SECTION 23 6416 - CENTRIFUGAL WATER CHILLERS

Maintain Section format, including the UH master spec designation and version date in bold in the center columns of the header and footer. Complete the header and footer with Project information.

Edit and finalize this Section, where prompted by Editor's notes, to suit Project specific requirements. Make selections for the Project at text identified **in bold**.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

Delete hidden text after this Section has been edited for the Project.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS:

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

B. The Contractor's attention is specifically directed, but not limited, to the following documents for additional requirements:

1. The current version of the *Uniform General Conditions for Construction Contracts*, State of Texas, available on the web site of the Texas Facilities Commission.
2. The University of Houston's *Supplemental General Conditions and Special Conditions for Construction.*

A.

1.2 DESCRIPTION OF WORK:

A. Section Includes: Provide water-cooled centrifugal water chillers and components as shown, scheduled, and indicated on the Drawings, including but not limited to:

1. Chiller package.
2. Charge of refrigerant and oil.
3. Controls and control connections.
4. Chilled water connections.
5. Condenser water connections.
6. Motor Controllers.
7. Electrical power connections.
8. Relief venting connections.

1.3 QUALITY ASSURANCE:

A. Ratings and Certifications: Products shall be rated and certified in accordance with the following:

1. Conform to AHRI Standard 550/590 code for rating and testing of centrifugal chillers.
2. Conform to UL 465 for construction of centrifugal chillers and provide UL label.

3. Conform to ASME Section VIII Boiler and Pressure Vessel Code for construction and testing of centrifugal chillers.
4. Conform to ASHRAE Standard 15 code for construction and operation of centrifugal chillers.
5. Unit shall bear the AHRI certification label for centrifugal water-cooled chillers as applicable.

B. Maintenance Service: Provide service and maintenance of chillers for period of [**one**] [**two**] [**five**] [_____] years from date of Substantial Completion. Manufacturer shall have local stock of parts for centrifugal chillers proposed. Manufacturer shall have local service organization that has been established for at least five years.

1.4 ACTION SUBMITTALS:

A. Submittals shall include, but not be limited to, the following:

1. Shop drawings indicating components, assembly, dimensions, weights and loadings, required clearances, and location and size of field connections. Indicate equipment, piping and connections, valves, strainers, and thermostatic valves required for complete system.
2. Product data indicating rated capacities, weights, specialties and accessories, electrical requirements and wiring diagrams.
3. Written description of equipment functions and normal operating characteristics.
4. Written operating instructions including check-out, adjustment, start-up, routine and normal operations, regulations and controls, and shutdown for emergency.
5. Written instructions for installation and assembly, where required, including assembly drawings showing match-marking of field-assembled components.
6. Chiller starter cut sheets with components, features, options, and wiring clearly indicated.
7. Motor data as specified in Section 23 0400, "Motors and Controllers".
8. Wiring diagrams showing power and control wiring for chiller components, safety devices, and controls, clearly indicating both factory and field wiring.
9. Written listing of limiting conditions of chiller including minimum permissible temperatures, minimum voltages, maximum and minimum permitted ambient conditions, maximum permitted chilled-water-entering temperature, recommended thermal shock, and change-over temperatures.
10. Performance certifications and certified reports.
11. Warranties and guarantees.
12. Additional information as specified in Section 23 0100 “Mechanical General Provisions.”

1.5 HANDLING:

A. Comply with manufacturer's installation instructions for rigging, unloading, and transporting units.

B. Protect units from physical damage. Leave factory shipping covers in place until installation.

1.6 WARRANTY

A. Warranty: Provide [**two**] [**five**] [**Insert Number**] year warranty for chillers including coverage for [**compressor**] [**compressor motor and drive**] [**evaporator**] [**condenser**] [**complete chiller package**] [**gear box**] as manufactured and delivered to site including [**materials**] [**and labor**] [**only**].

PART 2 - PRODUCTS

2.0 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide chillers manufactured by one of the following:

1. Carrier.
2. Trane.
3. York (JCI).
4. [**Daikin.**]

B. If other than scheduled chiller mfg. is used, Contractor shall coordinate Work to insure proper provisions for installation of the furnished units including, but is not limited to, the following:

1. Structural supports for units.
2. Piping size and location.
3. Electrical power requirement and wire, conduit and overcurrent protection sizes.
4. Contractor shall be responsible for all costs incurred for modifications associated change from basis of design.

2.1 PERFORMANCE

A. Tolerance: Comply with the following in lieu of tolerances allowed by AHRI 550/590:

1. Allowable Capacity Tolerance: [**Zero**] [**Insert value**] percent.
2. Allowable Full Load Operating Performance Tolerance: [**Zero**] [**Insert value**] percent.
3. Allowable Part Load Operating Performance Tolerance: [**Zero**] [**Insert value**] percent.

