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BuildingName
The Description of the Project
P00000000 0000

SPECIFICATION DIVISION 23

NUMBER SECTION DESCRIPTION

DIVISION 23 HEATING, VENTILATING AND AIR CONDITIONING (HVAC)
SECTION 236416 – CENTRIFUGAL WATER CHILLERS

END OF CONTENTS TABLE

MPLE ECONOMIC ANALYSIS FOR DESIGNERS USE AND/OR TO BE COMPLETED BY BIDDERS IS AVAILABLE FOR THIS SPECIFICATION SECTION; SEE THE "STANDARD DETAILS" SECTION OF THE U-M A.E.C. WEBSITE: WWW.UMAEC.UMICH.EDU. AN ECONOMIC ANALYSIS SHOULD TYPICALLY BE PERFORMED TO COMPARE CHILLER ALTERNATIVES.

REVISED FORMAT AND CONTENT 04/2011 D. KARLE AND M. PLATT.

CHANGED TO INDICATE LINE REACTORS CAN BE USED ON VSD PROVIDED THEY ARE NOT MOUNTED EXTERNAL TO THE DRIVE. D. KARLE/K. BIRRINGER 2-7-12.

DIVISION 23 HEATING, VENTILATING AND AIR CONDITIONING (HVAC)
SECTION 236416 – CENTRIFUGAL WATER CHILLERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

INCLUDE PARAGRAPH 1.1.A AND B IN EVERY SPECIFICATION SECTION. EDIT RELATED SECTIONS 1.1.B TO MAKE IT PROJECT SPECIFIC.

A. Drawings and general provisions of the Contract, Standard General and Supplementary General Conditions, Division 1 Specification Sections, and other applicable Specification Sections including the Related Sections listed below, apply to this Section.

B. Related Sections:

1. Section 220548: Vibration Control
2. Section 019100/019110: Commissioning
3. Division 26: Electrical

1.2 SUMMARY

A. Section Includes

1. Centrifugal chiller(s), both semi-hermetic and open drive types.
2. Centrifugal chiller installation, testing, commissioning, and start-up services.

TURN ON HIDDEN TEXT AND MAKE THE BELOW PARAGRAPH PROJECT SPECIFIC, IF IT APPLIES TO THE PROJECT.

B. The chiller(s) will be prepurchased and assigned to the contractor for installation. Except as otherwise indicated, chiller manufacturer/vendor is responsible for items listed in PART 1 and Part 2 of this specification, installing contractor is responsible for items listed in PART 3.

THE BELOW ARTICLE (IN HIDDEN TEXT) CONTAINS SAMPLE LANGUAGE FOR CHILLER ALTERNATES. PARAGRAPH "A" IS TYPICALLY USED ONLY IF THE CHILLER IS BEING PREPURCHASED. PARAGRAPH "B" IS USED TO SOLICIT ALTERNATIVE CHILLER SELECTIONS FOR TOTAL COST OF OWNERSHIP (TCO) EVALUATIONS. ONE MEANS OF SOLICITING TCO OPTIONS IS BY PREPURCHASING THE CHILLER(S); THERE ARE OTHER METHODS. THIS ARTICLE COULD ALSO BE USED TO DESCRIBE OTHER ALTERNATES BEING SOLICITED. EDIT THE ARTICLE TO MAKE IT PROJECT SPECIFIC, OR DELETE.

1.3 ALTERNATES

A. Manufacturers are encouraged to submit deduct alternates for early payment.

B. In addition to submitting a base bid proposal that complies with this specification and the scheduled performance data, manufacturers are encouraged to submit alternate chiller selections that provide best value/lowest total cost of ownership to the University. Clearly identify each alternate proposal, and highlight how it differs from base bid requirements. Alternative selections should typically be chillers that provide the scheduled capacity but with improved energy performance, while otherwise fully complying to this specification. For each alternative proposed, provide complete submittal data.

EDIT SUBMITTAL PARAGRAPHS ACCORDING TO BASE BID AND ALTERNATE CONDITIONS.

1.4 SUBMITTALS:

A. Provide product data as follows:

1. Rated capacity, weight with and without refrigerant charge, furnished specialties and accessories.
2. Manufacturer's assembly type shop drawings indicating dimensions, required clearances; pipe connection types, locations and sizes; component assembly methods, support and vibration isolator details, marine water box details, and location and size of all field connections.
3. Impeller speed (RPM), number of bearings, type of bearings, high speed impeller shaft RPM, number of stages, number of sets of inlet guide vanes, type and amount of refrigerant charge (in pounds), and amount of oil required.
4. “A”-weighted sound pressure level and octave band sound pressure levels in accordance with AHRI Standard 575. Provide sound data in the format recommended by the AHRI Standard 575 Appendix D and E.
5. Manufacturer's wiring diagrams for interlock and control wiring, clearly identifying required field wiring.
6. AHRI-550/590 certified computerized selections, adjusted for zero capacity and zero NPLV tolerance. Provide capacity and NPLV performance selections at 100/75/50/25 percent load, with a condenser water temperature of 85°F at 100 percent load; 75°F at 75 percent; 65°F at 50 percent, and 65°F at 25 percent load; at the specified evaporator leaving water temperature and condenser/evaporator water flow rates and fouling factor allowances. Provide complete performance data at all selection points, to include all data required by AHRI-550/590 Minimum Data Requirements for Published Ratings.

