SECTION 236416 - CENTRIFUGAL WATER CHILLERS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Architect." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

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

1. GENERAL
   * + 1. RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

* + - * 1. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
      1. SUMMARY
         1. Section Includes:

Packaged, water-cooled, electric-motor-driven centrifugal chillers.

Packaged, portable refrigerant-recovery units.

Heat-exchanger, brush-cleaning system.

* + - 1. DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

* + - * 1. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input, using consistent units for any given set of rating conditions.
        2. DDC: Direct digital control.
        3. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
        4. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit for a single chiller calculated according to the method defined by AHRI 550/590 and referenced to AHRI standard rating conditions.
        5. kVAR: Kilovolt-ampere reactive.
        6. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.
        7. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit for a single chiller calculated according to the method defined by AHRI 550/590 and intended for operating conditions other than the AHRI standard rating conditions.
        8. SCCR: Short-circuit current rating.
      1. SUBMITTALS
         1. Submittals for this section are subject to the re-evaluation fee identified in Article 4 of the General Conditions.
         2. Manufacturer's installation instructions shall be provided along with product data.
         3. Submittals shall be provided in the order in which they are specified and tabbed (for combined submittals).
         4. Product Data: For each type of product.

Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.

Performance at AHRI standard conditions and at conditions indicated.

Performance at AHRI standard unloading conditions.

Minimum evaporator flow rate.

Minimum condenser[**and heat-reclaim condenser**] flow rate.

Refrigerant capacity of chiller.

Oil capacity of chiller.

Fluid capacity of evaporator, condenser[**, and heat-reclaim condenser**].

Characteristics of safety relief valves.

Minimum entering condenser-fluid temperature.

Performance at varying capacities with constant design condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in [**5 deg F**] <**Insert temperature**> increments.

Force and moment capacity of each piping connection.

* + - * 1. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.

Wiring Diagrams: For power, signal, and control wiring.

Retain "Coordination Drawings" paragraph below for situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Coordinate paragraph with other Sections specifying products listed below. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

* + - * 1. Coordination Drawings:

Drawings, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

Structural supports.

Piping roughing-in requirements.

Wiring roughing-in requirements, including spaces reserved for electrical equipment.

Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

Coordination drawings showing plan, section, and elevation views, drawn to <**Insert scale**>.

Each view to show screened background with the following:

Column grids, beams, columns, and concrete housekeeping pads.

Room layout with walls, floors, and roofs, including each room name and number.

Equipment and products of other trades that are located in vicinity of chillers and part of final installation, such as lighting, fire-suppression, and plumbing systems.

Retain Certificates" paragraph below if retaining certification in "Quality Assurance" Article.

* + - * 1. Certificates: For certification required in "Quality Assurance" Article.

Retain "Seismic Qualification Data" paragraph below if required by seismic criteria applicable to Project. Coordinate with Section 230548 "Vibration and Seismic Controls for HVAC." See ASCE/SEI 7 for certification requirements for equipment and components.

* + - * 1. Seismic Qualification Data: Certificates, for chillers, accessories, and components, from manufacturer.

Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

* + - * 1. Source quality-control reports.
        2. Field Quality-Control Reports: Startup service reports.
        3. Sample Warranty: For special warranty.
      1. CLOSEOUT SUBMITTALS
         1. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.
         2. Instructional Videos: Including those that are pre-recorded and those that are recorded during training.
      2. MAINTENANCE MATERIAL SUBMITTALS

Retain this article to require tool kit and touch-up paint.

Consult Director’s Representative regarding chiller service and need for tool kit. Servicing of chiller by unqualified personnel is not recommended by chiller manufacturers and may void chiller warranty.

* + - * 1. Tool kit to include the following:

A tool kit specially designed by chiller manufacturer for use in servicing chiller(s) furnished.

Special tools required to service chiller components not readily available to Director’s Representative service personnel in performing routine maintenance.

Lockable case with hinged cover, marked with large and permanent text to indicate the special purpose of tool kit, such as "Chiller Tool Kit." Text size shall be at least 1 inch high.

A list of each tool furnished. Permanently attach the list to underside of case cover. Text size shall be at least 1/2 inch high.

* + - * 1. Touch-up Paint: [**32-oz.**] <**Insert volume**> container of paint used for finish coat. Label outside of container with detailed description of paint to allow for procurement of a matching paint in the future.
      1. QUALITY ASSURANCE

Retain "AHRI Certification" paragraph below if AHRI certification is required and Project requirements fall within limits of AHRI 550 certification program. AHRI 550/590 is broken into two certification programs; AHRI 550 certification program is applicable to centrifugal chillers. Review the latest version to verify requirements.

* + - * 1. AHRI Certification: Certify chiller according to AHRI 550 certification program.

Retain "Green Seal Compliance" paragraph below to require that chillers comply with GS-31. See discussion in the Evaluations. Retain first option to achieve compliance whether or not equipment is certified by Green Seal. Retain second option to require Green Seal certification that chillers comply with GS-31. Trane is the only listed manufacturer that currently participates in Green Seal's certification program. Retaining Green Seal certification will limit competition.

* + - * 1. Green Seal Compliance: Signed by [**manufacturer**] [**Green Seal**], certifying compliance with GS-31.
      1. DELIVERY, STORAGE, AND HANDLING

Retain one of first two paragraphs below. Retain first paragraph to restrict shipping requirements. Retain second paragraph to allow manufacturer alternatives. Consult manufacturers.

* + - * 1. Ship chillers from the factory fully charged with refrigerant.
        2. Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.
        3. Ship each oil-lubricated chiller with a full charge of oil.

Retain subparagraph and one of two options below to restrict shipping requirements. Consult manufacturers.

Ship oil [**factory installed in chiller**] [**in containers separate from chiller**].

Retain paragraph below only for projects with special shipping requirements. Export shipping adds cost.

* + - * 1. Package chiller for export shipping in totally enclosed [**bagging**] [**crate**] [**crate with bagging**].
      1. WARRANTY

When warranties are required, verify with Director’s Representative's counsel that special warranties stated in this article are not less than remedies available to Director’s Representative under prevailing local laws.

* + - * 1. Special Warranty: Manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.

Consult Director’s Representative about need for extended warranties.

Extended warranties include, but are not limited to, the following:

Retain one of first three subparagraphs below.

Complete chiller, including refrigerant and oil charge.

Complete compressor and drive assembly, including refrigerant and oil charge.

Refrigerant [**and oil**]charge.

Loss of refrigerant charge for any reason due to manufacturer product defect and product installation.

Parts [**only**] [**and labor**].

