**SECTION 23 64 15**

**WATER COOLED CHILLERS**

**BASED ON DFD MASTER SPECIFICATION DATED 12/20/2017**

***This section has been written to cover most (but not all) situations that you will encounter. Depending on the requirements of your specific project, you may have to add material, delete items, or modify what is currently written. The Division of Facilities Development expects changes and comments from you.***

**P A R T 1 - G E N E R A L**

**SCOPE**

This section includes specifications for ***(centrifugal/rotary screw)*** water chillers. Included are the following topics:

PART 1 - GENERAL

Scope

Related Work

Reference

Reference Standards

Quality Assurance

Performance Requirements

Operating Sound Pressure Level

Submittals

Operation and Maintenance Data

Delivery, Storage and Handling

Warranty

PART 2 - PRODUCTS

Manufacturers

Manufactured Units

Compressors

Evaporator

Condenser

Insulation

Pumpout and Storage System

Purge System

Controls

Starter

Variable Frequency Drive

Vibration Isolation

Factory Performance Test

Refrigerant Monitors

PART 3 - EXECUTION

Installation

Startup

Construction Verification Items

Functional Performance Testing

Agency Training

**RELATED WORK**

Section 01 91 01 or 01 91 02 – Commissioning Process

Section 23 05 00 - Common Work Results for HVAC

Section 23 05 13 – Common Motor Requirements for HVAC Equipment

Section 23 05 48 - Vibration and Seismic Controls for HVAC Piping and Equipment

Section 23 08 00 – Commissioning of HVAC

Section 23 32 13 – Hydronic Piping

Section 23 09 23/24 – Direct Digital Control for HVAC

Section 23 09 93 - Sequence of Operations for HVAC Controls

**REFERENCE**

Applicable provisions of Division 1 shall govern work under this section.

***This section has been written to cover most (but not all) situations that require applicable referenced standards. The specification writer can add the latest version number or a specific version if needed for a particular project.***

**REFERENCE STANDARDS**

AHRI 550/590-2003 Centrifugal or Rotary Screw Water-Chilling Packages

AHRI 575 Method of Measuring Machinery Sound Within an Equipment Space

ASHRAE 15 Safety Code for Mechanical Refrigeration

ASHRAE 90.1-2013 Energy Standard for Building except Low Rise Residential Buildings

ASME SEC 8 Boiler and Pressure Vessel Code

NEMA MG1 Motors and Generators

UL 1995 Central Cooling Air Conditioners

DSPS 345 Wisconsin Department of Safety and Professional Services Mechanical Refrigeration Code

**QUALITY ASSURANCE**

Refer to division 1, General Conditions, Equals and Substitutions.

Construct, test and rate chiller performance in accordance with AHRI 550 with exceptions as noted in this specification.

Construct, install and operate chillers in accordance with ANSI/ASHRAE 15- Safety Code for Mechanical Refrigeration and DSPS 345 Wisconsin Mechanical Refrigeration Code.

Construct and test chillers in accordance with ASME SEC 8.

Construct and label chillers in accordance with UL 1995.

**PERFORMANCE REQUIREMENTS**

***The following paragraphs give guidance to the designer for the performance requirement guidelines the State of Wisconsin must follow. The designer is encouraged to review the reference standards and comply with the latest version. The standards are the Federal Energy Management Program (FEMP) recommended efficiencies and ASHRAE Standard 90.1-2013.***

***Minimum performance of positive displacement(screw) chillers (less than 75 tons )selected and applied at standard AHRI Conditions shall meet the performance of 0.75 kW/Ton for design capacity and an IPLV of 0.63 kW/ton or 0.80 kW/Ton for design capacity and an IPLV of 0.60 kW/ton based on the FEMP energy recommendations.***

***Minimum performance of positive displacement(screw) chillers (75 to 149 tons )selected and applied at standard AHRI Conditions shall meet the performance of 0.71 kW/Ton for design capacity and an IPLV of 0.61 kW/ton or 0.79 kW/Ton for design capacity and an IPLV of 0.51 kW/ton based on the FEMP energy recommendations.***

***Minimum performance of positive displacement(screw) chillers (150 to 299)selected and applied at standard AHRI Conditions shall meet the performance of 0.68 kW/Ton for design capacity and an IPLV of 0.58 kW/ton or 0.72 kW/Ton for design capacity and an IPLV of 0.50 kW/ton based on the FEMP energy recommendations.***

***Minimum performance of positive displacement(screw) chillers (greater than 300 tons) selected and applied at standard AHRI Conditions shall meet the performance of 0.58 kW/Ton for design capacity and an IPLV of 0.54 kW/ton or 0.64 kW/Ton for design capacity and an IPLV of 0.48 kW/ton based on the FEMP energy recommendations.***

***Minimum performance of centrifugal chillers (between 150 and 300 tons) selected and applied at standard AHRI Conditions shall meet the performance of 0.59 kW/Ton for design capacity and an IPLV of 0.60 kW/ton or 0.64 kW/Ton for design capacity and an IPLV of 0.35 kW/ton based on the FEMP energy recommendations.***

***Minimum performance of centrifugal chillers (300 to 599 tons) selected and applied at standard AHRI Conditions shall meet the performance of 0.56 kW/Ton for design capacity and an IPLV of 0.55 kW/ton or 0.60 kW/Ton for design capacity and an IPLV of 0.36 kW/ton based on the FEMP energy recommendations.***

***Minimum performance of centrifugal chillers (600 tons and greater) selected and applied at standard AHRI Conditions shall meet the performance of 0.55 kW/Ton for design capacity and an IPLV of 0.40 kW/ton or 0.57 kW/Ton for design capacity and an IPLV of 0.35 kW/ton based on the FEMP energy recommendations.***