B. ASHRAE Compliance: Applicable requirements in ASHRAE 90.1.

2.2 CHILLER MATERIALS AND COMPONENTS:

A. General: Provide chiller manufacturer's standard materials and components as indicated by his published product information, designed and constructed as recommended by the manufacturer and as required for a complete chiller installation as specified herein.

B. Selection: Each chiller shall allow for a water side fouling factor of [**0.0001**] [**0.00025**] for evaporator tubes and [**0.00025**] [**0.0005**] **[0.00075] [0.001]** for condenser tubes. Evaporator and condenser water pressure drops shall not exceed those scheduled on the Drawings. The total kW power consumption of the units shall not exceed the scheduled kW on the Drawings. Chillers shall be rated in accordance with the latest edition of AHRI 550 and shall conform to ASHRAE 15.

C. Refrigerants: Chillers shall be provided with ASHRAE 34, Class A1 [**or B1**] refrigerants that do not have a phase-out date established by local, State and Federal regulations.

D. Efficiency: Chiller full load efficiency shall be equal to or greater than that scheduled.

E. Chillers: Shall consist of, but not be limited to, a complete system with compressor, motor, evaporator, condenser, lubrication system, purge system or pump-out unit, economizer or sub-cooler, capacity controller, instrument and control panel, unit mounted motor starter, factory-installed insulation and other items as specified herein or required.

2.3 COMPRESSORS AND MOTORS:

A. Compressors: Shall be direct drive or gear driven, single or multistage centrifugal type. Capacity control shall be provided by fully modulating variable inlet guide vanes and shall allow capacity modulation from 100% of scheduled capacity to 15% of scheduled capacity at scheduled design conditions and with condenser water temperatures down to 65°F**[, without hot gas bypass]**. Guide vanes shall be controlled by an externally mounted electric operator in response to the refrigeration load on the evaporator. Impellers shall be high strength aluminum alloy and shall be directly connected to the motor shaft or gear driven. Compressor bearings shall be hydrodynamic sleeve type or tapered roller bearings. Sleeve bearings shall be either aluminum insert or steel backed babbit. Tapered roller bearings shall be stainless steel. The entire motor/compressor assembly shall be statically and dynamically balanced and tested at 25% overspeed. The motor/compressor assembly on direct driven units or motor/gearbox/compressor assembly on gear driven units shall be balanced to a maximum vibration amplitude of one mil as measured on the motor/compressor housing. All compressor casings shall be cast iron and shall be proof-tested at 1.5 times the maximum working pressure and leak-tested with refrigerant trace gas.

B. Transmissions: If the compressor requires a speed-increasing transmission, it shall be hermetically sealed with the motor/compressor. The transmission shall be self-aligning with a parallel double helical gear arrangement having a minimum service factor of 1.2. If the thrust of the gears is counteracted by the design residual thrust of the impellers, single helix gear design will be acceptable. Each assembled compressor motor (transmission) shall be run-tested at the factory. At any bearing, neither the horizontal nor vertical vibration shall exceed 1.0 mil. Prior to installation, the manufacturer shall provide certified test results.

C. Motors: Shall be hermetically sealed low-slip squirrel cage induction motors designed and guaranteed for continuous operation at nameplate rating. Motors shall be cooled with liquid or suction refrigerant circulated directly over the starter windings and between the rotor and starter. All motor windings shall be designed for operation in a refrigerant atmosphere. The motor shall be suitable for **[SCR controlled solid-state or] [Star-Delta reduced voltage]** starting at the voltage scheduled on the drawings. Motor winding temperature sensors, interlocked for unit shutdown, shall be provided for each phase.

D. [Open-drive Option: At the Contractor's option, open-drive equipment may be furnished in lieu of the specified hermetic equipment provided the following conditions are strictly met.]

1. **[Heat rejected to the Central Plant shall be removed by air handling unit(s) complete with chilled water cooling coils, valves, piping, controls and other required components provided at no additional cost to the Owner.]**
2. **[Self-generated noise characteristics shall not exceed 78 dbA at full load, 81.5 dbA at 50% load and 81.5 dbA at 25% load.]**

3. **[Power consumption shall not exceed that of the specified hermetic machines over full operating range (15% to 100%), given constant 85°F to 95°F condenser water temperature.]**

E. Lubrication: Force-feed lubrication shall be provided by a direct drive, positive displacement oil pump which shall provide positive lubrication to all bearings at all times. Power for the oil pump shall be supplied through the control power transformer/source. A lubrication oil filter with a differential pressure gauge shall be provided. A low voltage-density oil heater shall maintain oil temperature at a level to minimize its affinity for refrigerant. Power for the oil heater shall be supplied from a separate control power circuit and wired through the unit control panel. An integral or independent oil cooling system shall be provided. An interlock shall be provided to prevent motor starting unless oil pressure is established.