Verify available warranties and warranty periods with manufacturers listed in Part 2 articles for units and components. A common manufacturer warranty offering will start 18 months from date of shipment or 12 months from date of startup, because date of Substantial Completion is more difficult for the manufacturer to estimate.

Warranty Period: [**Two**] [**Three**] [**Four**] [**Five**] [**10**] <**Insert number**> years from date of Substantial Completion.

1. PRODUCTS

Manufacturers and products listed in SpecAgent and MasterWorks Paragraph Builder are neither recommended nor endorsed by the AIA or Deltek. Before inserting names, verify that manufacturers and products listed there comply with requirements retained or revised in descriptions and are both available and suitable for the intended applications.

* + - 1. PERFORMANCE REQUIREMENTS

Retain "Seismic Performance" paragraph below with "Seismic Qualification Data" paragraph in "Informational Submittals" Article for projects requiring seismic design. Delete paragraph if performance requirements are indicated on Drawings. Model building codes and ASCE/SEI 7 establish criteria for buildings subject to earthquake motions. Coordinate requirements with structural engineer.

* + - * 1. Seismic Performance: Centrifugal chillers shall withstand the effects of earthquake motions determined according to [**ASCE/SEI 7**] <**Insert requirement**>.

Retain subparagraph below to define the term "withstand" as it applies to this Project. Definition varies with type of building and occupancy and is critical to valid certification. Option is used for essential facilities where equipment must operate immediately after an earthquake.

The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified[**and the unit will be fully operational after the seismic event**]."

For life-safety components required to function after an earthquake (such as fire-sprinkler systems, components that contain hazardous content, and storage racks in structures open to the public), the Component Importance Factor is 1.5. For other components, the Component Importance Factor is 1.0 unless the structure is in Seismic Use Group III and component is necessary for continued operation of facility or failure of component could impair continued operation of facility, in which case the Component Importance Factor is 1.5.

Component Importance Factor: [**1.5**] [**1.0**].

See ASCE/SEI 7, Coefficients for Architectural Component Table and Seismic Coefficients for Mechanical and Electrical Components Table for requirements to be inserted in subparagraph below.

<**Insert requirements for Component Amplification Factor and Component Response Modification Factor**>.

* + - * 1. Condenser-Fluid Temperature Performance:

Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of [**60 deg F**] [**55 deg F**] [**40 deg F**] <**Insert temperature**> and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.

Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of [**65 deg F**] [**60 deg F**] [**55 deg F**].

Make factory modifications to standard chiller design if necessary to comply with performance indicated.

* + - * 1. Site Altitude: Chiller shall be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.

Retain "Performance Tolerance" paragraph below if Project requires more stringent tolerances than allowed by AHRI 550/590.

* + - * 1. Performance Tolerance: Comply with the following in lieu of AHRI 550/590:

Allowable Capacity Tolerance: [**Zero**] <**Insert number**> percent.

Allowable Full-Load Energy Efficiency Tolerance: [**Zero**] <**Insert number**> percent.

Allowable Part-Load Energy Efficiency Tolerance: [**Zero**] <**Insert number**> percent.

* + - * 1. ASHRAE Compliance:

ASHRAE 15 for safety code for mechanical refrigeration.

ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.

Retain "ASHRAE/IES Compliance" paragraph below to require compliance with ASHRAE/IES 90.1. LEED 2009 Prerequisite EA 2 and LEED v4 Prerequisite "Minimum Energy Performance" require compliance with ASHRAE/IES 90.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on LEED prerequisites and credits.

* + - * 1. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1.
        2. ASME Compliance: Fabricate and label chillers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, as applicable to chiller design. For chillers charged with R-134a refrigerant, include an ASME U-stamp and nameplate certifying compliance.
        3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
        4. Comply with requirements of Underwriters Laboratories, and include label by a qualified testing agency showing compliance.

Retain "Operation Following Loss of Normal Power" paragraph below if uninterrupted chiller operation is required without operator intervention.

* + - * 1. Operation Following Loss of Normal Power:

Equipment, associated factory- and field-installed controls, and associated electrical equipment and power supply connected to backup power system shall automatically return equipment and associated controls to the operating state occurring immediately before loss of normal power without need for manual intervention by an operator when power is restored either through a backup power source, or through normal power if restored before backup power is brought online.

Refer to Drawings for equipment served by back-up power systems.

Provide means and methods required to satisfy requirement, even if not explicitly indicated.

Retain "Outdoor Installations" paragraph below for chillers installed outdoors.

* + - * 1. Outdoor Installations:

Chiller shall be suitable for outdoor installation indicated. Provide adequate weather protection to ensure reliable service life over a [**25**] <**Insert number**> -year period, with minimal degradation due to exposure to outdoor ambient conditions.

Chillers are equipped to provide safe and stable operation while achieving performance indicated when operating at extreme outdoor temperatures. Review historical weather database and provide equipment that can operate at extreme outdoor temperatures recorded over past [**30**] <**Insert number**> -year period.

* + - 1. MANUFACTURERS

* + - * 1. [Manufacturers:](http://www.specagent.com/Lookup?ulid=3567) Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

[Carrier Global Corporation](http://www.specagent.com/Lookup?uid=123457139283).

[Daikin Applied](http://www.specagent.com/Lookup?uid=123457139281).

[Trane](http://www.specagent.com/Lookup?uid=123457139284).

[YORK; brand of Johnson Controls International plc, Building Solutions North America](http://www.specagent.com/Lookup?uid=123457139282).

Approved equivalent.

* + - 1. MANUFACTURED UNIT
         1. Description: Factory-assembled and -tested chiller complete with compressor, compressor motor, compressor motor controller, [**lubrication system**]evaporator, condenser, [**heat-reclaim condenser as indicated,**]controls, interconnecting unit piping and wiring, and indicated accessories.

Retain "Multi-Piece Assembly" subparagraph below if limited space is available for installation. Retain option to be more restrictive by requiring disassembly only at the factory. Consult listed manufacturers.

Multi-Piece Assembly: Disassemble chiller into major assemblies as required by the installation after factory testing[**and before packaging for shipment**].

Dual-Compressor Chillers: For chillers with dual compressors, provide each compressor with a dedicated motor and motor controller, and provide for continued operation when either compressor-drive assembly fails.

Retain paragraph below for projects in seismic areas.

* + - * 1. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.
      1. COMPRESSOR-DRIVE ASSEMBLY
         1. Description: Single-stage or multistage, variable- or dynamic-displacement, centrifugal-type compressor driven by an electric motor.