***Chillers selected and applied at standard AHRI conditions will be factory tested at standard AHRI conditions.***

***Chillers selected and applied at non-standard conditions must meet efficiency requirements in ASHRAE standard 90.1-2013Table 6.8.1-3 (water-chilling packages-efficiency requirements) and 6.4.1.2 (minimum equipment efficiencies-listed equipment-nonstandard conditions). In addition, the selected/applied chiller must also be selected for standard AHRI conditions and meet the efficiency requirements listed above for the FEMP energy recommendations when selected at standard AHRI conditions. A chiller applied at nonstandard conditions should be factory tested at those nonstandard conditions but not at standard conditions.***

[Submit the following performance documentation within 24 hours of being informed of being the apparent low bidder]

***Include the above line if the chiller is being pre-purchased directly by the state.***

***Include the following performance information if the chiller is pre-purchased only. Do not include performance information in this specification section if the chiller is to be purchased by the Contractor. Include the DFD Master Chiller Schedule on the drawings if the chiller is to be purchased by the Contractor.***

 Design Submitted

 Design Capacity Tons(1) \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_

 Design capacity kW/Ton (2) \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_

 [NPLV kW/Ton][IPLV kW/Ton](2) \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_

 Minimum Continuous Operating Point % \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_

 Leaving Chilled Water Temperature \_\_\_\_\_\_\_\_\_\_oF \_\_\_\_\_\_\_\_\_\_oF

 Return Chilled Water Temperature \_\_\_\_\_\_\_\_\_\_oF \_\_\_\_\_\_\_\_\_\_oF

 Evaporator GPM \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 Maximum Evaporator Pressure Drop \_\_\_\_\_\_\_\_\_\_FT \_\_\_\_\_\_\_\_\_\_FT

 Evaporator Fouling Factor 0.0001 hr sq ft F/Btu \_\_\_\_\_\_\_\_\_\_\_\_

 Leaving Condenser Water Temperature \_\_\_\_\_\_\_\_\_\_oF \_\_\_\_\_\_\_\_\_\_oF

 Entering Condenser Water Temperature \_\_\_\_\_\_\_\_\_\_oF \_\_\_\_\_\_\_\_\_\_oF

 Minimum Condenser Operating Temperature(3) \_\_\_\_\_\_\_\_\_\_oF \_\_\_\_\_\_\_\_\_\_oF

 Condenser GPM \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_***\_***

 Maximum Condenser Pressure Drop \_\_\_\_\_\_\_\_\_\_FT \_\_\_\_\_\_\_\_\_\_FT

 Condenser Fouling Factor 0.00025 hr sq ft F/Btu \_\_\_\_\_\_\_\_\_\_\_\_

 Voltage/Hertz/Phase \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 Maximum Assembled Chiller Dimensions \_\_ lg x \_\_ hi x \_\_ wi \_\_\_\_\_\_\_\_\_\_\_\_

(1) Tons must be the net cooling output after deducting cooling required for chiller auxiliaries (oil cooler, purge, sound attenuation, etc.).

(2) kW/Ton or NPLV must be the total electrical consumption including all auxiliaries (including but not limited to motor starters, variable speed drives, oil heaters, etc.) required during normal operation.

(3) Chillers shall be able to operate continuously at this condition in accordance with AHRI standards. This operation shall be throughout the specified operating range (minimum load to design capacity tons).

**OPERATING SOUND PRESSURE LEVEL**

The unit shall operate at full load and all part load conditions without exceeding ***(85-dBA)*** sound pressure level in the equipment room. If units do not meet the ***(85-dBA)*** requirements, as measured in accordance with latest version AHRI Standard 575, furnish all attenuation devices necessary to meet this requirement. The sound pressure levels in all octave bands must be met as scheduled for full load and part load conditions.

 ***Modify the sound pressure level requirements based on the specific project needs.***

**SUBMITTALS**

Refer to division 1, General Conditions, Submittals

Submit chiller [and pumpout system] shop drawings including the following information: specific manufacturer and model numbers, dimensional and weight data, required clearances, materials of construction, capacities and ratings, minimum load achievable without hot gas bypass, pressure ratings, refrigerant charge, pumpout refrigerant storage capacity, component information, assembly information, size and location of piping connections, electrical connections, wiring diagrams, motor information (ref. 23 05 13), surfaces requiring insulation, SqFt of surface insulation, sound pressure levels in all octave bands at 25%/50%/75%/100% load, information for all specialties and accessories.

Include an AHRI approved chiller selection method for the specified refrigerants.

Indicate ASME construction and stamping of pressure vessels or unit physical characteristics and ASME code section and paragraph references that allow non-compliance with this construction and stamping requirement.

Factory certified test data must be provided to the Engineer for approval prior to shipping of chillers. Chillers shipped without approval will not be accepted. Submit Four (4) complete reports. Distribution of test reports will be:

Division of Facilities Development

BAE-Mechanical Team

101 East Wilson Street, 7th floor

Madison, WI 53703

One (1) copy

 [Others as defined by A/E]

***One A/E copy should be retained by the A/E for his/her use. Since the A/E is responsible for the system design, as reflected in the contract documents, the A/E will be expected to review, evaluate and comment on the contents of the report and to assist in the correction of any problems encountered.***

***Increase quantities of submittals during the editing process if necessary.***

Reports shall include the following information as a minimum:

1. Title Page with Project Name, DFD Project No., Date of Test
2. Report Certificate with Project Name, DFD Project No., Chiller Model Number, Chiller Serial Number, Test Date, Signature, Date of Signature, Printed Name of Company Officer, Title of Company Officer
3. Test Design Criteria (Submitted Data)
4. Test Performance at 100%
5. Test Performance at 75%
6. Test Performance at 50%
7. Test Performance at 25%
8. Test Performance at minimum (Minimum must be held over 15 minutes)
9. Test Data shall provide as a minimum the data outlined in Section C5 of AHRI 550/590
10. Test Instrumentation shall be certified in accordance with Section C4 of AHRI 550/590
11. Chiller vibration measurements
12. Chiller tube information including quantity, tube wall thickness, material, diameter, length (include a chiller submittal if it has the required information)

Submit manufacturer's installation and start-up instructions, maintenance data, troubleshooting guide, parts lists, controls and accessories.