2.4 VESSELS AND ACCESSORIES:

A. Evaporator and Condenser Vessels: Heat exchangers shall be of a shell and tube type designed in accordance with ASHRAE 15 and ASME Code for Unfired Pressure Vessels and shall be appropriately stamped where required by ASME Code. The refrigerant side shall be proof tested 1.5 times the maximum design working pressure. The waterside working pressure shall be **[150] [300]** psi and shall be tested at 1.5 times design working pressure. Heat exchangers shall include water side taps for vent and drain connections as required. Waterside pressure drop shall not exceed scheduled values. Water side heads shall be removable to allow direct access to all tubes. Provide flanged connections with ASME Class **[125] [150] [250]** compatible drilling for all heat exchanger supply and return piping.

1. Marine Water Boxes: Install marine water boxes for water boxes with field piping connections.
2. Standard Water Boxes: Install standard water boxes for water boxes without field piping connections.
3. Hinges: Install water boxes and covers of marine water boxes with hinges.
4. Lifting Provisions: Install water boxes and covers of marine water boxes with lifting lugs or mfg. recommended means of field lifting.
5. Flow Sensors: Thermal dispersion type, factory calibrated for Project specific application.
6. Additional Corrosion Protection: Replaceable electrolytic corrosion-inhibitor anode for condenser [**and evaporator**].

B. Evaporator: The evaporator shell shall be formed of carbon steel plate and shall incorporate a carbon rupture disc. The evaporator relief shall be piped through the building roof in conformance with applicable codes or as shown on the drawings. The chiller manufacturer shall be responsible for sizing the relief piping. End and intermediate tube sheets shall be carbon steel and shall be drilled for tube installation. Tube sheets shall be welded to the vessel shell and be fully self-supporting. Tubes shall be **[externally finned] [internally enhanced]** nominal 0.028" wall copper tubing mechanically expanded into the tube sheets. Tubes shall be individually cleanable and replaceable. Mesh screen eliminators shall be installed along the entire length of the evaporator to prevent liquid refrigerant carry over into the compressor. Liquid refrigerant entering the evaporator shall be distributed uniformly along its entire length without direct impingement of high velocity refrigerant on tubes. For standard water selections, minimum allowable refrigerant temperatures shall be 32°F at the design conditions scheduled with a minimum water side tube

temperature of 33.5°F. The refrigerant side of the evaporator shall be vacuum and pressure leak tested with refrigerant trace gas. The evaporator shall be tested as specified hereinabove for Evaporator and Condenser Vessels. Provide a site glass at each evaporator, located such that the proper refrigerant change is near the center of the glass with the unit off.

C. Refrigerant Flow Control: Shall be by means of a positive metering device and the chiller shall be capable of starting and operating with entering condenser water at 65°F. Adjustable or float type refrigerant metering devices and thermal expansion valves shall be inspected and adjusted by the manufacturer annually for the first 5 years of operation to assure equivalent reliability to a fixed orifice system.

D. Condenser: The condenser shell and tube sheets shall be formed of carbon steel plate. Condenser tubes shall be **[externally finned, internally smooth nominal 0.028"] [internally enhanced nominal 0.035"]** wall copper and shall be mechanically expanded into the tube sheets **[and shall be compatible with the Brush Cleaning System specified elsewhere in these specifications]**. Tubes shall be cleanable and replaceable. The condenser shall be tested as specified hereinabove for the Evaporator and for Evaporator and Condenser Vessels.

E. Economizer: An economizer may be incorporated to help maintain the correct differential between condensing and evaporator pressures over the entire range of loading. All units utilizing subcooling must be provided with a thermometer well to monitor the amount of subcooling.

F. Purge System: An automatic high efficiency purge system shall be provided on low pressure refrigerant units to remove any non-condensables and water vapor present in the refrigerant. At standard operating conditions and with a condensing refrigerant temperature of 80°F, the purge discharge shall be better than one pound of non-condensable per pound of refrigerant. The purge system shall include a purge compressor, controls, sight glass oil level indicator, electrically heated oil separator, sectionalized drum permitting separation of non-condensable gases and water from the discharge of the compressor purge, a means of return refrigerant to the condenser and drawing off of non-condensables and solenoid valves to automatically isolate the purge system from the refrigerant circuit when the purge compressor is not in operation. A purge pressure gauge, a number of starts counter, and an hour meter shall be included on the purge system.

G. Pump-out Unit: Automatic pump-out unit and storage vessel shall be factory installed on all high-pressure refrigerant units or the unit shall be capable of storing and isolating the entire refrigerant charge in the unit condenser vessel. Unit shall be factory-installed and piped and shall be furnished prewired with all necessary controls, transfer pump, condensing unit and tank constructed in accordance with ASME Code for unfired pressure vessels bearing the National Board stamp. Pump-out systems shall be supplied and warranted by the centrifugal machine manufacturer. Pumpouts shall comply with the following:

1. Pump-out tank(s) with ASME stamp capable of holding refrigerant charge when 80% full at 90°F.
2. Separate charging connections for liquid and gas refrigerant.
3. Piping and valves between pump-out and chiller to be supplied and installed by installing contractor. Contractor shall provide all piping, electrical equipment, and wiring required.