Retain "Oil-Free Technology" for chillers with oil-free technology. Three chiller manufacturers offer oil-free centrifugal chiller products over a limited capacity range. Daikin and York use magnetic bearing technology. Trane uses ceramic bearing technology. Chillers with oil-free technology cost more than traditional oil-lubricated chillers but can have a lower life-cycle cost. See the Evaluations.

* + - * 1. Oil-Free Technology:

Retain one of first two subparagraphs below. Retain first subparagraph to be less restrictive by allowing oil-free technologies other than magnetic bearing chillers. Retain second paragraph to restrict oil-free technology to only magnetic bearings.

[**Where indicated, compressors**] [**Compressors**] shall have oil-free technology.

[**Where indicated, compressors**] [**Compressors**] shall have oil-free technology using a permanent magnet synchronous motor, magnetic bearings, integral variable-frequency controller, and digital electronic controls.

Magnetic Bearings or Roller Element Bearings:

Levitated shaft position shall be actively controlled and monitored by an X-, Y-, and Z-axis digital position sensor.

Compressor assembly shall be capable of coming to a controlled, safe stop without damage during a power failure by diverting stored power to the magnetic bearing control system.

Integrate monitoring and controls associated with magnetic bearings into chiller controls, including following:

Operating Information: Positions, currents, temperatures, rotor elongation, and speed.

Warning Messages: Vibration.

Safety Shutdown: Internal fault, high bearing temperature or current, startup failure, speed signal fault, overspeed fault, communication error, rotor elongation, oscillator fault, rotor contraction, unauthorized rotation, and high and low voltage.

Cycling Shutdown: Position, low-frequency displacement, vibration, speed signal fault, startup failure, serial communications fault.

* + - * 1. Compressor:

Casing: Cast iron, precision ground.

Impeller: High-strength cast-aluminum or cast-aluminum alloy on carbon- or alloy-steel shaft.

First four options in "Drive" paragraph below limit competition; fifth option does not. Trane is the only listed manufacturer to offer a direct-drive, hermetic centrifugal chiller. York is the only listed manufacturer to offer an open-drive centrifugal chiller. Only Carrier and Daikin offer a gear-drive, hermetic centrifugal chiller.

* + - * 1. Drive: [**Direct-drive, hermetic**] [**Gear-drive, hermetic**] [**Gear-drive, open**] [**Direct- or gear-drive, hermetic**] [**Direct- or gear-drive, open or hermetic**] design, using an electric motor as the driver.

Retain "Gear Drives" subparagraph below for gear drives.

Gear Drives:

For chillers with oil-lubricated gear drives, provide single- or double-helical gear design continuously coated with oil while chiller is operating.

For chillers with oil-free technology, gear drives shall be of single- or double-helical gear design without the need for oil while chiller is operating, starting, and stopping.

Gears shall comply with American Gear Manufacturer Association standards.

Retain "Drive Coupling" subparagraph below for open drives.

Drive Coupling: For chillers with open drives, provide flexible disc with all-metal construction and no wearing parts to ensure long life without the need for lubrication.

Seals: Seal drive assembly to prevent refrigerant leakage.

* + - * 1. Compressor Motor:

Continuous-duty, squirrel-cage, induction-type, two-pole motor with energy efficiency required to suit chiller energy efficiency indicated.

Factory mounted, aligned, and balanced as part of compressor assembly before shipping.

Motor shall be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.

First option in first subparagraph below is standard offering and is suitable for most indoor applications. Consider second, third, or fourth option if chiller is installed outdoors or regularly exposed to high levels of moisture. Consult manufacturer.

For chillers with open drives, provide motor with [**open-dripproof**] [**weather-protected, Type I**] [**weather-protected, Type II**] [**totally enclosed**] enclosure.

Provide motor with thermistor or RTD in [**single motor winding**] [**each of three-phase motor windings**] to monitor temperature and report information to chiller control panel.

Provide motor with thermistor or RTD to monitor bearing temperature and report information to chiller control panel.

subparagraph below is not required for most indoor applications; retain if required.

Provide open-drive motor with internal electric heater, internally powered from chiller power supply.

* + - * 1. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.

First option in "Overspeed Test" subparagraph below is typical of Carrier. Second option is typical of other manufacturers.

Overspeed Test: At least [**20**] [**25**] percent above design operating speed.

Vibration Limits: Velocities not to exceed 0.15 inches/s and 0.8 mils peak to peak on all axes.

* + - * 1. Service: Easily accessible for inspection and service.

Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.

Provide lifting lugs or eyebolts attached to casing.

* + - * 1. Economizers: For multistage chillers, provide interstage economizers.
        2. Capacity Control: Modulating, variable-inlet, guide-vane assembly combined with hot-gas bypass, if necessary, to achieve performance indicated.

Maintain stable operation that is free of surge, cavitation, and vibration throughout range of operation. Configure to achieve most energy-efficient operation possible.

Standard operating range varies among manufacturers. Not all listed manufacturers comply with options in "Operating Range" subparagraph below without hot-gas bypass. Consult manufacturer for requirements.

Operating Range: From 100 to [**15**] [**10**] [**5**] [**zero**] <**Insert number**> percent of design capacity.

Condenser-Fluid Unloading Requirements over Operating Range: [**Constant-design of entering condenser-fluid temperature**] [**Drop-in entering condenser-fluid temperature of 2.5 deg F for each 10 percent in capacity reduction**] <**Insert conditions**>.

Chillers with variable-frequency controllers shall modulate compressor speed with variable-inlet, guide-vane control to achieve optimum energy efficiency.

Avoid use of hot-gas bypass if other options are available to achieve performance indicated. Apply hot-gas bypass according to ASHRAE/IES 90.1 and governing codes.

Retain "Oil Lubrication System" paragraph below for compressor-drive assemblies requiring oil lubrication.

* + - * 1. Oil Lubrication System: Consisting of pump, filtration, [**heater,**]cooler, factory-wired power connection, and controls.

Bearings, gears, and other rotating surfaces shall be lubricated at all operating, startup, coast down, and standby conditions, including power failure.

Retain first option in first subparagraph below to be less restrictive.

[**Manufacturer's standard method**] [**Thermostatically controlled oil heater properly sized**] to remove refrigerant from oil.

Not all listed manufacturers comply with requirements in first subparagraph below. Consult manufacturers.

[**Oil filter**] [**Dual oil filters, one redundant,**] shall be the easily replaceable cartridge type, minimum [**0.3**] [**0.5**]-micron efficiency, with means of positive isolation while servicing.

[**Refrigerant**] [**Water**] [**Refrigerant- or water**]-cooled oil cooler.