STRIKE THE BELOW PARAGRAPH WHEN AN ECONOMIC ANALYSIS TABLE IS NOT BEING REQUESTED. IF SUCH A TABLE IS BEING REQUESTED, INCLUDE THE BLANK TABLE ON THE DRAWINGS OR AS A PART OF THIS SPECIFICATION.

7. Manufacturer shall complete and submit one Chiller Economic Analysis Table form for each base and alternate selection.
8. For open motors, provide curve showing motor heat loss versus chiller load.
9. Shipping, handling, and storage instructions.
10. Installation and start-up instructions.

11. Project specific maintenance and operating data, and recommended spare parts list.
12. Certification of compliance with ASME, UL, & ASHRAE fabrication requirements, specified elsewhere in these specifications.
13. Certified factory test results as specified in Part 2.
14. Confirmation that Coefficient of Performance (COP) for centrifugal chiller is not less than prescribed by ASHRAE 90.1.
15. Reports specified in Part 3.

1.5 QUALITY ASSURANCE:

A. Manufacturers and Products: The products and manufacturers specified in this Section establish the standard of quality for the Work. Subject to compliance with all requirements, provide specified products from the manufacturers named in Part 2.

B. Reference Standards: Products in this section shall be built, tested, and installed in compliance with the following quality assurance standards; latest editions, unless noted otherwise.

C. UL, CSA, ETL, or MET label for chiller electrical requirements.

D. ANSI/ASME SEC VIII Div. 1 Boiler and Pressure Vessel Code for construction and testing.

E. NFPA 70/NEC 2005

F. ANSI/NEMA 250 Enclosures for Electrical Equipment (1000 volts maximum).

G. ANSI/NEMA MG 1 Motors and Generators.

H. ANSI/ASHRAE 15 Safety Code for Mechanical Refrigeration.

I. ASHRAE 90.1-2007 Energy Standards for Low Rise Buildings Except Low Rise Residential Buildings

J. ANSI/AHRI: Standard 550/590 Performance Rating of Water Chilling Packages Using the Vapor Compression Cycle.

K. ANSI/AHRI 575 Method of Measuring Machinery Sound Within an Equipment Space

L. ANSI/AHRI 580 Non-Condensable Gas Purge Equipment For Use With Low Pressure Centrifugal Liquid Chillers

M. ASTM C 534 Specification for Preformed Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form.

IF THE CHILLER MUST BE DISASSEMBLED TO BE SET IN PLACE, PROVIDE INFORMATION ON THE DRAWINGS AND OTHER CONTRACT DOCUMENTS DESCRIBING DISASSEMBLY/REASSEMBLY REQUIREMENTS.

1.6 DELIVERY, STORAGE, AND HANDLING:

A. Ship the chiller with weather-protected wrap for storage outdoors. Protect control panels, pipe openings, and other sensitive components with heavy plastic or other durable means to ensure unit cleanliness is maintained during shipping and storage.

B. Provide rigging and installation instructions in advance to allow for planning.

TURN ON HIDDEN TEXT AND MAKE THE BELOW PARAGRAPH PROJECT SPECIFIC, IF IT APPLIES TO THE PROJECT. SEE RELATED PART 3 ARTICLE.

C. The chiller will require disassembly and reassembly to allow movement into final location. The chiller manufacturer shall provide all labor and supervision to disassemble and reassemble the chiller, including any rigging required for these operations. The installing contractor shall provide all rigging to move the chiller to the point of final assembly. The chiller manufacturer shall assemble the unit complete with holding charge, ready for piping and electrical connections.

1.7 WARRANTY

A. Provide a complete parts and labor warranty for a minimum of 1 year from the date of Substantial Completion. Warranty coverage shall include loss of refrigerant.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers:

1. York International by Johnson Controls
2. Trane Co.

2.2 CENTRIFUGAL PACKAGED CHILLER

A. Provide factory assembled, factory-tested, packaged, water cooled, centrifugal liquid chiller consisting of compressor, starter or variable speed drive as indicated, condenser, evaporator, built in purge system, refrigeration accessories, lifting lugs for servicing and installation, and factory-mounted instrument/direct digital control panel.