Refrigerant piping shall be Type K hard-drawn copper with wrought copper fittings. Valves shall be packless type suitable for refrigerant use.

H. Recycle/Recovery Unit: The manufacturer shall provide a portable Recycle/Recovery System. The system shall be modular allowing a single operator to transport, unload and install the system without requiring hoists, cranes, etc. the system shall include modular storage tanks, portable evacuation pump, heater, pump high pressure control, water cooled condenser, and pump starter. The system shall be compatible with refrigerant installed and shall have a storage capacity at least equal to refrigerant charge for largest chiller. The system shall include 25 ft. of self-sealing refrigerant hoses.

I. [Heat Recovery Bundle: Provide a separate heat recovery tube bundle integral to the unit condenser, where scheduled.]

2.5 ACCESSORIES:

A. [Vibration Isolation: Vibration isolation shall be provided at all supports points. Refer to Section 23 0548, "Vibration Isolation", for requirements.]

B. Refrigerant and Oil Charge: Chillers shall be provided with a full charge of refrigerant and oil. Refrigerant and oil charge shall be checked prior to startup. All or any part of the refrigerant or oil that may be lost during startup or the warranty period, shall be replaced by the chiller manufacturer at no additional cost to the Owner.

C. Thermometer Wells and Site Glasses: Thermometer wells shall be provided to measure liquid refrigerant condensing and evaporating temperature and for all safety controls. Site glasses shall be provided for monitoring refrigerant and oil charge level, compressor rotation and the purge condenser drum.

D. [Differential Pressure Sensors: Provide Orange Research, Inc. or approved equal differential pressure sensors with pressure switches and direct reading differential pressure gauges factory-installed to read across each heat exchanger. Differential pressure gauges shall be factory-mounted in the face of the chiller control panel and the pressure switches shall be factory-interlocked with the chiller controls to provide heat exchanger water flow verification. Sensors shall be similar to Series 1516 with 3-1/2" gauge readout, two reed switches and 316 stainless steel construction. Gauge range shall be adequate to monitor pressure drop from clean tubes to 0.0001 fouled tubes plus a 25% safety margin. Gauges shall be calibrated with water and shall be liquid filled to prevent pointer pulsation.]

E. [Flow Switches: Chillers shall have McDonnell-Miller No. FVS-7 or approved equal flow switches factory-installed and wired to provide chilled and condenser water flow verification.]

F. Insulation: All low temperature surfaces and surfaces capable of forming condensation including, but not limited to, evaporator and water boxes, suction elbow, economizer and motor cooling piping, shall be factory-insulated with [**3/4**] [**1-1/2**] inch thick closed-cell flexible elastomeric insulation.

G. Painting: All exposed surfaces and insulation shall be primed and painted using the manufacturer's standard paint system and colors.

2.6 CONTROLS:

A. General: The chiller(s) shall be controlled by a stand-alone Direct Digital Control (DDC) System. The controller shall provide chiller capacity control in response to the leaving chilled water temperature.

B. Control Panel: The chiller control panel shall provide control of chiller operation and monitoring of chiller sensors, actuators, relays and switches.

C. Safeties: The chiller control panel shall monitor such safeties as motor starting and running current, motor winding temperature (hermetic motors only), time between compressor/motor starts, low chilled water temperature, high condenser refrigerant pressure, low evaporator refrigerant pressure, high discharge pressure, evaporator and condenser water flows, low oil flow/pressure, and proper operation of unit controls and sensors.

D. Visual Display: The chiller control panel is to be provided with the following system pressure information:

1. Evaporator refrigerant pressure.
2. Condenser refrigerant pressure.
3. Oil pressure.
4. Purge drum pressure.

E. Meters: The chiller control panel is to be provided with a starts counter and running time meter.

F. Indicator/Displays: The front of the chiller control panel shall be capable of displaying the following:

1. Entering and leaving evaporator water temperature.
2. Entering and leaving condenser water temperature.
3. Chilled water setpoint.
4. Electrical current limit set point.
5. Chiller operating mode.
6. Chiller diagnostic codes and operating messages.

G. Protection: The chiller control panel shall provide evaporator freeze protection and low limit control. This control shall be used to avoid low evaporator refrigerant temperature trip-outs during critical periods of chiller operation. The control shall take progressively more aggressive load limiting action in response to the severity of the rate of change and the actual value of the evaporator refrigerant temperature. A diagnostic code/message, reflecting the operating status, shall be automatically displayed at the front panel whenever this control is in effect.