Factory-installed and pressure-tested piping with isolation valves and accessories.

Oil compatible with refrigerant and chiller components.

Positive visual indication of oil level.

* + - 1. REFRIGERATION

Retain a specific refrigerant type in "Refrigerant" paragraph below to limit competition, or leave the choice to Contractor. Trane is the only listed manufacturer that offers R-123 refrigerant. Trane does not offer R-134a refrigerant in chillers manufactured domestically. Other listed manufacturers offer only R-134a. R-123 is scheduled to be phased out of production in 2030; R-134a is not scheduled for phaseout.

LEED 2009-NC, LEED 2009-CS, and LEED 2009 for Schools Credit EA 4 and LEED v4 Credit "Enhanced Refrigerant Management" require that new HVAC&R systems use refrigerants that reduce ozone-depletion potential and support early compliance with the Montreal Protocol while minimizing direct contributions to global warming. The credit requires that calculations be submitted to justify that refrigerant selected complies with requirements. See "Sustainable design Considerations" Article in the Evaluations for discussion of this credit.

* + - * 1. Refrigerant:

Type: [**R-123; ASHRAE 34, Class B1**] [**or**] [**R-134a; ASHRAE 34, Class A1**].

Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

* + - * 1. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.
        2. Pressure Relief Device:

Comply with requirements in ASHRAE 15, ASHRAE 147, and applicable portions of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

Select and configure pressure relief devices to protect against corrosion and inadvertent release of refrigerant.

Where dual pressure relief devices are installed in series, provide a sensor with indicator between devices to indicate refrigerant release past first device.

Retain one of two subparagraphs below if limiting refrigerant type, or retain both if not limiting refrigerant type. In first subparagraph, first option is standard and complies with codes; second and third options are nonstandard upgrades.

For Chillers Using R-123: [**Manufacturer's standard offering complying with ASHRAE 15 and ASHRAE 147**] [**Rupture disc constructed of frangible carbon**] [**or**] [**spring-loaded, pressure relief valve; single- or multiple-reseating type**].

For Chillers Using R-134a: ASME-rated, spring-loaded, pressure relief valve; single- or multiple-reseating type. Pressure relief valve(s) shall be provided for each heat exchanger. Condenser shall have dual valves with one being redundant and configured to allow either valve to be replaced without loss of refrigerant.

* + - * 1. Refrigeration Transfer: Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller to a remote refrigerant storage and recycling system. Comply with requirements in ASHRAE 15 and ASHRAE 147.

Retain "Refrigerant Isolation for Chillers Using R-134a" paragraph below to isolate chiller refrigerant charge within chiller heat exchangers.

* + - * 1. Refrigerant Isolation for Chillers Using R-134a:

Retaining option in first subparagraph below will exclude Daikin, because it offers check valves only.

Factory install [**positive shutoff, manual**]isolation valves in the compressor discharge line to the condenser and the refrigerant liquid line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell.

Requirement in subparagraph below is not available on all chillers. See the Evaluations and consult manufacturers for availability.

Suction side of compressor from evaporator shall have an isolation valve to allow for isolation and storage of full refrigerant charge in the chiller evaporator shell.

Retain "Purge System" paragraph below for chillers using R-123 refrigerant.

* + - * 1. Purge System:

For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic purge system for collection and return of refrigerant and lubricating oil and for removal of noncondensables, including, but not limited to, water, water vapor, and noncondensable gases.

System shall be of thermal purge design, refrigerant or air cooled, and equipped with a carbon filter that includes an automatic regeneration cycle.

Factory wire to chiller's main power supply and system complete with controls, piping, and refrigerant valves to isolate the purge system from the chiller.

Construct components of noncorrodible materials.

Controls shall interface with chiller control panel to indicate modes of operation, set points, data reports, diagnostics, and alarms.

Efficiency of not more than 0.02 lb of refrigerant per pound of air when rated according to AHRI 580.

Operation independent of chiller according to ASHRAE 147.

Retain "Positive-Pressure System" paragraph below for chillers using R-123 refrigerant if application warrants enhanced protection. paragraph defines requirements for nonstandard factory option that pressurizes chiller when not in use and is intended to minimize potential for noncondensables being drawn into chiller. Manufacturer may elect to comply with ASHRAE 15 and ASHRAE 147 requirements, using other means and methods as their standard product offering. Requirement for a positive-pressure system could be used to provide redundancy.

* + - * 1. Positive-Pressure System:

For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic positive-pressure system.

During nonoperational periods, positive-pressure system shall automatically maintain a positive pressure for atmosphere in the refrigerant-pressure vessel of not less than 0.5 psig adjustable up to a pressure that remains within the vessel design pressure limits.

System shall be factory wired and include controller, electric heat, pressure transmitter, or switch.

* + - 1. EVAPORATOR
         1. Description: Shell-and-tube design, with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.
         2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
         3. Designed to prevent liquid refrigerant carryover from entering compressor.
         4. Evaporator shall have sight glass or other form of positive visual verification of liquid-refrigerant level.
         5. Tubes:

Individually replaceable from either end and without damage to tube sheets and other tubes.

Retain option in first subparagraph below to allow manufacturer some flexibility in attachment of tubes at intermediate tube sheets. Consult listed manufacturers for their standard construction practices.

Mechanically expanded into end sheets and [**physically attached to**]intermediate tube sheets.

Tube materials vary among manufacturers and chiller models; verify availability with manufacturer. First option in "Material" subparagraph below is current standard of listed manufacturers.

Material: [**Copper**] [**Copper-nickel alloy**] [**Stainless steel**] [**Titanium**] [**Copper, copper-nickel alloy, stainless steel, or titanium**] <**Insert material**>.

Retain one of four options in "Nominal OD" subparagraph below. First and fourth options give manufacturer the choice of diameter size. Second option limits size available from listed manufacturers. Daikin and Trane offer the third option.

Nominal OD: [**Manufacturer's choice**] [**3/4 inch**] [**1 inch**] [**3/4 or 1 inch**].

In "Minimum Wall Thickness" subparagraph below, first option gives manufacturer the choice of wall thickness; second, third, and fourth options limit thickness. Second option is current standard of listed manufacturers but is subject to change. Third and fourth options are upgrades. If using materials other than copper, wall thickness may vary. See the Evaluations.

Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch**] [**0.028 inch**] [**0.035 inch**] <**Insert value**>.

External Finish: Manufacturer's standard.

First option in "Internal Finish" subparagraph below is standard of most manufacturers. Second option is for applications with dirty fluids that require frequent tube cleaning. Third option gives manufacturer the choice of finish.