B. Provide chillers with complete oil and refrigerant charge.

C. Provide chiller vibration isolation.

D. All components listed above shall be provided by the chiller manufacturer.

2.3 PERFORMANCE REQUIREMENTS

A. Refer to schedules on Drawings for fundamental performance requirements. Also comply with the performance requirements specified in this Section.

1. Fouling Factor Allowance:
   a. Evaporator tubes: 0.00010 $h \cdot ft^{2} \cdot {}^{o}F/Btu$
   b. Condenser tubes: 0.00025 $h \cdot ft^{2} \cdot {}^{o}F/Btu$

DO NOT MODIFY TERMINOLOGY (E.G."NET REFRIGERATION CAPACITY") IN BELOW PARAGRAPH, INCLUDING CAPITALIZATION OF WORDS. THESE TERMS MATCH DEFINITIONS IN AHRI 550/590.

B. Rated in compliance with AHRI-550/590, zero Net Refrigeration Capacity, zero Total Power Input, and zero Energy Efficiency (kW/ton) tolerance.

C. All chiller selections shall be capable of unloading to 15 percent of design tonnage at 85°F entering condenser water temperature while maintaining surge-free, stable operation.

D. Maximum self-excited vibration velocity at compressor and motor bearings in the vertical, horizontal and axial directions shall not exceed, in any direction, 0.19 inches per second RMS over the entire chiller operating range.

2.4 COMPRESSOR

A. Single or multiple stage compressor, inlet guide vanes or multi stage capacity control guide vanes, shrouded aluminum alloy impellers designed and assembled for no critical speeds within operating range.

B. The compressor shall be dynamically balanced and overspeed tested to 120 percent of design speed.

2.5 EVAPORATOR AND CONDENSER

A. Carbon steel plate shells with carbon steel tube sheets and intermediate tube support sheets as required to prevent tube vibration and to allow replacement from either end of heat exchangers. Provide suitable baffles or distributing plates in condenser tubes to distribute refrigerant discharge gas on tubes evenly. Test refrigerant side under vacuum and test water side at minimum 225 psig.

B. Tubes shall be seamless copper internally and externally enhanced, individually cleanable and replaceable. Tubes shall be minimum 0.025 inches wall thickness and provide 0.050 inches tube wall thickness at the plain lands contacting the intermediate tube supports and end sheets. Expand ends of tubes in tube sheets with intermediate tube support for tight fit.

C. Evaporator and condenser water boxes shall be marine type (unless otherwise indicated)of fabricated steel with integral water connections bolted to shell of vessel, with vent and drain connections and hinged water box covers on both ends of the condenser and evaporator. Provide water piping stub outs with welded flanges for flanged connections.

D. Units with multi-stage compressors shall incorporate an inter-stage flash vessel "economizer." Units with single stage compressor shall have the condenser circuited for liquid sub-cooling and be provided with a thermometer well to monitor the amount of sub-cooling.

E. Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller shell to chiller shell or from chiller to a remote refrigerant storage/recycling system and to sense refrigerant pressure or temperature.

2.6 COMPRESSOR CASING AND SHELL FINISHES

A. Casing shall be fine grain cast iron with gasket sealed joints.

B. Factory applied paint, all exposed ferrous metal surfaces on assembled chiller. Minimum one coat of primer, minimum 2 mils dry film thickness (DFT). Final finish with two coats of air dried or baked alkyd enamel metal coating, minimum 4 mils total DFT. Two coats of matching, insulation compatible paint on all factory installed insulation.

C. Factory applied insulation. 3/4 inch minimum thickness for the evaporator water box, compressor motor, motor barrel, suction elbow and suction cover, 3/8 inch minimum thickness on economizer, 1/2 inch thick pipe insulation on liquid lines and all cold surfaces of chiller capable of forming condensation.

D. Insulation: Flexible, closed cell elastomeric insulation, meeting requirements of ASTM C534, conductivity of 0.30, water vapor permeability of 0.20. Materials shall have a flame spread index of less than 25 and a smoke-developed index of less than 50 when tested in accordance with ASTM E 84, latest revision.

E. Before insulating steel surfaces, prepare surfaces for paint and prime and paint as indicated for other painted components.

F. Seal seams and joints to provide a vapor barrier.

G. Acceptable product and manufacturer:

1. AP Armaflex by Armacell LLC, or equivalent.

2.7 COMPRESSOR LUBRICATION SYSTEM

A. Submerged pump and replaceable oil filter; complete with automatic oil heater designed to separate refrigerant from oil, site glass and oil cooler. System shall provide positive pressure lubrication of journals, bearing, and seals (if any), during start-up, operation and coast-down of chiller, including power interruptions.

