven load by means of flexible coupling specified and provided elsewhere in these specifications.

Motor enclosure shall be (ODP-Open Drip Proof) (WP II - LoNoise) (TEWAC – Totally Enclosed Water-To-Air Cooled), as previously specified.

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If TEWAC Enclosure, motor shall be totally enclosed with top mounted water to air industrial straight through heat exchanger. Heat exchanger shall be double-tube type and shall incorporate adequate means of protecting electrical components from water. Inner tubes to be constructed of admiralty metal or 90/10 copper nickel, and designed for inlet cooling water temperature, Design Working Pressure, and fouling factor, as previously specified. The heat exchanger enclosure shall be arranged so all mounting hardware is external to the enclosure. Remote detection of leaks into the outer tube shall be provided by electronic leak detection devices alarming the chiller control panel.

Motor shall be premium efficiency of size and characteristics required to start the compressor, and bring it up to speed within the specified limitations; and operate the compressor at full load conditions without exceeding motor nameplate horsepower. The starting characteristics of the motor shall be as required for successful full or reduced voltage start-up of the entire unit as previously specified. Manufacturer shall guarantee inrush amperes to be not more than those specified, with the system starting voltage dip previously specified.

Motor shall be designed and fabricated to develop a minimum power factor as previously specified. If power factor correction capacitors (PFCC) are required, they are to be sized by the motor manufacturer, to be furnished by the starter manufacturer and installed in the starter enclosure.

Insulation Characteristics:

- a. Winding insulation shall be IEEE Class "F", rated for a maximum "hottest-spot" temperature of 130°C. Motor rating shall permit continuous operation at full nameplate horsepower load with temperature not exceeding 120°C (80°C rise above 40°C ambient) at 1.0 service factor as measured by the resistance method. Stator coils shall be form-wound and sealed.
- b. The motor insulation system must incorporate a solvent-less "Vacuum Pressure Impregnated Epoxy", (VPI) process. The insulation must be impregnated after the coils are wound into the stator and connections are made.
- c. Coil end turns shall be securely anchored to lock up the coils, prior to impregnation.
- d. Winding Temperature Sensors: Provide six, 3-lead, 100-ohm platinum RTDs imbedded in the stator coils, two per phase, at 60 degree intervals for connection to the microprocessor-based motor protective unit to be provided in the motor starter cubicle. Provide separate terminal box on motor

and terminate all sensor leads therein with ring-tongue terminals under screws.

Bearings, Lubrication & Temperature Indication:

- a. Bearings: Bearings shall be split sleeve, spherically (center) seated, self-aligning design. One bearing must be electrically insulated to prevent shaft electric currents. Design of bearings, housings, and brackets must permit inspection and replacement of bearings without disassembly of motor. The motor shall have horizontally split end bells.
- b. Lubrication: Motor to have oil rings and oil level indication on both bearings, if required. If required due to the size and/or speed of the motor, provide flooded lubrication of bearings with necessary seals, piping, orifices, visual flow indication, etc., utilizing the speed increaser positive displacement lube system.
- c. Temperature Indication: Provide each bearing with 3-lead, 100-ohm platinum RTDs, and junction boxes with 4-20mA transmitters for connection to remote temperature readouts on chiller control center.

OPTIONAL – A non-contacting proximity vibration monitoring system shall be provided as detailed below following Control Center.

Rotor:

- a. Rotor bars must be fabricated copper, or copper alloy bars; high frequency induction-brazed to centrifugally cast copper, or copper alloy resistance rings. Uniform cross section rotor bars to be swaged to assure tight bar construction and elimination of bar vibration. The use of aluminum in rotor construction will not be acceptable.
- b. Rotor to stator air gap measurements shall be made at final assembly at both ends of the motor. Readings shall be taken at 45° intervals clockwise and each reading recorded, so as to indicate the relative position of the stator, rotor as measurement location. "Twelve O'Clock" shaft position shall be permanently marked. Readings shall be included in Owner's manuals.
- c. The rotor shall be dynamically and statically balanced. Assembled motor shall be tested at the factory in accordance with latest applicable NEMA, MG 1.20.53 method of testing, and balanced to no more than 1.0 mils total peak-to-peak deflection on the bearing housing and 2.0 mils on the shaft. Overall vibration readings, including all vibration

frequencies, shall be taken and recorded with the motor running at design speed. Readings shall be included in Owner's Manual.