Internal Finish: [**Enhanced**] [**Smooth**] [**Enhanced or smooth**].

* + - * 1. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes, with positive seal between fluid in tubes and refrigerant in shell.

Retain option in "Intermediate Tube Sheets" paragraph below to be more restrictive. Consult listed manufacturers to determine compliance with requirement.

* + - * 1. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear[**, but not more than 4 feet apart**].
        2. Water Box:

Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.

[**Standard**] [**Marine**] type for water box with piping connections; standard type for water box without piping connections.

Provide water boxes [**and marine water-box covers**]with lifting lugs or eyebolts.

Retain one of first two subparagraphs below for special applications.

[**Hinged**] [**Davited**] [**Hinged or davited**] water boxes.

[**Hinged**] [**Davited**] [**Hinged or davited**] marine water-box covers.

Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].

Thermistor or RTD temperature sensor factory installed in each nozzle.

Fit each water box with [**3/4-inch**] [**1-inch**] [**3/4- or 1-inch**] <**Insert size**> drain connection at low point and vent connection at high point, each with threaded plug.

Retain "Additional Corrosion Protection" paragraph below for special applications.

* + - * 1. Additional Corrosion Protection:

Electrolytic corrosion-inhibitor anode, [**zinc**] [**or**] [**magnesium**].

Retain one of two subparagraphs below only for applications with special requirements. Only some applications require special treatment. Second subparagraph requires cladding and is not normally provided with copper tubes. Consult water treatment and corrosion expert for guidance.

Coat wetted surfaces with a corrosion-resistant finish.

Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

* + - * 1. Flow Sensor: Thermal dispersion type, factory calibrated for project-specific application.
      1. CONDENSER
         1. Description: Shell-and-tube design, with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator.
         2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
         3. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
         4. Condenser shall have sight glass or other form of positive visual verification of refrigerant charge and condition.
         5. Tubes:

Individually replaceable from either end and without damage to tube sheets and other tubes.

Retain option in first subparagraph below to allow manufacturer some flexibility in attachment of tubes at intermediate tube sheets. Consult listed manufacturers for their standard construction practices.

Mechanically expanded into end sheets and [**physically attached to**]intermediate tube sheets.

Tube materials vary among manufacturers and chiller models; verify availability with manufacturer. First option in "Material" subparagraph below is current standard of listed manufacturers.

Material: [**Copper**] [**Copper-nickel alloy**] [**Stainless steel**] [**Titanium**] [**Copper, copper-nickel alloy, stainless steel, or titanium**] <**Insert material**>.

In "Nominal OD" subparagraph below, first and fourth options give manufacturer the choice of diameter size. Second option limits size available from listed manufacturers. Daikin and Trane offer the third option.

Nominal OD: [**Manufacturer's choice**] [**3/4 inch**] [**1 inch**] [**3/4 or 1 inch**].

In "Minimum Wall Thickness" subparagraph below, first option gives manufacturer the choice of wall thickness; second, third, and fourth options limit thickness. Second option is current standard of listed manufacturers but is subject to change. Third and fourth options are upgrades. If using materials other than copper, wall thickness may vary. See the Evaluations.

Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch**] [**0.028 inch**] [**0.035 inch**] <**Insert value**>.

External Finish: Manufacturer's standard.

First option in "Internal Finish" subparagraph below is standard of most manufacturers. Second option is for applications with dirty fluids that require frequent tube cleaning. Third option gives manufacturer the choice of finish.

Internal Finish: [**Enhanced**] [**Smooth**] [**Enhanced or smooth**].

* + - * 1. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes, with positive seal between fluid in tubes and refrigerant in shell.

Retain option in "Intermediate Tube Sheets" paragraph below to be more restrictive. Consult listed manufacturers to determine compliance with requirement.

* + - * 1. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear[**, but not more than 4 feet apart**].
        2. Water Box:

Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.

[**Standard**] [**Marine**] type for water box with piping connections. Standard type for water box without piping connections.

Water boxes [**and marine water-box covers**]shall have lifting lugs or eyebolts.

Retain one of first two subparagraphs below for special applications.

[**Hinged**] [**Davited**] [**Hinged or davited**] water boxes.

[**Hinged**] [**Davited**] [**Hinged or davited**] marine water-box covers.

Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].

Thermistor or RTD temperature sensor factory installed in each nozzle.

Fit each water box with [**3/4-inch**] [**1-inch**] [**3/4- or 1-inch**] <**Insert size**> drain connection at low point and vent connection at high point, each with threaded plug.

Retain "Additional Corrosion Protection" paragraph below for special applications.

* + - * 1. Additional Corrosion Protection:

Electrolytic corrosion-inhibitor anode, [**zinc**] [**or**] [**magnesium**].

Retain one of two subparagraphs below only for applications with special requirements. Only some applications require special treatment. Second subparagraph requires cladding and is not normally provided with copper tubes. Consult water treatment and corrosion expert for guidance.

Coat wetted surfaces with a corrosion-resistant finish.

Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

* + - * 1. Flow Sensor: Thermal dispersion type, factory calibrated for project-specific application.

Retain article below if required for Project. Heat-reclaim condenser is uncommon.

* + - 1. HEAT-RECLAIM CONDENSER
         1. Description: Shell-and-tube design, with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator and condenser.
         2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
         3. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
         4. Tubes:

Individually replaceable from either end and without damage to tube sheets and other tubes.

Retain option in first subparagraph below to allow manufacturer some flexibility in attachment of tubes at intermediate tube sheets. Consult listed manufacturers for their standard construction practices.

Mechanically expanded into end sheets and [**physically attached to**]intermediate tube sheets.

Tube materials vary among manufacturers and chiller models; verify availability with manufacturer. First option in "Material" Subparagraph below is current standard of listed manufacturers.

Material: [**Copper**] [**Copper-nickel alloy**] [**Stainless steel**] [**Titanium**] [**Copper, copper-nickel alloy, stainless steel, or titanium**] <**Insert material**>.

In "Nominal OD" subparagraph below, first and fourth options give manufacturer the choice of diameter size. Second option limits size available from listed manufacturers. Daikin and Trane offer the third option.

Nominal OD: [**Manufacturer's choice**] [**3/4 inch**] [**1 inch**] [**3/4 or 1 inch**].

In "Minimum Wall Thickness" subparagraph below, first option gives manufacturer the choice of wall thickness; second, third, and fourth options limit thickness. Second option is current standard of listed manufacturers but is subject to change. Third and fourth options are upgrades. If using materials other than copper, wall thickness may vary. See the Evaluations.