2.8 PRESSURE RELIEF DEVICES

A. Comply with ASHRAE 15; provide rupture disc(s) or pressure relief device(s).

B. Additionally provide spring-loaded relief valve (s) (Trane Rupture-guard or York Vent-guard) to help contain refrigerant charge after an over-pressure event.

2.9 PURGE SYSTEM (R123 SYSTEMS ONLY)

A. Rated, tested, marking and nameplate data; meeting all conformance requirements of AHRI 580. To include purge tank with dryer elements and 115v/60/1 pump out compressor. Rated for no more than 0.0049 lb. of refrigerant per 1 lb. non-condensable at standard room conditions with condensing refrigerant temperatures greater than 80°F.

2.10 REFRIGERANT FLOW CONTROL DEVICES

A. Provide refrigerant flow control devices between evaporator and condenser (and as required elsewhere) to regulate refrigerant flow at volume and pressure required to maintain evaporator liquid refrigerant level sufficient to keep evaporator tubes adequately wetted through full range of chiller operation.

CHILLERS THAT ARE LOCATED ON SLAB ON GRADE DO NOT TYPICALLY REQUIRE SPRING ISOLATORS TO CONTROL VIBRATION TRANSMISSION TO THE BUILDING STRUCTURE. CONSULT WITH STRUCTURAL ENGINEER/VIBRATION CONSULTANT TO DETERMINE VIBRATION ISOLATION SYSTEM THAT IS REQUIRED. EDIT BELOW ARTICLE ACCORDING TO REQUIRED VIBRATION ISOLATION SYSTEM. BE SURE TO INDICATE ANY SUPPLEMENTAL STEEL REQUIREMENTS ON THE DRAWINGS AND TO INCLUDE THE VIBRATION CONTROL SPECIFICATION IF VIBRATION ISOLATION IS REQUIRED.

2.11 VIBRATION ISOLATION

A. Chiller manufacturer shall furnish vibration isolators of the type and performance specified in Related Section “Vibration Control.” Quantity, location, attachment method, and compatibility with the specific chiller provided shall be the responsibility of the chiller manufacturer.

B. Spring isolators shall be of the low profile “height saving” arrangement designed to minimize chiller height above finished floor.

C. When no vibration isolation is specified, provide neoprene pad isolators.

2.12 COMPRESSOR MOTOR AND ACCESSORIES

A. Continuous duty, squirrel cage, induction type, either hermetically sealed, refrigerant cooled or open drive/open drip proof, rated for operation at 460 volts, 3 phase, 60 Hz. Full load operation of the motor shall not exceed nameplate full load current rating or enter into the service factor. The first critical speed shall be above the operating speed. Provide for removal of the stator without breaking the main refrigerant piping connections. Provide RTD's or thermistors, one per phase, to monitor motor winding temperature.

B. Motors used with variable frequency drives shall be rated inverter duty and comply with NEMA MG-1 Part 31, with minimum insulation Class F and insulation temperature rise rating of Class B.

SELECT STARTER TYPE OR VARIABLE SPEED DRIVE FROM THE THREE SECTIONS BELOW. DELETE THE OTHER TWO SECTIONS. CONSULT WITH ELECTRICAL ENGINEER AND U-M DESIGN MANAGER TO DETERMINED WHICH STARTER TYPE OR IF A VSD IS APPROPRIATE FOR THE PROJECT. VARIABLE SPEED DRIVES ARE NORMALLY INSTALLED TO IMPROVE PART-LOAD EFFICIENCY. HIGH MAINTENANCE COST OF VSD'S HAS REOPENED THE ARGUMENT FOR CONSIDERING A STARTER IN LIEU OF VSD, ESPECIALLY IN MULTIPLE CHILLER PLANTS.

2.13 WYE DELTA STARTER

A. Unit mounted and pre-wired, wye-delta, closed-transition, reduced voltage type motor starter mounted in a NEMA 1 enclosure. The enclosure shall include a lockable hinged door with locking type retaining latches able to receive a padlock, and shall be UL labeled 508 compliant. Starter shall include a prewired pilot relay to initiate start sequence from the chiller controller, 4 contactors, motor overload protection and a 3 phase starting resistor/reactor bank.

B. The startup current draw shall be limited to 33 percent of locked rotor amps (LRA) for an adjustable time of 2 to 15 seconds minimum.

CONTACT ELECTRICAL ENGINEER AND SPECIFY BELOW THE SHORT CIRCUIT RATING REQUIRED FOR YOUR SPECIFIC PROJECT.