Space Heaters – Electric resistance space heaters shall be provided inside the motor enclosure. Capacity shall be as required to avoid moisture condensation during shutdown. Heaters shall be automatically energized by the motor starter whenever motor is shut down. Heaters shall be suitable for operation at 120 volts, single-phase, 60 (50) Hertz. Provide separate terminal box on motor with all leads terminated with ring-tongue terminals under screws.

Motor Leads – In order to provide for differential protection for the motor windings (optional), all six motor leads shall be brought out into the motor main terminal box and properly terminated with extended bus bars for NEMA 1-hole connectors.

Current Transformers (Optional) – Three current transformers of the appropriate rating and class for differential protection of the motor shall be provided and mounted in the motor main terminal box. These current transformers are to be connected to differential current protective relays to be provided in the motor starter cubicle. Differential protection CTs shall provide maximum coordinated sensitivity and utilize 50/5 or 100/5 ratios. Zone differential protection using six C.T. configuration is optional, with suitable ratios based on motor FLA. Three CTs in motor terminal box must be matched with three CTs provided in the Starter.

Surge Protection (Optional) – Provide arrestors and capacitors for motor voltage surge protection. Surge arrestors shall be station valve type rated 5.0 kV Min. Three-phase surge capacitors shall be rated 0.5 microfarads per phase. Units shall be adequately mounted and braced as indicated on the drawings.

Terminal Boxes – Manufacturer shall provide conduit boxes or terminal cabinets for all wiring connections to the motor. Boxes shall be cast iron, cast bronze, or sheet steel with a minimum thickness of 1/8 inch (3.2 mm) (11 gauge). Cover shall be bolted-on. All joints between box and cover or box and machine frame shall be sealed by means of durable gaskets resistant to heat, oil and moisture laden air. Auxiliary leads such as those provided for bearing temperature sensors, winding etc., shall be terminated on molded insulation terminal blocks in "independent" enclosed terminal boxes or compartments, effectively isolated from the line voltage main terminals.

Each terminal shall be plainly and permanently identified. Boxes shall be mounted for conduit entrance from (below) (above). All bolts and nuts shall be of hexagonal

type. Stainless steel hardware is preferred, although other corrosion-resistant metal or finishes are acceptable. All fittings and threaded parts shall be protected during shipment and erection by means of moisture resistant grease or other effective means. Motor main lead terminal box shall include ample space for "stress cone" installation, and optional current transformers and/or optional surge protection. Submit shop drawings for the surge protection equipment specified above.

Nameplates – Motor nameplates shall be stainless steel. Letters shall be permanently stamped and not less than 1/8 inch (3.2 mm) high. Information to be inscribed on main nameplate shall be per NEMA MG1-20.60, with the addition of the locked rotor current at rated voltage and frequency as determined by actual test. Provide nameplates for: space heaters (voltage and wattage); number of starts per hour; bearing identification and recommended lubricant; direction of rotation; electric-phase rotation for proper direction of mechanical rotation; and motor wiring diagram.

Submittals – Contractor shall submit shop drawings, brochures and characteristic curves for review in the manner and quantity specified. Shop Drawings, data, and brochures shall include:

- a. Dimensional data and stator and rotor construction details.
- b. NEMA enclosure type.
- c. Sound insulation.
- d. Bearing and lubrication system details.
- e. Resistance and temperature sensor details and location.
- f. Motor terminal box dimensions, locations, and internal arrangements and spacings.
- g. Nameplates.
- h. Characteristics curves with all units expressed in percent of rated values which shall be given on the graph, as follows:
 1. Current, motor torque, and drive load torque versus motor speed.
 2. Current, power factor, brake horsepower, efficiency and speed versus load.
 3. Thermal withstand curve, percent full load current vs. time in seconds. Specify ambient temperature.

Guide Specifications

4. Maximum number of safe start-ups when starting from “cold” conditions in 25°C ambient temperature, starting intermediate waiting period and other conditions.

Tests – Motor shall be given all the following factory tests:

- a. Winding resistance.
- b. Bearing inspection.
- c. No load running current and speed.
- d. High potential test.

Test Reports – Four copies of the certified test report for each of the tests specified above shall be submitted.

Instruction Books – Manufacturer shall furnish installation, operation and maintenance manuals, parts description and identification manuals and similar instruction books in the manner and quantity specified.