At substantial completion, submit warranty certificate and copy of start-up report.

# OPERATION AND MAINTENANCE DATA

All operations and maintenance data shall comply with the submission and content requirements specified under section GENERAL REQUIREMENTS.

***Delete the following if there are no additional requirements.***

In addition to the general content specified under GENERAL REQUIREMENTS supply the following additional documentation:

1. ***[A/E and commissioning provider to define detailed operation and maintenance data requirements for equipment specifications added to this section.]***

**DELIVERY, STORAGE AND HANDLING**

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

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

Shipping of the chillers to the project and unloading shall be the responsibility of the chiller manufacturer. Deliver chillers to the project by ***(month/day/year)***. The chiller manufacturer is responsible for coordinating delivery and unloading time and location with the installing Mechanical Contractor.

The above paragraph applies to projects where the chiller is bid separate from the installation. Delete the above paragraph if chiller and installation are bid together.

The maximum allowable dimensions of a single piece, factory assembled chiller is \_\_ long x \_\_ high x \_\_ wide. Chillers that exceed these maximum dimensions shall include the cost of shell and/or compressor doweling in the chiller manufacturer's bid to meet these dimension requirements. The chiller manufacturer shall provide the services of a factory trained and authorized refrigeration mechanic to supervise the disassembly and reassembly of the chiller that will be done by the installing mechanical contractor. The chiller manufacturer shall be responsible for the removal, storage and replacement of all refrigerant and oil charge in the chiller to accommodate disassembly and reassembly of the chiller for installation. If the refrigerant charge is separate from the machine, the chiller manufacturer shall be responsible for shipping and receiving the refrigerant and charging the chiller.

If a chiller is bid separate from installation, plan sufficient time between the bids to allow the installation documents to reflect the scope of disassembly and reassembly required.

If a chiller needs to be disassembled for installation, add the following paragraph.

The chiller manufacturer, at its option and expense, can assemble the complete chiller for testing and verification and then disassemble the chiller into components that can be shipped and rigged into place. All components must be sealed and leak free with a nitrogen holding charge prior to shipping. The chiller manufacturer shall provide the services of a factory trained and authorized refrigeration mechanic to supervise the reassembly of the chiller that will be done by the installing mechanical contractor. The chiller manufacturer shall be responsible for the removal, storage and replacement of all refrigerant and oil charge in the chiller to accommodate disassembly and reassembly of the chiller for installation. If the refrigerant charge is separate from the machine, the chiller manufacturer shall be responsible for shipping and receiving the refrigerant and charging the chiller.

**WARRANTY**

Provide a one year all-inclusive warranty to begin upon acceptance of project by owner.

Provide an additional four (4) year material and labor warranty extension for compressor motor, compressor assembly and unit controls.

**PART 2 - PRODUCTS**

**MANUFACTURERS**

Carrier, Trane, York or McQuay.

**MANUFACTURED UNITS**

Provide factory assembled and tested, packaged, water-cooled, liquid chiller consisting of ***(centrifugal/rotary screw)*** ***(single/dual)*** compressor(s), compressor motor, condenser, evaporator, refrigeration accessories, instrument and control panel, gages and indicating lights, auxiliary components and accessories, ***(reduced voltage/autotransformer/wye-delta closed transition ,variable frequency drive, solid state)*** motor starter.

Acceptable refrigerants are R-514a and R-134a.

Firmly attach metal nameplates to major components indicating the name of the manufacturer, unit model number, compressor/condenser/cooler type, refrigerant used, pounds of refrigerant needed for normal operation, operating pressures, and unit serial number.

**COMPRESSORS**

Compressor assembly shall be run tested at the factory. Vibration shall not exceed 1.0 mil peak to peak. Over-speed test compressor impeller(s) to not less than 20% above operating conditions.

 Provide compressors with ***(pre-rotation vanes or slide valve)*** for modulating capacity control from 100% down to ***(15%)*** of full load without the use of hot gas bypass.

***Modify the % minimum operation based on the actual chiller selections used for the basis of design. Verify that multiple manufacturers can meet the minimum operating conditions specified. If the project conditions require a very low minimum operating condition, then discuss allowing hot gas bypass with DFD engineer.***

 **EVAPORATOR**

 Provide a shell and tube evaporator, seamless or welded steel construction with cast iron or fabricated steel heads, marine water box with flanged connections perpendicular to shell ***(marine water box required 500 tons and larger, optional on smaller)***, seamless copper tubes with integral fins and a minimum tube wall thickness of .028 inches measured at the root of fin or enhancement, rolled into tube sheets and trimmed within 0.067 inches with end tube sheets.

 Design, test, and stamp refrigerant side for 180 psig (R-134A) or 30 psig (R-514a) working pressure and water side for 150 psig working pressure, in accordance with ASME SEC 8.

 Provide thermometer wells for temperature controller and low temperature cutout.

 Provide refrigerant chambers with baffles to distribute entering liquid and separate liquid from leaving gas.

Provide a pressure relief device, factory rated and factory installed per all applicable codes, with alarm contacts for indicating loss of refrigerant, on shell in accordance with ASHRAE 15. Chillers utilizing low-pressure refrigerants shall include a back-up reseating pressure relief valve for each rupture disc. Chillers utilizing medium-pressure refrigerants shall include a reseating pressure relief valve.

**CONDENSER**

 Provide shell and tube condenser, seamless or welded steel construction with cast iron or fabricated steel heads, marine water box with flanged connections perpendicular to shell ***(marine water box required 500 tons and larger, optional on smaller)***; seamless copper tubes or red brass tubes with integral fins minimum tube wall thickness of .028 inches measured at the root of fin or enhancement, rolled into tube sheets and trimmed within 0.067 inches with end tube sheets. Space tube support sheets approximately 2.5 feet.