C. Starter shall have a 100,000 AIC short circuit withstand rating.

D. Provide 120 volt control power transformers to power chiller controller, purge system, oil system, and all other auxiliary equipment and controls.

E. The following motor protection features shall be integrated with the chiller controller:

1. Current phase loss
2. Current phase unbalance
3. Current phase reversal
4. Excessive acceleration time
5. Incomplete starting sequence
6. Over/Under line voltage
7. Motor current overload during start up and running
8. Momentary power loss protection with auto restart
9. Starter contactor fault protection
10. Starter transition failure

2.14 SOLID STATE STARTER

A. Unit mounted and pre-wired solid state type motor starter utilizing silicon controlled rectifiers, mounted in a NEMA 1 enclosure. The enclosure shall include a lockable hinged door with locking type retaining latches able to receive a padlock, and shall be UL labeled 508 compliant. Starter shall include a two-wire control input to initiate start sequence from the chiller controller.

B. The starter mode shall be closed loop, current limit control and shall provide a smooth acceleration of the motor without current transitions or transients. The following shall be user programmable:

1. Acceleration ramp time, 1 to 30 seconds minimum adjustment range.
2. Motor start current.
3. The starter shall provide transient voltage protection to the SCR's through RC snubbers and MOV's connected line-to-line and line-to-ground. High heat sink temperature protection shall also be provided

CONTACT ELECTRICAL ENGINEER AND SPECIFY BELOW THE SHORT CIRCUIT RATING REQUIRED FOR YOUR SPECIFIC PROJECT

C. Starter shall have a 100,000 AIC short circuit withstand rating.

D. Provide 120 volt control power transformers to power chiller controller, purge system, oil system, and all other auxiliary equipment and controls

E. Provide the following motor protection features:

1. Current phase loss
2. Current phase unbalance
3. Current phase reversal
4. Excessive acceleration time
5. Over/Under line voltage
6. Motor current overload during start up and running
7. Momentary power loss protection with auto restart

2.15 VARIABLE SPEED DRIVE

A. Unit mounted and pre-wired variable speed drive to adjust compressor motor speed automatically in conjunction with compressor vane position, to maximize part load efficiency. Drive shall be mounted in a NEMA 1 enclosure and UL labeled 508C

B. PWM type, utilizing IGBT’s with a power factor of 0.96 or higher at all loads and speeds.

C. Drive efficiency shall be 97 percent or higher at full load and full speed.

CONTACT ELECTRICAL ENGINEER AND SPECIFY BELOW THE SHORT CIRCUIT RATING REQUIRED FOR YOUR SPECIFIC PROJECT

D. Drive shall have a 65,000 AIC short circuit withstand rating.

E. Drive shall be insensitive to incoming power phase rotation and shall be capable of auto restart after a momentary power loss.

F. Provide 120 volt control power transformers to power chiller controller, purge system, oil system, and all other auxiliary equipment and controls

G. Variable speed drive shall include the following features:

1. Over-voltage and-under voltage protection; 3-phase sensing motor over-current protection, single phase protection, and over temperature protection

2. Digital readout at the chiller controller of output frequency, input voltage, 3-phase output current, input kilowatts, and self-diagnostic service parameters. Separate meters for this information will not be acceptable.
3. kW Meter - The unit's input power consumption shall be measured and displayed digitally via the chiller controller. The kW meter accuracy shall be +/- 3 percent of reading.
4. Ammeter – Simultaneous three-phase true RMS digital readout via the chiller controller. Three current transformers shall provide isolated sensing. The ammeter accuracy shall be plus or minus 3 percent of reading.
5. Voltmeter – Simultaneous three-phase true RMS digital readout via the chiller controller. The voltmeter accuracy shall be plus or minus 3 percent of reading.
6. Elapsed Time Meter – Digital readout of the unit's elapsed running time (0 – 876,600 hours, resettable) shall be displayed via the chiller controller.

HOSPITAL PROJECTS MAY REQUIRE AN "IEEE 519" STUDY THAT ADDRESSES HARMONIC CONCERNS RELATED TO THE ELECTRICAL SYSTEM AS A WHOLE (NOT JUST HARMONIC CONCERNS THAT ARE SPECIFIC TO ANY PARTICULAR PIECE OF EQUIPMENT). AE SHALL DISCUSS THIS POSSIBLE REQUIREMENT WITH THE HOSPITAL'S ASSIGNED DESIGN MANAGER.

H. At any VSD operating speed from 20% to 100%, current total harmonic distortion (THD) shall not exceed 100% of the VSD input current waveform, and voltage THD shall not exceed 3% of the VSD input voltage waveform, both as measured at the drive's incoming power connection lugs. Provide UL listed harmonic filter or power conditioner if required to guarantee these limits. Line reactors mounted external to the drive shall not be used. Filter/conditioner shall be unit mounted on the chiller. Manufacturer shall provide all wiring and conduit between filter, variable speed drive and motor.