H. Control Interface Outputs: The chiller control panel shall provide a relay output to start the condenser water pump and/or enable the cooling tower temperature controls.

I. Alarm Outputs: The chiller control panel shall provide an alarm relay output that shall energize whenever a fault requiring manual reset is detected by the panel.

J. Condenser Limit Control: The chiller control panel shall provide condenser limit control to include a pressure transducer and interconnecting piping and wiring. This control shall be used to avoid high condenser refrigerant pressure trip-outs during critical periods of chiller operation. The control shall take progressively more aggressive load limiting action in response to the severity of the rate of change and actual value of the condenser refrigerant pressure. A diagnostic code/message, reflecting the operating status, shall be automatically displayed at the front panel whenever this control mode is in effect.

K. Low Temperature Startup: Include necessary controls to allow the water chilling unit to start with a condenser water temperature of 45°F and operate continuously at 65°F condenser water temperature. Single stage units or 2-stage units with inlet vanes in front of only one stage of compression, may utilize automatic hot gas bypass to allow operation at reduced load.

L. [Chilled Water Temperature Reset: The chiller control panel shall provide leaving chilled water temperature reset based upon return water temperature or ambient temperature.]

M. [Chilled Water Temperature Reset: The unit control panel shall provide leaving chilled water temperature reset based upon a pulse width modulated (PWM), [SCR controlled solid state or] 4-20ma or 0-10 VOLTS DIRECT CURRENT signal from a building automation system.]

2.7 600 VOLT MOTOR CONTROLLERS:

A. General: Each chiller motor shall be provided with a **[unit mounted] [free-standing] [SCR controlled solid state or] [star delta closed transition]** controller. Motor controller shall have NEMA 1A gasketed enclosure. **[Unit mounted starters shall be fully wired and tested such that only external power and control wiring connections are required in the field.]** Enclosure shall be constructed of 12-gauge steel minimum with the exception of doors which shall be code gauge steel minimum. **[Unit mounted enclosures shall have ventilating louvers or water-cooled heat sinks.]** Each door or enclosure more than 48" high shall have three-point vault-type latches with padlockable handles and gasketing.

B. Connections: Motor controllers shall include incoming line provisions for the number and size copper cables shown on the Drawings. Incoming line lugs shall be copper **[mechanical] [compression]** type. Connection directly to the contactors is not permissible.

C. Contactors: Star-delta controller contactors shall be sized properly, per the NEMA requirements, to the chiller full load and locked rotor currents. Contactors shall have double break main contacts with weld resistant silver cadmium faces. Auxiliary interlocks that interface with the control panel shall have low resistance palladium silver contacts.

D. Control Accessories: Each motor controller shall include a control power transformer with fused primary and secondary. Current transformers of the proper size, ratio and burden capacity shall be provided to provide a signal to the control panel and optional devices. Control relays shall be provided within the motor starter to interface with the control panel.

E. Starter Wiring: Power wiring within the controller shall be Type MTW copper stranded 90°C. Power wire bends shall show no evidence of nicking or insulation degradation. Control wire shall be Type MTW copper stranded 90°C, 14 gauge minimum.

F. Motor Protection: Controller shall include motor protection system incorporating electronic three phase overloads and current transformers. The electronic motor protection system shall monitor and protect against the following conditions:

1. Three phase overload protection.
2. Overload protection during start-up.
3. Phase imbalance.
4. Phase loss.
5. Phase reversal.
6. Low voltage.
7. Distribution fault protection consisting of 3-phase, current sensing devices that monitor the status of the current. Distribution faults of 1-1/2 electrical cycle durations shall be detected and the compressor motor shall be disconnected within six electrical cycles.
8. A lockout transition safety circuit shall be provided to prevent damage from prolonged energization due to malfunction of the transition contractor. Malfunction shall cause the machine to be shut down and the "starter circuit fault" indicator to be displayed. The overload system shall be coordination with the current control system to provide fail-safe circuitry. A single adjustment shall be used to set all three overloads.
9. **[The motor protection system can, at the manufacturer's option, be furnished as part of the chiller control panel.]**

G. Ambient Temperature: The controller shall be able to operate in temperatures up to 120°F.

H. Additional Features: The following controller features shall be provided:

1. **[Circuit Breaker: Controller shall contain a circuit breaker with an interrupting capacity of [_____] RMS symmetrical amperes. Operating handle and trip indicator shall be located in the door. This handle shall be capable of being padlocked.]**
2. **[Disconnect: A non-fused disconnect switch shall be provided.]**
3. Ammeters and Voltmeters: Three ammeters shall be provided, one per phase. Ammeters shall be calibrated so the inrush current can be indicated. Three voltmeters shall be provided, each reading a phase-to-phase voltage.
4. UL Approval: Starters shall be Underwriters' Laboratories, Inc. approved.
5. **[Capacitors: Power Factor Correction Capacitors shall be provided to correct to 93.5-95.5% at full load conditions (free standing starters only).]**

2.8 600 VOLT VARIABLE FREQUENCY CONTROLER

A. Factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.

B. Description: Listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.

C. Enclosure: Unit mounted, NEMA 250 Type 1, with hinged full-front access door with lock and key.

D. Integral Disconnecting Means: NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than [**65,000**] [**100,000**] A.