 Design and stamp refrigerant side for 180 psig (R-134A), 30 psig (R-514a) working pressure. Design, test and stamp water side for 150 psig working pressure. Design, test and stamp in accordance with ASME SEC 8.

 Provide relief valve on shell in accordance with ASHRAE 15.

 Provide baffles to ensure even distribution of incoming gas and to concentrate non-condensable gases.

**INSULATION**

3/4”thick, flexible closed cell elastomeric foam insulation; minimum nominal density of 5.5 lbs. per cu. ft., thermal conductivity of not more than 0.27 at 75 oF, minimum compressive strength of 4.5 psi at 25% deformation, maximum water vapor transmission of 0.17 perm inch, maximum water absorption of 6% by weight, rated for service range of -20 oF to 180 oF.

 Factory insulate the following:

 - Evaporator shell and heads

 - Suction elbow

 - Economizer

 - Motor housing (hermetic compressors)

 - Motor cooling lines (hermetic compressors)

 - All lines and surfaces 65oF or colder

 **PUMPOUT AND STORAGE SYSTEM**

***Modify this portion of the specification after consulting with the facility and DFD. Many facilities may already have this capability from previous projects. Designer should verify that facility has space availability for storage device and proper room alarm, ventilation, signage, etc. as required by ASHRAE 15 or applicable code.***

For chillers with 1000 pounds or more of refrigerant, provide a separate and independent pumpout and storage system. System shall meet the requirements of ANSI/ASHRAE l5-(latest version) which includes a condenser, vacuum pump(s)/compressor(s), storage tank(s), rupture disk/relief valve, electric heater if necessary for proper operation , filter drier, safety devices and all required instrumentation, suitable for use with the refrigerant provided with the chiller.

Condenser may be air-cooled or water-cooled. If water-cooled, provide assembly with shutoff valve on the inlet water connection and balancing valve on the outlet water connection.

Vacuum pump(s)/compressor(s) to be capable of producing a vacuum which meets or exceeds the required pump down standard as established by the EPA Clean Air Act for the refrigerant used, have a free air capacity not less than 3.0 cubic feet per minute, and be capable of discharging against a pressure appropriate for the refrigerant used in the system.

Provide a storage tank for permanent installation of sufficient capacity to contain the entire refrigerant charge of the chiller in this specification when 90% full at 90 oF. The tank shall be constructed for an operating pressure suitable for the refrigerant pressures involved, but not less than 45 psig. Furnish with a rupture disk or relief valve properly sized for the specific application.

Provide assembly with integral operating controls, safety devices and instrumentation that are factory piped and/or wired to allow safe operation. When installed and operated in accordance with the manufacturer’s instructions, unit shall provide recycled refrigerant with moisture and contaminant levels which meet the manufacturer’s specifications for the refrigerant used in the chiller assembly.

**PURGE SYSTEM**

 Low Pressure Chillers:

Provide a purge system incorporating a low temperature refrigeration system to automatically remove non-condensables, water and air.

System discharge shall be maximum 0.049 pound of refrigerant per pound of air discharged. Purge unit shall use a non-CFC refrigerant.

Any excess purge requirement shall enable an alarm indication light at the chiller unit control panel. A contact closure at the purge unit shall be provided for a remote alarm and a diagnostic with date and time of occurrence shall be stored in the chiller unit control panel’s diagnostic memory.

 **CONTROLS**

 Provide fully automatic microprocessor controller in a lockable steel control panel containing solid state chiller operating and safety controls. Factory mount, wire and test controls on chiller. Operating set points and diagnostic procedures to be programmed through a color-coded, tactile-feel keypad. Provide an alphanumeric display showing all system parameters, safety and cycle shutdowns in the English language with numeric data in English units. Safety and cycle shutdown display to consist of date, time, cause of shutdown, and type of restart required.

 Provide the following safety controls arranged so that activation of any one will shut down chiller and require manual reset:

 Low evaporator refrigerant temperature

 High condenser refrigerant pressure

 Low oil pressure

 High oil pressure

 High oil filter pressure differential

 High oil temperature

 High motor current

 High motor temperature

 High compressor discharge temperature

 Motor controller fault

 Low refrigerant (evaporator) pressure

 High bearing temperature

 Low safety chilled water temperature

 Low chilled water flow

 Low condenser water flow

 Sensor malfunction

Provide the following cycling shutdown controls with automatic reset:

 Low operating chilled water temperature

 Power fault

 Internal time clock

 Anti-recycle

Provide the following operating controls:

 Leaving chilled water temperature control and reset

 Variable timers to prevent compressor short cycle

 Automatic start which determines demand for chilled water from proof of chilled water flow and temperature differential between chilled water set point and supply temperature

 Percent current limit

 Pulldown demand limiting

The front of the chiller control panel shall display the following including the discrete external point connections, in clear language, without the use of codes, look-up tables, or gauges.