Minimum Wall Thickness: [**Manufacturer's choice**] [**0.025 inch**] [**0.028 inch**] [**0.035 inch**] <**Insert value**>.

External Finish: Manufacturer's standard.

First option in "Internal Finish" subparagraph below is standard of most manufacturers. Second option is for applications with dirty fluids that require frequent tube cleaning. Third option gives manufacturer the choice of finish.

Internal Finish: [**Enhanced**] [**Smooth**] [**Enhanced or smooth**].

* + - * 1. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes, with positive seal between fluid in tubes and refrigerant in shell.

Retain option in "Intermediate Tube Sheets" paragraph below to be more restrictive. Consult listed manufacturers to determine compliance with requirement.

* + - * 1. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear[**, but not more than 4 feet apart**].
        2. Water Box:

Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.

[**Standard**] [**Marine**] type for water box with piping connections; standard type for water box without piping connections.

Water boxes [**and marine water-box covers**]shall have lifting lugs or eyebolts.

Retain one of first two subparagraphs below for special applications.

[**Hinged**] [**Davited**] [**Hinged or davited**] water boxes.

[**Hinged**] [**Davited**] [**Hinged or davited**] marine water-box covers.

Nozzle Pipe Connections: [**Welded, ASME B16.5, flat-face flange**] [**Welded, ASME B16.5, raised-face flange**] [**Grooved for mechanical-joint coupling**] [**Grooved with mechanical-joint coupling and flange adapter**].

Thermistor or RTD temperature sensor factory installed in each nozzle.

Fit each water box with [**3/4-inch**] [**1-inch**] [**3/4- or 1-inch**] <**Insert size**> drain connection at low point and vent connection at high point, each with threaded plug.

Retain "Additional Corrosion Protection" paragraph below for special applications.

* + - * 1. Additional Corrosion Protection:

Electrolytic corrosion-inhibitor anode, [**zinc**] [**or**] [**magnesium**].

Retain one of two subparagraphs below only for applications with special requirements. Only some applications require special treatment. Second subparagraph requires cladding and is not normally provided with copper tubes. Consult water treatment and corrosion expert for guidance.

Coat wetted surfaces with a corrosion-resistant finish.

Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

* + - * 1. Flow Sensor: Thermal dispersion type, factory calibrated for project-specific application.
      1. INSULATION
         1. Closed-cell, flexible elastomeric thermal insulation complying with ASTM C534, Type I for tubular materials and Type II for sheet materials.

Second option in "Thickness" subparagraph below may not be available from all manufacturers as a standard factory option. Consult manufacturer.

Thickness: [**3/4 inch**] [**1-1/2 inches**] <**Insert value**>.

* + - * 1. Adhesive: As recommended by insulation manufacturer.
        2. Factory-applied insulation over all cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.

Apply adhesive to 100 percent of insulation contact surface.

Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.

Seal seams and joints to provide a vapor barrier.

After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

Manufacturer has option to factory or field insulate chiller components installed in multiple pieces to reduce potential for damage during installation.

Manufacturer has option to factory or field insulate water boxes and nozzles to reduce potential for damage during installation.

* + - * 1. Field-Applied Insulation:

Components that are not factory insulated shall be field insulated to comply with requirements indicated.

Manufacturer shall be responsible for chiller insulation whether factory or field installed, to ensure manufacturer is the single point of responsibility for chillers.

Manufacturer factory-authorized service representative shall instruct and supervise installation of field-applied insulation.

After field-applied insulation is complete, paint insulation to match factory-applied finish.

* + - 1. ELECTRICAL
         1. Factory installed and wired, and functionally tested at factory before shipment.

Retain first paragraph below for single-point, field-power connection. Requirement is limited to chillers equipped with factory-mounted motor controllers.

* + - * 1. Single-point, field-power connection to [**fused disconnect switch**] [**nonfused disconnect switch**] [**circuit breaker**]. Minimum short circuit current rating (SCCR) according to UL 508 shall be as required by electrical power distribution system, but not less than [**42,000**] [**65,000**] [**100,000**] <**Insert value**> A.

First option in first subparagraph below is most common. Consult listed manufacturers.

Branch power circuit to each motor, electric heater, dedicated electrical load, and control, with [**circuit breaker**] [**or**] [**disconnect switch**] having SCCR to match main disconnecting means.

Retain one of or both of first two subparagraphs below, depending on option(s) retained in subparagraph above.

NEMA KS 1, heavy-duty fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.

NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.

NEMA ICS 2-rated motor controller for auxiliary motors, hand-off-auto switch, and overcurrent protection for each motor. Provide variable-frequency controller for each variable-speed motor furnished.

Control-circuit transformer with primary and secondary side fuses.

* + - * 1. Terminal blocks with numbered [**and color-coded**]wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.

Retain first paragraph below to enclose wiring if required by special application, such as a corrosive or humid environment, or an outdoor application. Requirement will add cost and is unnecessary for many indoor applications. Chiller manufacturers do not normally enclose all wiring. Consult listed manufacturers for availability.

* + - * 1. Factory-installed wiring located outside of enclosures shall be installed in metal raceway, and terminal connections shall be made with not more than a 24-inch length of [**liquid tight**] [**flexible metallic**] [**liquid tight or flexible metallic**] conduit.

Retain paragraph below to correct chiller power factor. Requirement is redundant on chillers with variable-frequency controllers, because power factor correction is integral to controller. Second option is more common. Consult listed manufacturers to address impact of power factor correction at all operating conditions.

* + - * 1. Factory install and wire capacitor bank for the purpose of power factor correction to [**0.95**] <**Insert value**> at [**full load**] [**all operating conditions**].

If capacitors are mounted in a dedicated enclosure, use same NEMA enclosure type as that for motor controller. Provide enclosure with service entrance knockouts and bushings for conduit.

Capacitors shall be of non-PCB dielectric fluid, metallized electrode design, with low loss with low-temperature rise. The kVAR ratings shall be indicated and shall not exceed the maximum limitations set by NFPA 70. Provide individual cells as required.

Provide each cell with current-limiting replaceable fuses and carbon-film discharge resistors to reduce residual voltage to less than 50 V within one minute after de-energizing.

Provide a ground terminal and a terminal block or individual connectors for phase connection.

* + - 1. MOTOR CONTROLLER

Retain this article for chillers with factory-furnished motor controllers other than variable-frequency controllers. See the Evaluations.

Not all chiller manufacturers provide all features specified in this article; verify availability. Coordinate electrical requirements with Drawings and electrical Sections.