E. Technology: Pulse width modulated (PWM) output with insulated gate bipolar transistors (IGBT); suitable for variable torque loads.

F. Controller shall consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.

1. Rectifier section shall be a full-wave diode bridge that changes fixed-voltage, fixed-frequency, AC line power to a fixed DC voltage. Silicon controller rectifiers, current source inverters, and paralleling of devices are unacceptable. Rectifier shall be insensitive to phase rotation of the AC line.
2. Regulator shall provide full digital control of frequency and voltage.
3. Inverter section shall change fixed dc voltage to variable-frequency, variable ac voltage, for application to a squirrel-cage motor. Inverter shall produce a sine-coded, pulse width modulated (PWM) output wave form and shall conduct no radio-frequency interference back to the input power supply.

G. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.

H. Operating Requirements:

1. Input AC Voltage Tolerance: 460-V ac, plus 10 percent or 506 V maximum.
2. Input frequency tolerance of 60 Hz, plus or minus 2 Hz.
3. Capable of driving full load, without derating, under the following conditions:

    a. Ambient Temperature: **[- to - deg F.]**
    b. Relative Humidity: Up to 95 percent (non-condensing).

4. Minimum Efficiency: 96 percent at 60 Hz, full load.
5. Minimum Displacement Primary-Side Power Factor: 95 percent without harmonic filter, 98 percent with harmonic filter.
6. Overload Capability: 1.05 times the full-load current for 7 seconds.
7. Starting Torque: As required by compressor-drive assembly.
8. Speed Regulation: Plus or minus 1 percent.
9. Isolated control interface to allow controller to follow control signal over a 10:1 speed range.
10. To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
11. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.

I. Internal Adjustability Capabilities:

1. Minimum Output Frequency: 6 Hz.
2. Maximum Output Frequency: 60 Hz.
3. Acceleration: 2 seconds to a minimum of 60 seconds.
4. Deceleration: 2 seconds to a minimum of 60 seconds.
5. Current Limit: 30 percent to a minimum of 100 percent of maximum rating.

J. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:

1. Overtemperature.
2. Short circuit at controller output.
3. Ground fault at controller output. Variable frequency controller shall be able to start a grounded motor.
4. Open circuit at controller output.
5. Input undervoltage.
6. Input overvoltage.
7. Loss of input phase.
8. Reverse phase.
9. AC line switching transients.
10. Instantaneous overload, line to line or line to ground.
11. Sustained overload exceeding 100 percent of controller rated current.
12. Starting a rotating motor.

K. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.

L. Automatic Reset and Restart: Capable of three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Controller shall be capable of automatic restart on phase-loss and overvoltage and undervoltage trips.

M. Visual Indication: On face of controller enclosure or chiller control enclosure; indicating the following conditions:

1. Power on.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.
7. Motor speed (percent).
8. Fault or alarm status (code).
9. DC-link voltage.
10. Motor output voltage.
11. Input kilovolt amperes.

12. Total power factor.
13. Input kilowatts.
14. Input kilowatt-hours.
15. Three-phase input voltage.
16. Three-phase output voltage.
17. Three-phase input current.
18. Three-phase output current.
19. Three-phase input voltage total harmonic distortion.
20. Three-phase input current total harmonic distortion.
21. Output frequency (Hertz).
22. Elapsed operating time (hours).
23. Diagnostic and service parameters.

N. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.

O. Control Signal Interface:

1. Electric Input Signal Interface: A minimum of two analog inputs (0 to 10 V or 0/4-20 mA) and six programmable digital inputs.

P. Active Harmonic Distortion Filter: Factory mounted and wired to limit total demand distortion for voltage and current to 5 percent. Complying with IEEE 519.

Q. Cooling: Refrigerant or water cooled.

R. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.

1. Control Relays: Auxiliary and adjustable time-delay relays.

S. Chiller Capacity Control Interface: Equip chiller with adaptive control logic to automatically adjust the compressor motor speed and the compressor pre-rotation inlet vane position independently to achieve maximum part-load efficiency in response to sensor inputs that are integral to the chiller controls.

2.9 SOURCE QUALITY CONTROL - FACTORY TESTING

A. Perform functional run testing of assembled chillers before shipment.

B. Factory-testing for vibration, acoustical performance and unit run testing shall be witnessed by the Owner's Representative. The Contractor shall pay for air fare, accommodations, and similar expenses so that two Owner's Representatives can witness the test.