 Compressor starts and run time

 Compressor motor winding temperature(s). (Hermetic compressors)

 Purge compressor suction temperature

 Excessive purge operation

 Chilled water setpoint and setpoint source

 Electrical current limit setpoint and setpoint source

 % RLA

 Chiller diagnostics including a time and date of occurrence (minimum 20 historic diagnostics stored in non-volatile chiller panel memory)

 Differential oil pressure

 Compressor motor voltage and amperes, by phase

 Compressor discharge temperature

 Chilled water entering and leaving temperatures

 Condenser water entering and leaving temperatures

 Evaporator and condenser refrigerant pressures

 Evaporator and condenser saturation temperatures

Provide the following terminal connections for discrete input and output points as listed below:

 Digital inputs:

 Enable/disable chiller

 Digital outputs:

 Start/stop chilled water pump

 Start/stop condenser water pump

 Start/stop cooling tower fan(s) (if required to be by chiller in 23 09 93 sequence of operation)

 Analog Outputs:

 Cooling tower bypass valve modulation (if required to be by chiller in 23 09 93 sequence of operation)

 Analog Inputs:

 Demand Limiting

 Supply Temperature Reset

***Verify whether integration with the direct digital energy management system is required.  If requested by agency, discuss with DFD to determine protocol type and for approval.   If integration is desired, and the DDC controls are known (the project is utilizing Section23 09 24 negotiated control specification), modify the following specification section to address the requirements of the specific DDC system - select the appropriate protocol and connection type.  Specify integration is required in the General section of the 23 09 93 specification.  If the DDC system is open bid, utilize an open protocol such as BACnet and coordinate this specification with the Section 23 09 23 specification.  If integration is not to be provided, delete the following paragraph and points listing.***

The chiller control panel shall convert information into the [BACnet MSTP] [BACnet/IP] [LonWorks] [Johnson Controls N2 (RS-485)] [Other] protocol that will be compatible with the building direct digital control system (DDC) as specified in Section 23 09 23 or 23 09 24.  This output shall be through the appropriate interface port capable of two-way communication with the building DDC system.  Coordinate with the DDC contractor so that the data port connection provided at the chiller shall not require any additional intermediate gateway or media conversion devices to provide throughput of data.  No additional labor by the DDC contractor to integrate the chiller data points to the DDC system shall be required other than to make the communication trunk connection and program the points at the DDC workstation.

Provide the following data input points:

 Chilled water entering and leaving temps

 Condenser water entering and leaving temps

 Percent FLA

 Evaporator & condenser refrigerant pressures

 Differential oil pressure

 Evaporator & condenser saturation temperatures

 Compressor discharge temperature

 Compressor motor voltage and amperage for each of the three phases

 Oil sump temperature

 Operating hours

 Number of starts

 Specific reason for cycling or safety shutdown (i.e. low oil pressure)

 Chiller alarm

 Provide evaporator freeze protection and low limit control to avoid low evaporator refrigerant temperature trip-outs. Control system 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. If the condition exists for more than 20 minutes, a warning alarm relay shall energize to indicate that the condition has persisted.

Provide condenser high limit control to avoid condenser high-pressure trip outs. Control system shall take progressively more aggressive load limiting action in response to the severity of the rate of change and the actual value of the condenser pressure. If the condition exists for more than 20 minutes, a warning alarm relay shall energize to indicate that the condition has persisted.

***Modify this section to reference the type of flow switch recommended by the manufacturer or facility preference.  DFD preference would be to provide thermal dispersion as listed.***

For chillers that do not integral flow sensing, provide two (2) [McDonnell Miller Type FS7-4L] [IFM Efector model SI1006 Thermal Dispersion, Fluid Components Intl (FCI) model FLT93S Thermal Dispersion, or approved equal] flow switches to the Mechanical Contractor for installation in the condenser and chilled water piping. Provide all power supplies required for the flow sensors. The Mechanical Contractor shall provide and coordinate all field wiring from the flow switches to the chiller control panel.

 **STARTER**

 ***Modify this portion of the specification after consulting with the facility and DFD. Many facilities have a preference for starter types. The starter being provided must allow the chiller to start with a minimum of 33% starting torque and 33% of inrush current (LRA).***

 Motor starter shall be a ***(480)*** volt, ***(reduced voltage/autotransformer/ wye-delta/solid-state)*** type with closed-circuit transition.

 Isolating switch and contactor assemblies, including current limiting fuses, shall be of the component-to-component design without any interconnecting cables or flexible shunts, removable from the front of the enclosure. Line and load cable terminations shall be completely accessible from the front.

 The isolating switch shall be an externally operated manual three pole draw-out, such that in the open position it completely grounds and isolates the starter from the line connectors. Integral mechanical interlocks shall prevent entry while the starter is energized and shall prevent accidental opening or closing of the isolating switch when the door is open or contactor is closed. The isolating switch handle shall have provision for three (3) padlocks.

 Current limiting power fuses shall be of the self-protecting type with visible fuse condition indicators, and with special time/current characteristics for motor service allowing proper coordination with the contactor and overload protection for each phase for maximum motor protection. The power fuses shall be vertically mounted permitting easy inspection and replacement without starter disassembly.

 Isolate the low voltage starter control from the high power voltage area. Provide a control power transformer (CPT), fuses for each leg of the primary and secondary side of the CPT, “Start” and “Stop” pushbuttons, a red “Running” pilot light, and at least two normally open, and two normally closed contractors for control interlocking. CPT shall be of sufficient size to accommodate all control power needs of the starter/chiller combination.

***Add or modify the following paragraph when an autotransformer starter is to be used. The requirement of the additional tap is allow for chiller starts under most operating conditions while limiting voltage drops on facility’s power system.***

[In addition to the standard auto transformer taps of 50%, 65% and 80%, the starter shall contain a tap at 57% (-0%, +1%) voltage. Normal operation will involve starting the chiller at the 57% tap. The chiller manufacturer shall guarantee the chiller will start under typical conditions (hot equipment, high tower, etc.) at the 57% autotransformer tap.]

 Enclosure shall meet ANSI/NEMA ICS-6 enclosure standards, be NEMA 1 unless otherwise noted, be completely accessible from the front and allow freestanding, against a wall or back-to-back mounting.

 Starter assembly shall be UL listed, and bear the UL label of approval where a UL standard or code exists.