Spare Parts – Motor manufacturer shall provide a recommended list of all spare parts for this particular motor including current, parts costs. In addition, provide renewal parts bulletins, price lists, factory part numbers of all components of the motor. Quantity shall be as specified.

Manufacturers – Motor to be manufactured by ABB (ASEA/Brown-Boveri), General Electric, Ideal, Louis Allis, Reliance, Siemens, Westinghouse, or pre-approved equal.

COMPRESSOR MOTOR CONTROLLER (STARTER)

The centrifugal chiller manufacturer shall provide a full or reduced voltage, electro-mechanical starter in a free-standing NEMA enclosure, as previously specified, for safe, dependable starting of each compressor motor. Installation and wiring shall be by the electrical contractor.

Starter shall be in a one-high line up of NEMA enclosures, floor mounted, with 3-phase, horizontal AC power bus (or with incoming power terminal board if bus duct is not used). For personal safety, a positive mechanical disconnect switch shall completely ground and isolate the starter from the line connectors with a mechanically driven isolating shutter, leaving no exposed high voltage. High voltage door shall be mechanically locked closed with the disconnect. Low voltage section shall have separate door and be segregated from the high voltage section. Control power shall be provided from a control power transformer in each starter. Current-limiting fuses for the transformer shall be provided.

Starter must comply with NEMA Standards for Industrial Control IS 3-234 CLASS E2.

Starter shall be a high-interrupting capacity, high voltage, non-reversing type sized for the specified motor horsepower and supply voltage. Controller shall be combination starter and disconnect.

Starter shall be fused type employing current-limiting power fuses that give the starter an interrupting capacity of 400,000 kVA, 3-phase, symmetrical at 4600 volts, 60 hertz. One set of fuses shall be included. Starter shall employ magnetic vacuum contactors rated 5000 volts, and have an interrupting capacity of 50,000 kVA, 3-phase symmetrical. Line contactors shall be of the drawout type.

Starter shall include a programmable microprocessor based motor protection system with operation features and performance equal to Westinghouse IQ 1000 II with IQ Data Plus II, Multilin 269+ with MTM, or pre-approved equal.

The motor protection module shall:

- a. Be microprocessor based and shall be programmable to allow the user to establish system parameters and enter specific motor data. The data input shall be done via a keyboard on the front of the motor starter.
- b. Have separate trip points for each function. There shall be an annunciator panel on the motor starter door to indicate which protective function has operated.
- c. Include separate alarm and trip output contacts. The alarm contacts shall be wired to an alarm indicator remotely located in the chiller control panel to indicate a potential motor trip.

The motor protection module shall include:

- a. Time over current.
- b. Locked rotor trip.
- c. Current unbalance.
- d. Ground current trip.
- e. Underload trip.
- f. Jam.
- g. Long acceleration.
- h. Instantaneous current trip.
- i. Over voltage and under voltage trip.

- j. Phase loss, phase reversal, phase unbalance.
- k. Winding over temperature (6 RTD locations).

Motor protection module shall display instantaneous readings of the following:

- a. AC Amps - Phases A, B & C.
- b. AC Volts - Phases A, B & C.
- c. Winding Temperatures - Phases A, B & C (2-RTD/Phase)
- d. Megawatts
- e. Megavars
- f. Power Factor
- g. Frequency
- h. Megawatt Demand

The motor controller panel shall also include a utility quality kilowatt transducer, for connection for input to the chiller unit control panel.

The motor controller shall also include a differential protection relay (if **OPTIONAL** differential current transformers are specified for motor).

The motor controller shall provide power factor correction capacitors, if required by the motor manufacturer, mounted and wired in controller enclosure. Size as required by motor manufacturer.

Control power transformer (**OPTIONAL**) to provide control power, 5 kVA, 120 V -1 phase - 60 (50) Hertz for chiller control exclusive of starter control requirements.

Manufacturers – Starter to be manufactured by Cutler-Hammer/Westinghouse, General Electric, Ideal, Siemens, or pre-approved equal.

PRESSURE VESSELS – ASME CODE

Pressure vessels (evaporator, condenser, flash economizer (intercooler) and pumpout receiver) as hereinafter specified shall be designed, constructed, tested and stamped in accordance with the requirements of the ASME Boiler and Pressure Vessels Code, Section VIII, Division 1. Refrigerant Side Design Working Pressure (DWP) shall be as determined by manufacturer for the refrigerant and service; and evaporator and condenser water side DWP shall be as previously detailed in this specification.