C. Submit test reports for each test indicating test equipment, procedures, results, dates, personnel performing tests and witnesses.

D. [Factory Performance Testing: One chiller of each size specified for the project shall be factory performance tested under full load conditions in an AHRI-certified test facility. The manufacturer shall supply a certified test report to confirm performance as specified. Proper AHRI certification documents for the test loop shall be made available upon request from the

manufacturer. The performance test shall be conducted in accordance with AHRI Standard 550/590 procedures and tolerances.

1. **The performance test shall be run with clean tubes in accordance with ARI 550 to include the following:**

   a. **A downward temperature adjustment shall be made to the design leaving evaporator water temperature to adjust from the design fouling to the clean tube condition.**
   b. **An upward temperature adjustment shall be made to the design entering condenser water temperature to adjust from the design fouling to the clean tube condition.**
   c. **Test temperature adjustments can be verified prior to test by the Vice President, Engineering, AHRI. There shall be no exceptions to conducting the performance test with clean tubes and with temperature adjustments. The manufacturer shall clean tubes, if necessary, prior to test to obtain a test fouling factor of 0.0000 hr. sq. ft. F/BTU.**
   d. **Factory performance testing shall include integrated part load value (IPLV) testing. Test reports provided with O&M Manuals shall include raw data used in IPLV calculations.**

2. **The factory test instrumentation shall be per AHRI Standard 550, and the calibration of all instrumentation shall be traceable to the National Institute of Standards and Technology.**
3. **The Owner or his Representative shall be notified 14 days in advance to witness the factory performance test.**
4. **A certified test report of all data shall be submitted to the Engineer prior to shipping of chillers to the job site. The factory-certified test report shall be signed by an officer of the manufacturer's company. Preprinted certification will not be acceptable; certification shall be in the original.**
5. **Equipment will be accepted if the test procedures and results are in conformance with AHRI Standard 550. If the equipment fails to perform within allowable tolerances, the manufacturer will be allowed to make necessary revisions to his equipment and retest as required. The manufacturer shall assume all expenses incurred by the Owner or his Representative to witness the retest. In the event that these revisions do not achieve submitted performance, the following penalties will be imposed:**

   a. **<u>Capacity Test</u>: For each ton below the allowable capacity as set forth in AHRI 550 of the design capacity, five hundred dollars ($500.00) per ton will be deducted from the contract price.**

      Allowable capacity = (1 - tolerance) x design capacity; tolerance per AHRI 550, Section 5.4.
   b. **<u>Power Consumption Test</u>: The power consumption penalty for all load points shall be based upon the tolerances set forth in AHRI 550. The power consumption penalty (P.C.P.) will be calculated based upon the following formula:**

      P.C.P. = [Measured kW - (Measured Tons x Allowable kW/Ton*)] x $1000/kW

      *** Allowable KW/Ton = (1 + tolerance) x design kW/Ton; tolerance per AHRI 550.**
   c. **<u>Total Performance Penalty</u>: The total performance penalty will be the sum of Capacity Penalty and Power Consumption Penalty, times the number of typical chillers, regardless of whether all chillers are tested.**

6. **Equipment manufacturer shall not invoice for the centrifugal chillers(s) until successful completion of the performance test or acceptance of penalty deduction from the contract.]**

E. Eddy Current Testing:

1. Perform eddy current testing of chiller condenser and evaporator tubes by an ASNT Level III technician.
2. Submit detailed test report describing tests, results, deficiencies, observations and recommendations.

PART 3 - GENERAL

3.1 INSTALLATION:

A. General: Install chillers, including components and controls required for chiller operation, in accordance with chiller manufacturer's instructions.

B. Location: Locate chiller in general position indicated in relation to other work. Position chiller with sufficient clearance for normal service and maintenance, including clearance for cleaning and replacement of tubes and motor.

C. Components: Install auxiliary piping, solenoid valves, shutoff valves, water strainers and controls for accessory systems, including but not limited to, oil cooler, compressor motor cooler, and purge and transfer system. Comply with manufacturer's instructions.

D. Interlock: Interlock flow switches with chiller controls in accordance with the manufacturer's instructions, except as otherwise indicated.

E. Supervision: The unit manufacturer shall supervise the installation and final checkout of the electrical interlock control wiring and review the location of the flow switches so that they perform the safety function without faulty operation or excessive vibration of the sensor.

F. Finish: Paint damaged and abraded factory finish with touch-up paint matching factory finish.

3.2 RELATED WORK:

A. General: Provide work related to and connected to chiller work and required for a complete chiller installation, including, but not limited to:

1. Piping connections including provisions for disconnecting and servicing of chiller and cleaning/ replacing of tubes.
2. Relief pipe from chiller relief opening to the outside, including a dirt trap and flexible connection. Size relief piping as recommended by the manufacturer.
3. Tapping in condenser lines for acid cleaning.
4. Isolation of chilled water and condenser water piping connections to chiller.
5. Balancing valves in water piping for balancing system operations.
6. Pipe strainers to protect chiller components and controls including pumps, automatic modulating valves, and pneumatic controls.