2.16 CHILLER DISCONNECT SWITCH

THE ELEVATION OF THE DISCONNECT SWITCH INDICATED BELOW IS EXACTLY PER NATIONAL ELECTRIC CODE REQUIREMENTS AND WILL BE STRICTLY ENFORCED BY THE U-M INSPECTION DEPARTMENT. DURING DESIGN, VERIFY WHAT DISCONNECT HEIGHT IS AVAILABLE AS STANDARD WITH CHLR. MFR. AND MAKE DESIGN PROVISIONS ACCORDINGLY. FOR EXAMPLE, AN ELEVATED SERVICE PLATFORM MAY BE REQUIRED.

A. Provide a factory-mounted, prewired, NEMA heavy-duty rated, fused disconnect switch with the starter. The disconnect switch shall be lockable in the "off" position and shall serve as the single point of power connection to the chiller.

B. Configure the disconnect switch for top or side conduit entry. Provide line side lugs of the long barrel, two hole, compression type. Mechanical lugs are not acceptable.

C. Mount the disconnect switch to comply with NEC requirements. The distance from the finished floor to the center of disconnect handle grip in its highest position shall not exceed 6 feet 7 inches, inclusive of housekeeping pad and vibration isolator heights.

2.17 CHILLER CONTROLLER

A. Unit mounted pre-wired chiller controller mounted in a NEMA 1 enclosure, labeled by UL, CSA, ETL or MET. All external factory wiring shall be installed to minimize potential damage, and all power wiring, 110V and higher, shall be in a NEC compliant conduit system. Controller shall include an adjustable mounting system such that center of panel may be set at a maximum of 6 feet 6 inches above the finished floor, inclusive of housekeeping pad and vibration isolator heights.

B. The chiller controller shall automatically adjust compressor pre-rotation vane position, variable speed drive when provided, and other chiller systems to maximize part-load efficiency and to provide capacity control.

1. Capacity modulation shall be maintained within plus or minus 0.5°F of CHW set point, at entering condenser water temperatures as low as 65°F from full load to 15 percent load, without overshoot, hunting, surging, or cycling the machine off.

C. Provide the chiller controller with the required hardware and software for the following functions.

1. Safeties:
   a. Compressor starter failure detection
   b. Compressor start up, shut down sequences
   c. High compressor discharge temperature
   d. Surge detection and protection
   e. High lubricating oil temperature
   f. Low lubricating oil pressure
   g. High bearing temperature
   h. Evaporator and or condenser loss of flow
   i. High condenser pressure limit and high pressure cut out
   j. Evaporator low refrigerant temperature limit
   k. Low evaporator leaving fluid cut out
   l. Motor current limit, motor current overload
   m. High motor winding temperatures
   n. High vacuum operation limit
   o. Power loss, phase unbalance, phase loss, reverse rotation
   p. Over/under voltage
   q. Short cycling protection
2. Front panel display in clear English language and inch/pound units of the following:
   a. Operating mode run status
   b. Set point source or reset source
   c. Password protection security
   d. Evaporator freeze protection and low limit control data
   e. Evaporator leaving fluid set point
   f. Evaporator and condenser flow proof

g. Calculated chiller capacity (tons)
h. Compressor discharge temperature
i. Chiller starts and run-time counter
j. Entering and leaving evaporator water temperature
k. Entering and leaving condenser water temperature
l. Saturated condenser temperature and pressure
m. Saturated evaporator temperature and pressure
n. Bearing or bearing oil temperatures
o. Lubricating oil temperature and pressure
p. Current limit or demand limit
q. Phase voltage and current
r. Motor winding temperature
s. Power demand (kW) and power factor
t. Purge compressor suction temperature (R123 machines only)
u. Purge pump out rate (R123 machines only)
v. Purge pump out time last or current cycle (R123 machines only)
w. Total purge pump out time (R123 machines only)
x. Total purge run time (R123 machines only)

3. DDC Control Inputs:
   a. Remote Start/Stop
   b. Chilled water temperature set point reset
4. Binary Outputs:
   a. Evaporator Pump Relay
   b. Condenser Pump relay
   c. Chiller Running Relay
   d. Alarm Relay (manual reset required)

D. The controller shall provide an output signal to the Owner’s DDC system for controlling condenser water temperature to maximize chiller operating efficiency while maintaining proper refrigerant head pressure at all times. Provide in the chiller controller a 4 to 20 mA or 0 to 10 volt output signal to allow Owner’s DDC system to reset condenser water temperature via cooling tower fan speed control and tower bypass valve modulation while maintaining proper chiller refrigerant head pressure.