EVAPORATOR AND CONDENSER

The liquid evaporator and refrigerant condenser shall be of the horizontal shell and tube type with necessary integral mounting stands including provision for level-adjusting, limited rise, spring-type isolators as hereinafter specified. The shells shall be of steel with fusion welded seams having steel tube sheets welded to each end of shell, and internal intermediate tube support sheets to support tubes at 48-inch (1219 mm) maximum spacing. Shell shall be fabricated so each tube may be individually replaced. Tubes shall be roller expanded into tube sheets to ensure a gas tight joint. Integral marine water boxes, factory welded to the tube sheets, shall be furnished with removable covers to permit access to the tubes for inspections and cleaning without disturbing or breaking any piping connections. Water connections shall be radially oriented, weld end, sealed for shipment.

EVAPORATOR

Liquid evaporator shall be fabricated as specified above for EVAPORATOR AND CONDENSER and shall include liquid headers and a distribution baffle to ensure optimum liquid refrigerant distribution, and a tube bundle configuration to ensure wetting of tubes under all load conditions. Adequate space shall be provided above tube bundle for separation of refrigerant liquid and vapor, and a suction baffle or mesh eliminator shall be furnished located to ensure uniform distribution of suction gas flow and to prevent liquid from being carried over to the compressor. Evaporator tubes shall be roller expanded into intermediate tube supports. The evaporator shall be provided with sight ports and a suitable relief device in accordance with ANSI/ASHRAE Std. 15 – (latest edition) Safety Code (and local codes) consisting of bursting disc(s) in series with relief valve(s). Properly sized suction, liquid inlet, hot-gas bypass, liquid transfer and relief connections shall be provided.

CONDENSER

Condenser shall be fabricated as specified above for EVAPORATOR AND CONDENSER and shall include a discharge gas baffle to provide efficient distribution of discharge gas and to prevent direct impingement of gas on tubes, and an integral axial flow liquid sub-cooler, with pilot refrigerant liquid level controller and pneumatically operated high pressure liquid valve. Properly sized discharge gas inlet, liquid outlet, hot-gas bypass, pumpout and purge connections shall be provided.

FLASH ECONOMIZER (INTERCOOLER)

Each multistage compressor unit shall be furnished with a flash type refrigerant economizer (intercooler) to improve overall cycle efficiency.

Guide Specifications

Economizer shall be vertical type, consisting of a welded steel construction pressure vessel with internally mounted mesh eliminators and liquid spray pipe, an externally mounted level transmitter and an external, pneumatic control valve to meter refrigerant liquid flow to the evaporator. Properly sized liquid inlet, liquid outlet and interstage gas connections shall be provided. Sight glasses shall be provided above and below mesh eliminators, at the liquid spray pipe and in the liquid line leaving the economizer. A thermometer well shall be provided for checking refrigerant liquid temperature. Provision shall be made for level adjusting, limited rise, spring type isolators as hereinafter specified.

REFRIGERANT TRANSFER UNIT/PUMPOUT RECEIVER

A complete compressor-operated transfer unit and horizontal pumpout receiver shall be provided to permit transfer and isolation of the refrigerant charge, as previously specified. The pumpout receiver shall be of welded steel construction and include integral floor mounting stands, dial type liquid level gauge, and dual relief arrangement in accordance with ANSI/ASHRAE Std. 15- (latest edition) Safety Code (and local codes), consisting of bursting discs in series with relief valves. Properly sized refrigerant liquid, gas and relief connections shall be provided. Pumpout receiver shall include four lifting lugs for rigging into place.

The refrigerant transfer unit shall be of the open reciprocating compressor type belt drive with a 10 HP (7.5 kW) TEFC motor, with water cooled condenser, oil separator and necessary safety controls for manual operation, including starter with fused disconnect switch and control power transformer. The refrigerant transfer unit shall be factory mounted on and piped to the receiver. Piping shall include necessary valve manifolding for efficient refrigerant liquid/gas transfer.

CONTROL CENTER

Each unit shall be furnished with a microprocessor-based, or PLC (programmable logic controller) based, control center with color graphic TFT display of all operating and protective parameters, factory assembled and wired in an upright, finish painted, rugged steel NEMA-1 enclosure with locked full height access door(s).