7. Pipe support and bracing, adequately separated from chiller work in a manner preventing transfer of pipe stresses to chiller components.
8. Flow switches or pressure differential switches, properly installed in a horizontal run of the chilled water piping and condenser water piping near the chiller.
9. Connecting all miscellaneous piping including oil cooler and auxiliary water piping.
10. Vibration and noise isolation as specified in Section 23 0548 “Vibration Isolation.”
11. Ambient room conditions, including additional cooling, if required, for open drive motors.
12. Wiring of flow switches or pressure differential switches for chiller interlock.
13. Pressure gauges and thermometers as specified in Section 23 2010, "HVAC Piping Valves and Accessories."
14. Electrical wiring by Division 26 to compressor motor controller with interconnecting wiring to chiller control panel and unit motors, as required.
15. Electrical wiring by Division 26 to oil pump/starter, refrigeration transfer compressor/starter and controls, if required.
16. The unit control circuit shall be arranged so that on start-up, the chilled water pump, condenser water pump and oil pump shall start first and the compressor motor shall start after operation conditions have been satisfied. On shutdown, the compressor motor shall stop first and the chilled water pump, condenser water pump and oil pump shall stop after a suitable time-delay period.

B. Prestart-up: Complete the preparation and review the report on related work prior to chiller start up; do not start chiller until inadequacies have been corrected in a manner acceptable to the chiller Installer.

3.3 START-UP SERVICES:

A. Manufacturer Supervision: A factory-trained technical service representative of the manufacturer shall supervise the field-assembly (if any), installation and startup of each chiller, for a minimum of five working days, plus one additional day for each chiller unit in excess of one unit. Prepare manufacturer's written report/log of the installation and startup, signed by the service representative and the Owner.

1. Representative shall supervise leak testing, evacuation, dehydration, vacuum pumping, charging, lubrication, including the filling of reservoirs and confirm that lubricant is of the quantity and type as instructed by the manufacturer.
2. Representative shall instruct the Owner's operating personnel in the operation and service of the units for a period of one week, based on a 40-hour week, excluding nights, weekends, and travel time to and from the Project.

B. Sustained Operation: Do not place chiller in sustained operation prior to initial balancing of the mechanical systems affected by chiller operation. Refer to "Operation Test-Adjust-Balance" requirements of Section 23 0593. “Testing, Adjusting and Balancing.”

C. Cooperation: Cooperate with other trades and installers of other work during the testing, adjusting, balancing, and start-up of mechanical systems.

3.4 TESTING:

A. General: Except as otherwise indicated, test chiller in accordance with AHRI 550.

B. Pressure Test: Conduct a standing pressure test on the refrigerant circuit for a period of 12 hours using nitrogen without exceeding test pressure recommended by the manufacturer. Conduct a standing vacuum test on the vessel equal to 1 mm Hg absolute for a 24-hour period. Refrigerant shall be charged, through filter dryers, to a recommended level. Machine shipped pre-charged need not comply with this requirement unless the factory pre-charge or holding charge is lost during shipment or prior to start up, in which case the Contractor shall test as indicated. Perform all tests and start up in such a manner as not to introduce moisture into the machine. Flush system as required to remove non-condensables.

C. Oil Samples: Obtain oil samples from each compressor at start up, label and send one sample in a clean, clear, suitable container with screw cap to the Engineer's office**. [Send one sample in a suitable container to Analysts Services, Inc., 12715 Royal Drive, Stafford, Texas.]** This sample will provide a base reference for all samples taken during the warranty period. At the end of the next two 30-day periods, samples as above shall be taken and distributed. If no recommendations are made by the Engineer or Analysts Services, Inc., samples shall then be taken at 60-day intervals and distributed as above. This testing program shall provide a minimum of eight samples of two each during the warranty period. Test shall include Karl Fisher Titration Test. If a problem is indicated at any time during this process, the Contractor shall take whatever steps necessary to ascertain the cause of any oil contamination. Any remedial measures shall be done at no expense to the Owner. The Contractor may at any time submit additional samples to the compressor manufacturer for analysis and a factory-recommended procedure to be followed. All remedial measures shall be reviewed by the Architect before beginning any work.

D. [Annual Service: At the end of the one-year warranty period, the chiller manufacturers service organization shall provide all labor, materials and equipment for an annual chiller service including, but not limited to: removing heat exchanger heads and inspecting/cleaning tubes, oil change/analysis, motor servicing and other manufacturer recommended service. This service shall be performed at no cost to the Owner.]

END OF SECTION 23 6416