In "Enclosure" paragraph below, retain "NEMA 250" option for chillers connected with 600 V and less. Retain "NEMA ICS 6" option for chillers connected with more than 600 V.

* + - * 1. Enclosure: [**Factory installed, unit mounted**] [**Factory furnished, field mounted**], [**NEMA 250**] [**NEMA ICS 6**], [**Type 1**] [**Type 4**] [**Type 4X**] [**Type 12**] <**Insert type**>, with hinged full-front access door[**with lock and key or padlock and key**].
        2. Control Circuit: Obtained from [**integral control power transformer**] <**Insert source of control power**> with a control power [**transformer**] [**source**] of enough capacity to operate connected control devices.

See the Evaluations in Section 262913.03 "Manual and Magnetic Motor Controllers" or Section 262913.06 "Soft-Start Motor Controllers" for discussion on overload relays.

* + - * 1. Overload Relay shall be sized according to UL 1995 or shall be an integral component of chiller control microprocessor.

Retain "Across-the-Line Controller," "Star-Delta, Reduced-Voltage Controller," "Autotransformer Reduced-Voltage Controller," or "Solid-State, Reduced-Voltage Controller" paragraphs below to require the appropriate controller to suit Project. Coordinate with Drawings. See the Evaluations for selection considerations. For applications operating at 600 V and less, retain either star-delta or solid-state, reduced-voltage controllers unless special applications require another type. For applications more than 600 V, retain either across-the line, autotransformer reduced-voltage, or solid-state, reduced-voltage controllers unless special applications require another type.

* + - * 1. Across-the-Line Controller: NEMA ICS 2, Class A, full voltage, nonreversing; include isolation switch and current-limiting fuses.
        2. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition.
        3. Autotransformer Reduced-Voltage Controller: NEMA ICS 2, closed transition; include isolation switch and current-limiting fuses.
        4. Solid-State, Reduced-Voltage Controller: NEMA ICS 2.

Include surge suppressor in solid-state power circuits to provide three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.

Visual indication of motor and control status, including the following conditions:

Controller on.

Overload trip.

Loss of phase.

Starter fault.

* + - * 1. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.

Retain applicable subparagraphs below. Some options may be supplied as standard accessories in chiller control panel and are not required with controller. Consult listed manufacturers if attempting to avoid potential duplication of features.

Externally Operated[**, Door-Interlocked**] Disconnect: [**Fused disconnect switch**] [**Nonfused disconnect switch**] [**Circuit breaker**]. Short circuit current rating (SCCR) according to UL 508 shall be as required by electrical power distribution system, but not less than [**42,000**] [**65,000**] [**100,000**] <**Insert value**> A.

Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.

Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.

Control Relays: Time-delay relays.

Retain "Elapsed-Time Meters" and "Number-of-Starts Counter" subparagraphs below if information is not displayed at chiller control panel.

Elapsed-Time Meters: Numerical readout in hours on face of enclosure.

Number-of-Starts Counter: Numerical readout on face of enclosure.

Retain "Meters" or "Multifunction Digital-Metering Monitor" subparagraph below if information is not displayed at chiller control panel.

Meters: Panel type, [**2-1/2 inches**] [**4-1/4 inches**] with [**90**] [**120**] [**270**]-degree scale and [**1**] [**2**] percent accuracy. Where indicated, provide transfer device with an off position. Meters shall indicate the following:

Ammeter: Output current for each phase, with current sensors rated to suit application.

Voltmeter: Output voltage for each phase.

First subparagraph below is an optional feature.

Frequency Meter: Output frequency.

Real-time clock with current time and date.

Total run time.

<**Insert features**>.

Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:

Selectable, digital display of the following:

Retain any of first nine subparagraphs below as required.

Phase Currents, Each Phase: Plus or minus 1 percent.

Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.

Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.

Three-Phase Real Power: Plus or minus 2 percent.

Three-Phase Reactive Power: Plus or minus 2 percent.

Power Factor: Plus or minus 2 percent.

Frequency: Plus or minus 0.5 percent.

Integrated Demand with Demand Interval Selectable from Five to 60 Minutes: Plus or minus 2 percent.

Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.

Mounting: Display and control unit flush or semirecessed in instrument compartment door.

Retain first subparagraph below if not supplied by chiller control panel.

Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.

Power Protection: Chiller shall shut down within six cycles of power interruption.

* + - 1. VARIABLE-FREQUENCY CONTROLLER

Retain this article for variable-frequency controllers. Consult manufacturers for availability of requirements indicated. Not all manufacturers provide all features specified in this article. Coordinate electrical requirements with Drawings and electrical Sections.

* + - * 1. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
        2. Description: NEMA ICS 2; listed and labeled according to UL 508 as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
        3. Enclosure: Unit mounted, NEMA 250, [**Type 1**] [**Type 4**] [**Type 4x**] [**Type 12**], with hinged full-front access door with lock and key.
        4. Integral Disconnecting Means: [**Door-interlocked,**]NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum short circuit current rating (SCCR) according to UL 508 shall be as required by electrical power distribution system, but not less than [**42,000**] [**65,000**] [**100,000**] <**Insert value**> A.
        5. Technology: Pulse width modulated (PWM) output with insulated gate bipolar transistors; suitable for variable torque loads.
        6. Controller shall consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.

Rectifier section shall be a full-wave diode bridge that changes fixed-voltage, fixed-frequency, ac line power to a fixed dc voltage. Silicon controller rectifiers, current source inverters, and paralleling of devices are unacceptable. Rectifier shall be insensitive to phase rotation of the ac line.

Regulator shall provide full digital control of frequency and voltage.

Inverter section shall change fixed dc voltage to variable-frequency, variable ac voltage for application to a squirrel-cage motor. Inverter shall produce a sine-coded, PWM output waveform and shall conduct no RFI back to the input power supply.

* + - * 1. Output Rating: Three phase, with voltage proportional to frequency throughout voltage range.
        2. Operating Requirements:

Input AC Voltage Tolerance: [**460-V ac, plus 10 percent or 506 V maximum**] <**Insert voltage and tolerance**>.

Input frequency tolerance of 60 Hz, plus or minus 2 Hz.

Capable of driving full load, without derating, under the following conditions:

Ambient Temperature: [**Zero**] <**Insert number**> to [**40**] [**50**] <**Insert number**> deg C.

Relative Humidity: Up to [**90**] [**95**] <**Insert number**> percent (noncondensing).

Altitude: Up to [**3300 feet**] [**6600 feet**] <**Insert value**>.

Minimum Efficiency: 96 percent at 60 Hz, full load.