The control center shall contain all necessary controls and control logic to provide stand-alone automatic start-up, fail-safe fully automatic operation, electronic capacity control and safety protection of the chiller unit, speed increaser gear/electric motor drive. It shall also provide for

automatic pre-lube and post-lube operation of the speed increaser gear and compressor auxiliary oil pumps (AOP); and operation of the AOPs during any low pressure lube condition. Controls shall also be included for automatic control of compressor capacity to limit maximum motor power consumption, manually adjustable 100 to 40% of chiller capacity.

Control center shall be 100 % electronic/electric, with all values displayed in the graphic TFT. Refrigerant, oil and bearing temperatures and/or pressures, and control air pressures, are all to be electronically monitored from locally mounted RTDs with transmitters and pressure transducers. Also to be monitored are pre-rotation vane, high pressure liquid valve, interstage gas valve, and hot-gas valve signals; drive motor power requirements; and chilled and condenser water flows and temperatures. This data is to be displayed on a series of color graphic screens, including, but not limited to: Power-up, Screen List, Start-up/Lubrication, Main Refrigerant/Water Flow Diagram, Manual/Automatic Control, PID Tuning, Lube System Status, Refrigerant and Water Status, Miscellaneous Operating Status, and Alarm History.

The control center shall also include an Emergency Stop button, bypassing all controls. It is to be mounted on the front of the panel, together with the color graphic display and its membrane keypad, and a Power Failure Reset button. A separate hard wired high pressure cutout, remotely mounted at the compressor, shall be provided in accordance with ASHRAE/ANSI Std 15 Safety Code requirements.

All controls are to be arranged for easy access - internally wired to clearly marked terminal strips for external (field) wiring connections; wiring color coded black (control), white (neutral), and green (ground), with each wire numerically identified at both ends. A copy of the unit wiring diagram is to be provided in a pocket inside the enclosure door.

The control center is to be supplied a 5 kVA 120 volt single phase-60 (50) Hertz power supply (by others). The panel is to be all electric. The pre-rotation vanes, high pressure liquid valve, interstage gas valve, and hot-gas valve are all to be electronically controlled and pneumatically actuated, and are to be supplied a total of 4-5 SCFM (1887 to 2359 cc/s) of clean dry filtered instrument air at 80 to 100 PSIG (312 to 390 kPa) pressure (By others). All temperature and pressure displays are to be in _____ English (Metric) units of measure.

TABLE 4 - INPUT LIST

Device Tag#	Description	Signal	Remarks
ANALOG INPUTS:			
FT-100	Chilled Water Flow rate	4-20 mA DC ^{1,6}	Flow Element & Transmitter by Others
FT-102	Condenser Water Flow rate	4-20 mA DC ^{1,6}	Flow Element & Transmitter by Others
JT-160	Motor Power (Kilowatts) 0-125% FL	4-20 mA DC ⁵	from Starter
LT-114	Subcooler Refrig. Liquid Level	4-20 mA DC	
LT-116	Flash Economizer (Intercooler) Refrig. Liquid Level	4-20 mA DC	
PT-111	Evaporator Refrigerant Pressure	4-20 mA DC	
PT-113	Condenser (Compr. Disch.) Pressure	4-20 mA DC	
PT-116	Flash Economizer (Intercooler) Refrigerant Pressure	4-20 mA DC	
PT-140	Compressor Supply Oil Pressure	4-20 mA DC	
PT-143	Compressor Sump Pressure	4-20 mA DC	
PT-144	Compressor Shaft Pump Oil Pressure	4-20 mA DC	
PT-146	Compressor Balance Piston Pressure	4-20 mA DC	
PT-150	Gear Supply Oil Pressure	4-20 mA DC	
PT-156	Gear Shaft Pump Oil Pressure	4-20 mA DC	
PT-180	Control Supply Air Pressure	4-20 mA DC	
TT-100	Chilled Water Out Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-101	Chilled Water In Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-102	Condenser Water In Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-103	Condenser Water Out Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-111	Evaporator Refrig. Liquid Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-113	Compressor Refrig. Discharge Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-114	Condenser Refrig. Liquid Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-120	Oil Separator Temp	4-20 mA DC	100 OHM RTD with Transmitter
TT-115	Subcooled Refrig. Liquid Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-142	Compressor Shaft End Brg. Oil Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-147	Compressor Thrust Brg. Oil Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-150	Gear Supply Oil Temperature	4-20 mA DC	100 OHM RTD with Transmitter
TT-151	Gear H.S. Shaft End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-152	Gear H.S. Blind End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-153	Gear L.S. Blind End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-154	Gear L.S. Shaft End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-161	Motor Shaft End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter
TT-162	Motor Blind End Bearing Temp.	4-20 mA DC	100 OHM RTD with Transmitter