 ***4160 volt equipment may not be available with UL rating.***

Starter shall include motor protection system incorporating electronic three-phase overloads and current transformers. This electronic motor protection system shall monitor and protect against the following conditions:

 Three-phase overload protection

 Overload protection during start-up

 Phase imbalance

 Phase loss

 Phase reversal

 Overvoltage — each phase

 Undervoltage — each phase

 Distribution fault protection with manual restart at the starter consisting of three-phase, current sensing devices that monitor the status of the current. Distribution faults of 1-1/2 electrical cycle duration shall be detected and the compressor motor shall be disconnected within six (6) electrical cycles.

 Alternately, the advanced motor protection system can be furnished in the chiller control panel

 The starter shall be able to operate in temperatures up to 120 degrees F.

 All field supplied wires, bus bars and fittings shall be copper only.

**VARIABLE FREQUENCY DRIVE (VFD)**

Chiller VFD shall be provided and installed by the chiller manufacturer.

The unit shall be variable torque, modular design for control of the motor(s) and rated at the motor full load nameplate amps.

The unit shall be U.L. listed, solid state, micro processor-based with a pulse width modulated (PWM) output wave form (none others are acceptable).

The VFD shall employ a full wave bridge rectifier and capacitors to minimize the ripple of the rectified voltage to maintain near constant DC voltage. Insulated gate bipolar transistors (IGBT’s) shall be employed as the output switching device. Units shall be suitable for input power of electrical system as scheduled on the drawings ±10%, 3 phase, 60 Hertz nominal.

The VFD package shall contain –an integrated active rectification control system to limit total demand distortion (TDD) in current at the VFD to less than 5%.

Units to be suitable for an operating environment from 0°C to 40°C temperature and humidity up to 90% non-condensing.

Electrically and physically isolate control circuitry and conductors from power circuitry and power conductors. Control conductors and power conductors shall not be run in the same pathway.

The unit enclosure shall be NEMA1 as required for the application minimum and all components shall be fully factory assembled and tested prior to leaving the manufacturing facility.

The unit shall have a circuit breaker to de-energize - the drive - with door interlocked handle and lock-open padlocking provisions.

Use a current limiting control device to limit output current to 110% continuous for one minute or 150% for five seconds. Full load output current available from drive shall not be less than motor nameplate amperage. The full load amp rating of the VFD shall not be less than the values indicated in the NEC Table 430-150.

Additional performance capabilities to include the following:

 -

 Capable of automatic restart into a rotating load after a preset, adjustable time delay following a power outage

 Input power factor: Min 0.95 throughout the speed range

 Minimum efficiency: 97% at 100% speed, 97% at 50% speed

Adjustable acceleration and deceleration rate so that the time period from start to full speed and from full speed to stop can be field adjusted

Adjustable minimum and maximum speed settings

The unit control panel shall be capable of displaying:

 VFD bus voltage

 Frequency

 Speed

 VFD output power (kW)

 VFD transistor temperature (F)

 Variable speed settings and limits

 Input line KW

 Input line voltage

 Motor Speed (Hz)

 Motor Speed (rpm)

 Motor Winding Temps 1, 2, 3 (F)

Use electronic protection circuitry in the power circuits to provide an orderly shutdown of the drive without blowing fuses or tripping circuit breakers and prevent component loss under the following abnormal conditions:

 Activation of any safety device;

 Instantaneous overcurrent and/or over voltage of output;

 Power line overvoltage and undervoltage protection;

 Phase loss;

 Single and three phase short circuiting;

 Ground faults;

 Control circuit malfunction;

 Overtemperature; and

 Output current over limit.

Provide the following additional protective features:

Input transient overvoltage protection up to 3000 volts per ANSI 37.90A;

DC bus fusing or other electronic controls which limit the rate of rise of the DC bus current and de-energizes the drive at a predetermined current level;

Fusing for the control circuit transformer;

Grounded control chassis; and

Provide an English character display (no error codes) with indicators for the following diagnostics:

 Phase loss

 Ground fault

 Overcurrent

 Overvoltage

 Undervoltage

 Over temperature

 Overload

 DC bus status

 **VIBRATION ISOLATION**

 The chiller supplier shall furnish refrigeration machine vibration isolation in accordance with 23 05 48 for the installation by the mechanical contractor.

If chiller is bid separate from installation, insert isolator description from 23 05 48 here and edit the above sentence accordingly.

 **FACTORY PERFORMANCE TEST**

Factory performance test the chiller in accordance with the latest version of AHRI 550 and the following exceptions:

1. As an exception to AHRI 550, no tolerance (0%), of specified design capacity tons will be allowed at Design capacity.
2. Test under 100%, 75%, 50%,and 25% load at NPLV (or IPLV if applicable) conditions in an AHRI certified test facility per AHRI procedure. All exceptions to AHRI 550 listed in this specification apply. If the chiller is being applied at non-standard conditions then the test should be at those non-standard conditions and a seperate test at standard AHRI conditions is not required. A certified performance selection for the selected chiller at Standard AHRI conditions is required. If the chiller is being applied at standard AHRI conditions then the schedule includes only that performance and the test should be at standard AHRI conditions.
3. Tons must be the net cooling output after deducting cooling required for chiller auxiliaries (oil cooler, purge, sound attenuation, etc.).
4. kW must be the total electrical consumption including all auxiliaries (including but not limited to motor starters, variable speed drives, oil heaters, etc.) required during normal operation for each of the test points.

The manufacturer shall submit a factory certified test report to confirm performance as specified prior to shipping of chillers. The report shall be an original signed by an officer of the manufacturer’s company. Preprinted certification will not be acceptable. Test data to include evaporator and condenser refrigerant design and actual saturated temperatures.

The factory test instrumentation shall be per AHRI 550, and the calibration of all instrumentation shall be traceable to the National Institute of Standards and Technology. Proper AHRI certification documents for the test loop shall be made available upon request from the manufacturer for inspection.