E. Provide an ON-OFF-AUTO rocker switch on the front of the controller panel to allow local control or remote control of the start/stop function by Owner’s DDC system. When switch is set to ON or OFF positions, the remote start or stop signal from the Owner’s DDC shall be ignored. If turning the chiller on or off at the chiller control panel interface accomplishes the same thing, an ON-OFF-AUTO rocker switch is not required.

F. Provide factory installed and pre-wired proof-of-flow switches that confirm flow thorough the evaporator and condenser to the chiller control panel. Alternatively, provide United Electric Model J21K-14829 differential pressure switches for field installation to prove evaporator and condenser water flows.

THE BELOW ARTICLE (IN HIDDEN TEXT) CONTAINS SAMPLE LANGUAGE FOR VARIABLE PRIMARY FLOW (VPF) CONTROL. THE ADDITIONAL FEATURES TO PROVIDE ACCURATE CONTROL ON VPF SYSTEMS IS AN OPTION ON CHILLERS AS OF MARCH 2011.

G. Variable Primary (Evaporator) Flow Compensation

1. The controller shall provide accurate and stable response to changes in evaporator water flow rate. The control algorithm shall automatically adjust the control gain (and/or other control parameters) to maintain leaving chilled water temperature within +/- 0.5°F of set point at flow rate variations up to 25% change per minute, and within +/- 2°F of set point at flow rate variations up to 50% per minute.
2. Include factory mounted transducers to read differential evaporator water pressure and differential condenser water pressure, and any other necessary parameter.
3. The controller shall display the following additional data:
   a. Evaporator differential pressure
   b. Condenser differential pressure
   c. Evaporator water flow rate
   d. Condenser water flow rate
   e. Evaporator capacity (tons)

IF THE PROJECT INVOLVES THE PURCHASE OF MULTIPLE CHILLERS OF THE SAME TYPE AND SIZE, CONSIDER REVISING THE BELOW TO ONLY REQUIRE A FACTORY TEST ON ONE OF EACH TYPE AND SIZE.

2.18 SOURCE QUALITY CONTROL

A. Chiller shall be factory performance tested in an AHRI certified test facility per AHRI standard 550/590. Factory test instrumentation calibration shall be traceable to the National Institute of Standards And Technology.

1. Chiller shall be tested at the following load/condenser water temperature conditions, at the specified evaporator leaving water temperature and condenser/evaporator water flow rates and fouling factor allowances:
   a. No Chiller Economic Analysis Table Requested: 100 percent/85°F, 75 percent/75°F, 50 percent /65°F, 25 percent /65°F, 15 percent/85°F.
   b. Chiller Economic Analysis Table Requested: At any four loads and conditions indicated in the table, as selected by the Owner, and at 15 percent/85°F.

B. Factory vibration test to demonstrate compliance to vibration performance requirements.

C. The Owner’s Representative shall be allowed to witness the factory testing. An officer of the manufacturer’s company shall certify by signature that the factory tests were performed as specified, the report accurately reflects the test results, and that the chiller met or exceeded all performance requirements. The report shall clearly identify any performance requirements that were not achieved.

DO NOT MODIFY TERMINOLOGY (E.G."NET REFRIGERATION CAPACITY") IN BELOW PARAGRAPH, INCLUDING CAPITALIZATION OF WORDS. THESE TERMS MATCH DEFINITIONS IN AHRI 550/590

D. The equipment will be accepted by the Owner if the manufacturer’s certified test results are provided and the equipment met or exceeded all performance requirements (zero Net Refrigeration Capacity, zero Total Power Input, and zero Energy Efficiency (kW/ton) tolerance).

PART 3 - EXECUTION

3.1 EXAMINATION, STORAGE, AND PREPARATION

A. Upon delivery, validate holding charge and that integrity of the delivery protection has been maintained, the chiller is undamaged, and all accessory parts were delivered. Reject damaged chillers. Verify that center of disconnect and chiller control panel height will be a maximum of 6 feet 7 inches above the finished floor, inclusive of housekeeping pad and vibration isolator heights. Restore protection. Provide a delivery report indicating chiller condition to the Owner’s Representative.

B. Rig units off delivery trucks. Comply with Manufacturer's rigging instructions.

C. Move all refrigerant or oil supplied by the manufacturer to a location next to the chiller and contact the Owner's Representative to inform them of the amount and type of refrigerant and oil delivered.

D. Store units protected from weather, dirt, water, construction debris, and physical damage. Support stored units at points as required by manufacturer.

E. Verify during storage that unit refrigerant or nitrogen holding charge levels are being maintained. Record the charge pressure and ambient temperature weekly and provide report to Owner’s Representative. Take immediate action under the supervision of the manufacturer to restore any significant reduction in charge pressure level.