TABLE 4 - INPUT LIST - CONTINUED

Device Tag#	Description	Signal	Remarks
DISCRETE INPUTS:			
M1R	Compr. Motor Starter "Run" Interlock	120 VAC	from starter
M2	Compr. AOP Starter Run Interlock	120 VAC	from starter
M3	Gear AOP Starter Run Interlock	120 VAC	from starter
MPDA	Starter Motor Protective Relay Trip	120 VAC	from starter
LSL-120	Oil Separator Low Level Switch	120 VAC	
LSL-143	Compressor Oil Sump Low Level Switch	120 VAC	
PSHH-113A	Cond. Refrig. High Press. Switch	120 VAC ²	
PDSLL-140A	Comp. Oil Low Diff. Press. Cutout	120 VAC ²	
PDSLL-101A	Chilled Water Low Diff. Flow Press. Sw.	120 VAC ²	
PDSLL-102A	Cond. Water Low Diff Flow Press. Sw.	120 VAC ²	
TSHH-147A	Comp. Thrust Bearing High Temp Sw.	120 VAC ²	
	Chiller Start Push-button	120 VAC	
	Chiller Stop Push-button	120 VAC	
	Emergency Stop Push-button	120 VAC ^{2,3}	
	Reset Push-button	120 VAC	

TABLE 5 – OUTPUT LIST

ANALOG OUTPUTS			
Device Tag #	Description	Signal	Remarks
LY-114	Subcooler Level Control Valve	4-20 ma	
LY-116	Flash Economizer (Intercooler) Level Control Valve	4-20 ma	
PDY-116	Interstage Control Valve	4-20 ma	
TY-100A	Compressor Pre-rotation Vanes	4-20 ma	
TY-100B	Hot-gas Bypass Control Valve	4-20 ma	
DISCRETE OUTPUTS:			
CR	Compressor Motor Starter Control Relay	120 VAC	Interposing relay in motor starter
FCV-105	Aux. Cooling Water Solenoid Valve	120 VAC	
FCV-114	Liquid Injection Solenoid Valve	120 VAC	
FCV-120	Oil Return (Jet Pump) Solenoid Valve	120 VAC	
M2	Comp. AOP Motor Starter Coil	120 VAC	
M3	Gear AOP Motor Starter Coil	120 VAC	
M5	Oil Separator Heater Contactor A	120 VAC	
M6	Oil Separator Heater Contactor B	120 VAC	
PCV-143B	Comp. Auto. Sump Vent Valve	120 VAC	
R1	Hardwired Trip Relay	120 VAC	
R2	Compressor Oil Heater Control Relay	120 VAC	
R3	Start-up Bypass Relay	120 VAC	
R4	Chilled Water Pump "Emergency" Start Relay	120 VAC ⁴	
	Chiller Run to DCS	Dry contact	
	Remote Alarm dry contact open on alarm	Dry contact	

FOOT NOTES:

- 1 Installation methods must comply with industry and manufacturer's requirements (particularly straight lengths up and downstream, coordinated pipe wall thickness).
- 2 This input will also be hardwired to trip the chiller independent of the Allen-Bradley PLC trip output.
- 3 An Emergency stop pushbutton is provided on the front of the control panel which when pulled will stop the chiller, even in the event of a failure of the Allen-Bradley PLC output.
- 4 This contact output is energized by an evaporator low pressure condition. **The customer must establish chilled water flow through the chiller when this contact is closed to prevent tube freeze-up. It is recommended that this contact be hardwired into the chilled water pump motor starter control circuit.**
- 5 Isolated Input
6. Optional Input (not necessarily a control or safety point)

VIBRATION MONITORING SYSTEM (OPTIONAL)

1. Factory-mounting:
 - a. Provide Allen-Bradley XM series proximity probes at those radial and thrust bearings specified in paragraph 2 below.
 - b. Extension cables and proximitors to be terminated in proximitor housings supplied and installed by chiller manufacturer, or sub-vendors, and mounted on the machinery skid.

2. Chiller Driveline Bearings Configurations:

NOTE: Alternative lower cost/less definitive configurations are available. Contact your Johnson Controls representative.