Run the performance test with clean tubes per AHRI 550. Adjust design leaving evaporator water temperature downward and entering condenser temperature upward per Section C6.3 to adjust from the design fouling to the clean tube condition. There will be no exceptions to conducting the performance test with clean tubes and these temperature adjustments. The manufacturer shall clean tubes, if necessary, prior to test to obtain a test-fouling factor of .0000 hr. sq. ft. F/BTU.

The chiller will be accepted if the test procedures are in conformance with AHRI 550 and the results are in conformance with this specification. If the equipment fails to perform, the manufacturer will be allowed to make necessary revisions to the equipment and retest as required.

In the event that these revisions do not achieve submitted performance, the following penalties will be imposed at the State’s discretion:

***Consult with DFD to determine if the penalties should be modified.***

 CAPACITY PENALTY: For each ton below the Design Capacity Tons but not greater than three (3) percent less, $**1500** per ton will be deducted from the contract price. Chillers that are more than 3% below the scheduled capacity will not be accepted.

 ENERGY INCENTIVE PENALTY: One lump sum of [$xxxxx] will be imposed at the State’s discretion if the selected chiller does not meet the specified Design Capacity KW/Ton and IPLV KW/Ton values at standard AHRI conditions. This penalty will be based on the AHRI certified selection and not an actual test.

*Discuss the ENERGY INCENTIVE PENALTY with DFD. This penalty equals the energy rebate available from Focus on Energy for the specified chiller. The AE is responsible for contacting Focus on Energy and working with them to establish the rebate amount as well as coordinating pre-approval for the specified chiller.*

 TOTAL PERFORMANCE PENALTY: The total performance penalty will be the sum of the CAPACITY PENALTY and the ENERGY INCENTIVE PENALTY, times the number of typical chillers required.

No payment will be made prior to acceptance of performance or penalty deduction from the contract.

The chiller will not be accepted if capacity is less than ninety-seven (97) percent of net design capacity tons or if power consumption is greater than one hundred five (105) percent of [design CAPACITY][NPLV] [IPLV]kW/ton.

Stable operation at a minimum load of [10%][15%][20%] shall be demonstrated during the factory performance test with a constant [65ºF] [75ºF] [85ºF] entering condenser water temperature.

***Modify the % minimum operation to match the % minimum number included in the compressor specification in the products part of this spec.***

The initial performance test shall begin not later than Wednesday of a full business week. Test shall be conducted between the hours of 7:00 AM and 5:00 PM, local time in force at the location of the factory test. The manufacturer shall notify the Owner in writing and include a printout of the predicted AHRI Certified Performance Test at all test point load conditions with complete fouling factor calculations at least 14 days in advance of the performance test. The Owner will assume travel, transportation, meals and lodging (two nights) cost for the Owner’s representative to witness the initial chiller performance test. Should the chiller fail the initial performance test and re-testing occur, the bidder shall be responsible for all additional expenses, including additional travel, transportation, meals, lodging, etc. for the Owner’s representative to complete the factory witness test. Re-testing shall conclude by 5:00 PM Friday.

 ***Include the above paragraph when factory tests are witnessed. Coordinate expenditures in advance with project manager.***

 **REFRIGERANT MONITORS**

Furnish one (1) refrigerant monitor to continuously monitor and detect refrigerant leaks from ***[three (3)]*** sample locations Unit shall be based on the infrared photo-acoustic absorption principle of operation or infrared solid state sensor, have an accuracy of 1 PPM over the range of 0-50 PPM and +/- 10% of reading 51-1000 PPM, have a sensitivity and resolution of 1 PPM, have a linear response over the 0-100 PPM range and +*/-* 2 % of full scale over the 100-1000 PPM range.

System to be compound specific and calibrated for chiller refrigerant. Provide an audible alarm with silence switch, visual alarm, display of each sample status and refrigerant concentration. System to provide two individually adjustable levels of alarm, each with a separate output relays. The monitor shall allow the user to retrieve from each sampling zone the peak daily leak rate, date and time of peak. Visual alarm to reset automatically when conditions are no longer potentially dangerous. Sampling to be automatic with adjustable duration for each channel. Units shall operate on 115-volt single-phase power, use NEMA 4 enclosure and be UL/ETL listed. Unit to be rated for ambient temperature of 59oF to 104oF and humidity of 10-90% RH. Furnish units with *calibration equipment (strike if facility has equipment already)* and expendable filters and supplies necessary for not less than one year of operation.

[Sample Tubing: 1/4” OD virgin polyethylene plastic tubing classified as flame retardant under UL 94 and conforming to ASTM D1693 stress-crack test installed in conduit (EMT). 1/4” OD copper tubing, ASTM B75 seamless, hard drawn with tool drawn bends and ANSI B16.22 wrought copper fittings, except final connections to apparatus may be made with brass compression-type fittings. Use ANSI/ASTM B32, 95/5 tin antimony solder. Provide sample tube inlet particle filter for each zone.]

***Include the above paragraph when the monitor or refrigerant detection system uses discrete samples via a pump.***

**PART 3 - EXECUTION**

 **INSTALLATION**

Install chillers and refrigerant monitors in accordance with manufacturer’s installation instructions.

Chillers shall be factory assembled, tested, and shipped to the job site.

***If chiller is being pre-purchased then describe who is responsible for unloading the chiller when it is delivered.***

Mount refrigerant monitor where indicated. Mount ***two (2)*** sampling tube inlets near each lower end of chiller adjacent to valves/fittings and other potential sources of leaks. Position away from areas likely to create dust, water or oil aerosol contamination. Mount one (1) sensor in the common relief line of the chiller(s). Extend tubing to exhaust and purge clean air (if required by manufacturer for calibration). Do not exceed 150’ zone tubing length. Mechanically fasten tubing to equipment and building to prevent sagging and excess vibration. Route plastic tubing in conduit (EMT) or exposed where not exceeding 18” and used for connection to monitor or inlet. Adjust first level alarm to 15 PPM for R-514a and 200 PPM for R-134A. Adjust second level alarm to 30 PPM for R-514a and 300 PPM for R-134A.