F. Examine chillers before installation. Validate holding charge has been maintained and that the chiller is undamaged. Provide a pre-installation report indicating chiller condition to the Owner’s Representative.

G. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.

1. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

H. Rig units into final locations. Comply with Manufacturer's rigging instructions. Conduct a pre-installation conference to review rigging and installation requirements with all parties involved.

TURN ON HIDDEN TEXT AND MAKE THE BELOW ARTICLE PROJECT SPECIFIC, IF IT APPLIES TO THE PROJECT.

3.2 CHILLER ASSEMBLY

A. The chiller will require disassembly and reassembly to allow movement into final location. The chiller manufacturer shall provide all labor and supervision to disassemble and reassemble the chiller, including any rigging required for these operations. The installing contractor shall provide all rigging to move the chiller to the point of final assembly. The chiller manufacturer shall assemble the unit complete with holding charge, ready for piping and electrical connections.

3.3 CHILLER INSTALLATION

A. Install the chiller in strict compliance with manufacturer's installation instructions and Related Sections. Maintain manufacturer's recommended clearances for service and maintenance.

B. Install chiller on support structure or concrete base as indicated. Install the specified vibration isolation, furnished by the chiller manufacturer, in strict compliance with chiller manufacturer’s directions.

C. Provide connection-size ball valves with threaded hose end connections at all water vent and drain connections on the evaporator and condenser, whether indicated on Drawing details or not.

D. Install relief vent piping in strict accordance with chiller manufacturer's recommendations.

E. Adjust chiller control panel so that center of panel is set at maximum of 6 feet 7 inches above finished floor, inclusive of housekeeping pad and vibration isolator heights.

F. Install separate devices furnished by manufacturer and not factory installed.

G. Repair all damaged insulation to factory equivalent.

H. Repair scratches to factory equivalent finish, using chiller manufacturer provided paint.

I. Complete the manufacturer’s pre-start checklist and submit it for scheduling of the manufacturer’s field startup technician.

3.4 COMMISSIONING

A. Perform the commissioning activities as outlined in Related Section “Commissioning” and other requirements of the Contract Documents.

3.5 SYSTEM STARTUP

A. Manufacturer shall provide a factory-trained representative for the time required to complete start-up, commissioning, and testing each chiller. This service shall be provided on days and at times required to meet the construction schedule and/or project phasing requirements, at the complete discretion of the Owner's representative, without additional charges. There shall be no time limit on this service, but shall be the time required to bring the unit to proper operation. This service must include all necessary written and verbal instructions to U of M operating personnel. The manufacturer's factory-trained representative shall:

1. Verify correct installation and organize, instruct and assist the mechanical contractor's personnel in start-up procedures.
2. Fill chiller with oil if not factory installed, and charge the chiller with refrigerant.
3. Verify all pre-start checks. Start-up the chiller, set controller parameters, make field adjustments, refrigerant balance the chiller, verify proper chiller operation. Assist Owners personnel with proper set-up of remote control operation of the chiller. Provide a written report after each visit, prior to leaving.
4. Participate in the commissioning of the chiller to the extent required by the project Commissioner.

B. If the initial start-up and machine trim is accomplished under chiller load condition of less than 100 percent load, the manufacturer's representative shall return to the job site and re-adjust the machine during 100 percent load conditions at no additional cost.

C. The manufacturer representative's written report shall include complete data on all services provided, and document all programmed settings as well as the amount of refrigerant and other fluids installed, both from the factory and in the field during startup.

3.6 OWNER TRAINING

A. Manufacturer's factory-trained representative shall train Owner's maintenance personnel on start-up and shutdown procedures, trouble-shooting, vibration test locations, service schedules, and preventative maintenance procedures, minimum of 8 hours. Review with Owner's personnel, the data contained in the Operating and Maintenance Manuals.

B. Schedule training with Owner through the Architect/Engineer with at least 7 days prior notice. Training and start up services are separate functions and training shall not be combined with startup services.

3.7 FIELD QUALITY CONTROL

A. Chiller manufacturer shall perform vibration testing. Measure at compressor and motor bearings in the vertical, horizontal and axial directions, to demonstrate compliance with Part 2 vibration performance requirements. Permanently label the location where each vibration measurement was taken with a unique identification number.

B. Provide report to owner within 1 week of testing. Include diagram of chiller with measurement points labeled to match field labels.

C. The Chiller manufacturer shall make corrections and retest if it is determined the cause of excess vibration is due to defective equipment. The Installing contractor shall make corrections and pay for a chiller mfr. retest if it is determined the cause of excess vibration is improper installation.

END OF SECTION 236416