- a. Compressors:
 1. Two proximity probes installed on each of two (2) radial bearings 90 degrees apart in an X-Y configuration.
 2. One proximity probe installed at the thrust bearing in a Z (axial) configuration.
 3. One keyphasor probe for speed reference signal.
 - b. Speed Increaseers:
 1. Two proximity probes installed on each of two (2) low-speed shaft radial bearings and each of two (2) high-speed shaft radial bearings, 90° apart in an X-Y configuration.
 2. One keyphasor probe on low speed shaft for speed reference signal.
 - c. Compressor Motors: Two proximity probes installed on each of two (2) motor shaft radial bearings 90° apart in an X-Y configuration.
- ### 3. Control Panel Monitoring Configurations
- a. Chiller control panel shall monitor all vibration signals with an Allen-Bradley XM Condition Monitoring System displaying those levels in a vibration monitoring screen on an Allen-Bradley Logix PLC and PanelView PLUS Display equipped control center.

MISCELLANEOUS

The unit manufacturer shall also furnish the following for each unit:

1. Necessary steel refrigerant piping, valves and fittings to interconnect the compressor, condenser, evaporator, and flash economizer (intercooler)

including high pressure liquid and interstage gas valves; necessary automatic hot-gas bypass valve, piping and fittings; and necessary refrigerant and oil gauge and control piping. Also necessary steel refrigerant piping, valves and fittings to interconnect the liquid chilling unit and the refrigerant transfer unit/pumpout receiver located within fifty (50) ft. (15,240 mm) of each other. All piping shall be furnished in accordance with ANSI-B31.5 Piping Code.

2. Oil return unit (electrically heated), and piping for field mounting, piping, and wiring.
3. Necessary external lines for compressor lubrication system.
4. Necessary compressor and gear oil pump(s) and refrigerant transfer unit compressor motor starter(s) for field mounting and wiring.
5. 5"(127 mm) dial bimetal-type thermometers for bearing supply oil, thrust bearing discharge oil, compressor sump oil, compressor refrigerant discharge gas and low pressure refrigerant liquid.
6. Special wrenches and/or special tools necessary for proper compressor installation and maintenance; and tool box.
7. Complete initial charge of refrigerant and lubricating oil for compressor and driveline components.
8. Level-adjusting (jack-screw) spring type vibration isolator assemblies, limited rise, with non-skid pads – designed for 1" (25 mm) deflection – for mounting the compressor driveline assembly, shell assembly and economizer.
9. One coat of factory applied heavy duty Amerlock 2 (dark blue) epoxy primer, suitable for field applied thermal and/or acoustic insulation, and finished coat paint.

SUPERVISION AND INSTRUCTION

The contractor shall include in his bid the services of the centrifugal unit manufacturer's factory trained field representatives to supervise the drive alignment, final leak testing, charging, and initial start-up of the unit, including proper coordination with the contractor on startup of the cooling tower(s), condenser water pump(s), and chilled water pump(s).

The contractor shall also include the services of the manufacturer's representative to instruct the owner or his operating personnel in the proper operation and maintenance of the unit for a period of five (5) days for first unit, plus three (3)

days for each additional unit.

(Optional) The contractor shall include in his bid the services of the manufacturer's factory trained field representative to supervise the installation and the assembly of all components to be field assembled at the job site.

OTHER CONSIDERATIONS

The following items are necessary to complete the installation of the chilling unit(s), and should be detailed elsewhere in the specifications:

Construction – Openings into buildings for admission of equipment and patching of any openings made; and concrete housekeeping pads or foundations (if desired or required).

Rigging – Destination storage and hauling to job site; and rigging of unit components into final position.

Refrigerant Piping – Major and minor refrigerant piping to be cut/fit/welded/assembled (material furnished by Johnson Controls – partially pre-fabricated) to interconnect chiller unit components, including refrigerant liquid and gas connections to the refrigerant transfer unit/receiver.

Piping – Chilled and condenser water piping and valves; chilled and condenser water circuit drain and vent valves, and piping to drain (if desired); chilled and condenser water flow measuring stations, thermometers and pressure gauges; water supply and drain piping to driveline oil coolers beyond unit base; water supply and return piping to

refrigerant transfer unit condenser. Refrigerant relief vent lines from relief devices (liquid chilling unit and pumpout receiver) to outside (as required by codes).

Compressed Air Source and Pneumatic Piping – Necessary compressed air equipment, piping, valves and filter regulators to supply clean, dry instrument quality air (80 to 100 PSIG / 312 to 390 kPa) to the pneumatic vane actuator, high pressure liquid valve, interstage gas valve, and hot-gas valve.