 ***Select and show monitor panel location on plan. The mechanical room may not be the best location if ambient temperature/humidity, room cleanliness or accessibility are unfavorable.***

**STARTUP**

Include the service of a factory-trained technician/mechanic employed by the chiller manufacturer for the initial startup, one fall shutdown, and one additional spring startup. Accomplish initial startup before State acceptance of the installation. .

Furnish a startup log to the Owner's operating personnel with a copy to the state construction representative for this project. Document each subsequent startup or shutdown procedure and send report to Owner’s operating personnel. Demonstrate the following items have been accomplished:

1. Inspect/clean cooler and condenser tubes.

Fall shutdown: Remove the condenser and cooler water boxes; visually inspect tubes, tube sheets and water box cover for corrosion, pitting, erosion, broken division plate bracket(s) and general appearance.

If tube cleaning is indicated, clean tubes with nylon brushes only; metallic brushes are not acceptable. After cleaning, flush tubes with water to remove the loose residue. Chemical cleaning of tubes will not be allowed.

Replace water box covers using new gaskets if required.

2. Perform leak test on fabricated compressor, vessel and piping joints after the system has been serviced and closed.

a. Initial startup: Follow manufacturer's instructions with respect to evacuation, charging, positive pressure and/or vacuum testing. Pressure/vacuum testing to be in accordance with manufacturer's instructions. Perform any repairs necessary to obtain a successful pressure test. Do not operate chiller until it is successfully pressure tested. Use nitrogen and suitable refrigerant for pressure test unless manufacturer's instructions require otherwise.

b. Fall shutdown: Electronically leak test all fabricated compressor and vessel joints in accordance with manufacturer's instructions and perform any repairs necessary to obtain a successful test.

c. Spring startup: Provide leak testing as recommended in manufacturer's instructions.

3. Lubrication system

a. Initial startup: Charge unit with oil in accordance with manufacturer's instructions. Energize oil sump heater and verify thermostat setting per manufacturer's specification.

b. Fall shutdown: Remove lubrication charge from oil sump. Visually inspect for color, dirt, sludge, and burnt or acidic condition. Test oil in the chiller manufacturer's laboratory or a laboratory approved by the manufacturer to determine condition of oil and notify owner of the results. Clean lubrication system if visual and/or laboratory results indicate necessary. Recharge with new oil per manufacturer's specifications and replace oil filter elements.

c. Spring startup: Provide lubrication system work as recommended in manufacturer's instructions.

4. Pumpout units where required.

At each inspection, verify proper operation and/or condition of floats, sight glasses, condensers, belts, compressors, operating controls, safety controls and any other device required for proper operation.

5. Filters and strainers.

 At the fall shutdown, remove and replace all oil and refrigerant filters, strainers and filter-drier cores. Use acid/moisture type replacement filter-drier cores.

6. Energize oil sump heater and verify thermostat setting is per manufacturer's instructions at each inspection.

7. Electrical

 Tighten all starter electrical power connections and all control terminations at each inspection.

 Check all contactors at each inspection for proper mechanical linkage, freedom of operation and contact surfaces for pitting, corrosion and spring tension. Clean all contact surfaces as required; notify owner if replacement is recommended.

 Megger test and record all compressor and oil pump motor insulation readings at initial startup and each succeeding inspection. Compare findings to previous readings and make recommendations on any preventative maintenance required.

 Check reduced voltage starters for proper transition timing in accordance with manufacturer's instructions.

***Add or modify the following paragraph when an autotransformer starter is to be used. The requirement of the additional tap is allow for chiller starts under most operating conditions while limiting voltage drops on facility’s power system.***

 For auto transformer starters, the manufacturer’s start-up representative shall test the starting of the chiller at the autotransformer 50% tap. If the tests results are satisfactory, the manufacturer shall allow the normal start of the chiller at the 50% tap.

 Visually inspect and clean all components including resistor banks, disconnects, fuse holders, arc chutes, ammeters, voltmeters, watt-hour meters, dash-pots, etc.

8. At initial startup and whenever refrigerant is transferred from a storage device to the chiller, record date and pounds of refrigerant in machine.

9. Clean and touchup paint unit as required for protection.

10. Repair or replace damaged insulation caused by service/repair/maintenance work.

11. Give any used compressor oil to owner; owner will make arrangements for proper disposal.

12. At the initial startup and each spring startup, check unit operation, check all safety and operating controls, log all pertinent parameters of the unit, including but not limited to the following:

 a. Refrigerant pressure in cooler and condenser

 b. Saturated refrigerant temperature in cooler and condenser

 c. Water inlet and outlet temperatures in cooler and condenser

 d. Water side pressure drop in cooler and condenser

 e. Flow rate in gallons per minute in cooler and condenser

 f. Bearing temperatures

 g. Oil sump temperature

 h. Oil pressure

 i. Motor voltage and amperage in each phase

 j. Purge count and purge unit operating hours, if applicable

 k. Purge condensing pressure, if applicable

 l. Starter transition time, actual as measured

**CONSTRUCTION VERIFICATION**

Contractor is responsible for utilizing the construction verification checklists supplied under specification Section 23 08 00 in accordance with the procedures defined for construction verification in Section 01 91 01 or 01 91 02.

**FUNCTIONAL PERFORMANCE TESTING**

Contractor is responsible for utilizing the functional performance test forms supplied under specification Section 23 08 00 in accordance with the procedures defined for functional performance testing in Section 01 91 01 or 01 91 02.

# AGENCY TRAINING

All training provided for agency shall comply with the format, general content requirements and submission guidelines specified under Section 01 91 01 or 01 91 02.

Contractor to provide factory authorized representative and/or field personnel knowledgeable with the operations, maintenance and troubleshooting of the system and/or components defined within this section for a minimum period of 4 hours.

\*\*\*