Electrical – Power wiring from power source to compressor motor starter, and from starter to motor; control interlock wiring between unit control center and compressor motor starter. Auxiliary oil pump and refrigerant transfer unit motor power wiring from power source to starters and from starters to motors. Control wiring from power source to liquid chilling unit control center, and all necessary interconnecting control wiring from Control Center to all unit Input/Output locations; including fused disconnects, circuit breakers, terminal lugs, etc., as required. Chilled water pump and cooling tower fan motor starters; chilled and condenser water flow switches, and other related control devices; including all power and control wiring for these devices.

Insulation and Painting – Thermal and acoustic insulation, and finish painting of unit, as required. (If Free Cooling option is specified, it will normally be desirable to require anti-sweat thermal insulation of condenser water boxes and piping).

SI Metric Unit Conversion

The following factors can be used to convert from English I-P (inch pounds) to the most common SI Metric values.

MEASUREMENT	MULTIPLY THIS ENGLISH VALUE	BY	TO OBTAIN THIS METRIC VALUE
CAPACITY	TONS REFRIGERANT EFFECT (ton)	3.516	KILOWATTS REFRIGERATION (kW _R)
POWER	KILOWATTS (kW)	NO CHANGE	KILOWATTS (kW)
	HORSEPOWER (hp)	0.7457	KILOWATTS (kW)
FLOW RATE	GALLONS / MINUTE (gpm)	0.0631	LITERS / SECOND (L/s)
LENGTH	FEET (ft)	304.8	MILLIMETERS (mm)
	INCHES (in)	25.4	MILLIMETERS (mm)
WEIGHT	POUNDS (lb)	0.4536	KILOGRAMS (kg)
VELOCITY	FEET / SECOND (fps)	0.3048	METERS / SECOND (m/s)
PRESSURE DROP	FEET OF WATER (ft)	2.989	KILOPASCALS (k Pa)
	POUNDS / SQ. INCH (psi)	6.895	KILOPASCALS (k Pa)
TEMPERATURE	To convert degrees Fahrenheit (°F) to degrees Celsius (°C), subtract 32° and multiply by 5/9 or 0.5556.		To convert a temperature range (i.e., 10°F or 12°F chilled water range) from Fahrenheit to Celsius, multiply by 5/9 or 0.5556.
FOULING FACTOR	ENGLISH I-P (ft² °F hr/Btu)		EQUIVALENT SI METRIC (m² °C/W)
	0.00025		0.000044
	0.00050		0.000088
	0.00075		0.000132
	0.00100		0.000176
EFFICIENCY	In the English I-P system, chiller efficiency is measured in kW / ton: $\text{kW / ton} = \frac{\text{kW input}}{\text{tons refrigerant effect}}$	In the SI Metric system, chiller efficiency is measured in Coefficient of Performance (COP). $\text{COP} = \frac{\text{kWR refrigeration effect}}{\text{kW input}}$	kW / ton and COP are related as follows: $\text{kW/ton} = \frac{3.516}{\text{COP}}$ $\text{COP} = \frac{3.516}{\text{kW/ton}}$

INTEGRATED PART LOAD VALUE (IPLV or APLV)¹

In the English I-P system, IPLV is calculated by the following formula.

$$\text{IPLV or APLV} = \frac{1}{\frac{0.17}{A} + \frac{0.39}{B} + \frac{0.33}{C} + \frac{0.11}{D}}$$

Where:

- A = kW/ton at 100% load
- B = kW/ton at 75% load
- C = kW/ton at 50% load
- D = kW/ton at 25% load

In SI Metric, the formula is

$$\text{IPLV or APLV} = 0.17A + 0.39B + 0.33C + 0.11D$$

Where:

- A = COP at 100% load
- B = COP at 75% load
- C = COP at 50% load
- D = COP at 25% load

¹ **Integrated Part Load Value (IPLV)** is a single number part-load efficiency figure of merit calculated per the method, and at the Standard Rating Conditions (54-44 / 85-95) defined and detailed in ARI Standard 550 (Latest Edition)-Centrifugal and Rotary Screw Water-Chilling Packages.

Application Part Load Value (APLV) is a single number part-load efficiency figure of merit, comparable to IPLV, calculated at specific project operating conditions, as defined and detailed in ARI Standard 550 (Latest Edition).