Minimum Displacement Primary-Side Power Factor: 95 percent without harmonic filter; 98 percent with harmonic filter.

Overload Capability: 1.05 times the full-load current for seven seconds.

Starting Torque: As required by compressor-drive assembly.

Speed Regulation: Plus or minus 1 percent.

Isolated control interface to allow controller to follow control signal over a 10:1 speed range.

To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.

Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.

* + - * 1. Internal Adjustability Capabilities: Integral to controller or through chiller control panel.

Minimum Output Frequency: 6 Hz.

Maximum Output Frequency: 60 Hz.

Acceleration: Two seconds to a minimum of 60 seconds.

Deceleration: Two seconds to a minimum of 60 seconds.

Current Limit: 30 percent to a minimum of 100 percent of maximum rating.

* + - * 1. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:

Overtemperature.

Short circuit at controller output.

Ground fault at controller output. Variable-frequency controller shall be able to start a grounded motor.

Open circuit at controller output.

Input undervoltage.

Input overvoltage.

Loss of input phase.

Reverse phase.

AC line switching transients.

Instantaneous overload, line to line or line to ground.

Sustained overload exceeding 100 percent of controller-rated current.

Starting a rotating motor.

* + - * 1. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
        2. Automatic Reset and Restart:

Capable of [**three**] [**five**] <**Insert number**> restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction.

Controller shall be capable of automatic restart on phase-loss and overvoltage and undervoltage trips.

* + - * 1. Visual Indication: On face of controller enclosure or chiller control enclosure. indicating the following conditions:

Retain any of 23 subparagraphs below as required by application. Some requirements may not be available from all listed manufacturers. Consult listed manufacturers to confirm availability.

Power on.

Run.

Overvoltage.

Line fault.

Overcurrent.

External fault.

Motor speed (percent).

Fault or alarm status (code).

DC-link voltage.

Motor output voltage.

Input kilovolt amperes.

Total power factor.

Input kilowatts.

Input kilowatt-hours.

Three-phase input voltage.

Three-phase output voltage.

Three-phase input current.

Three-phase output current.

Three-phase input voltage THD.

Three-phase input current THD.

Output frequency (Hertz).

Elapsed operating time (hours).

Diagnostic and service parameters.

* + - * 1. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.

Retain "Control Signal Interface" paragraph below and revise to suit Project; delete if control signal interface is not required.

* + - * 1. Control Signal Interface:

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

Manufacturer has option to incorporate control signal interface into chiller control panel.

Retain "Active Harmonic Distortion Filter" or "Input Line Conditioning" paragraph below. Retain first if active harmonic distortion filters satisfy requirement for input voltage or current distortion due to harmonic generation in controllers. Retain second for other optional features, such as dc-bus-link reactors, isolation transformers, passive harmonic filters, and phase-shifting transformers. Insert requirements in second paragraph. Consult manufacturers for additional information.

* + - * 1. Active Harmonic Distortion Filter:

Retain one of first two subparagraphs below. First subparagraph is more restrictive. Consult Project electrical engineer for requirements.

Factory mounted and wired to limit total voltage and current distortion to [**5**] <**Insert number**> percent.

Factory mounted and wired to limit total demand distortion (TDD) to [**5**] <**Insert number**> percent of unit input.

* + - * 1. Input Line Conditioning: <**Insert requirements**>.
        2. Cooling: [**Air**] [**Refrigerant**] [**Water**] [**Air, refrigerant, or water**] cooled.
        3. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.

Control Relays: Auxiliary and adjustable time-delay relays.

* + - * 1. Chiller Capacity Control Interface: Equip chiller with adaptive control logic to automatically adjust the compressor motor speed and the compressor pre-rotation inlet vane position independently to achieve maximum part-load efficiency in response to sensor inputs that are integral to the chiller controls.
      1. CONTROLS

Coordinate this article with Section 230923 "Direct Digital Control (DDC) System for HVAC."

* + - * 1. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory, so that reprogramming is not required on loss of electrical power.
        2. Enclosure: Unit mounted, NEMA 250, [**Type 1**] [**Type 4**] [**Type 4x**] [**Type 12**] <**Insert type**>, hinged or lockable, factory wired with a single-point, with field-power connection and a separate control circuit.
        3. Factory-installed wiring outside of enclosures shall be in a NFPA 70-approved raceway.[**Make terminal connections with liquidtight or flexible metallic conduit.**]
        4. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units selectable through the interface, display the following information:

Revise list below to suit Project. Verify availability of displayed information with listed chiller manufacturers. Some information may be optional; other information may not be available from all listed manufacturers.

Date and time.

Operating or alarm status.

Fault history with not less than last 10 faults displayed.

Set points of controllable parameters.

Trend data.

Operating hours.

Number of chiller starts.

Outdoor-air temperature or space temperature if required for chilled-water reset.

Entering- and leaving-fluid temperatures of evaporator and condenser.

Difference in fluid temperatures of evaporator and condenser.

Fluid flow of evaporator and condenser.

Fluid-pressure drop of evaporator and condenser.

Refrigerant pressures in evaporator and condenser.

Refrigerant saturation temperature in evaporator and condenser shell.

Compressor refrigerant suction and discharge temperature.

Compressor bearing temperature.

Motor bearing temperature.

Motor winding temperature.

Oil temperature.

Oil discharge pressure.

Phase current.

Percentage of motor-rated load amperage.

Phase voltage.

Demand power (kilowatts).

Energy use (kilowatt-hours).

Power factor.

For chillers equipped with variable-frequency controllers and harmonic filters, include the following:

Output voltage and frequency.

Voltage THD for each phase.

Supply current TDD for each phase.

Inlet vane position.

Controller internal ambient temperature.

Heatsink temperature.

Retain first two subparagraphs below for chillers using R-123 refrigerant.

Purge suction temperature if purge system is provided.

Purge elapsed time if purge system is provided.

<**Insert status display items**>.

* + - * 1. Control Functions:

Revise list below to suit Project. Verify availability; functions may vary among listed manufacturers and models.

Manual or automatic startup and shutdown time schedule.

Entering and leaving chilled-water temperatures, control set points, and motor load limits. Evaporator-fluid temperature shall be reset based on [**return-water**] [**outdoor-air**] [**space**] temperature.

Current limit and demand limit.

Condenser-fluid temperature.

External chiller emergency stop.

Variable evaporator flow.

Thermal storage.

Heat reclaim.

<**Insert control functions**>.

* + - * 1. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:

Revise list below to suit Project. Verify availability; conditions may vary among listed manufacturers and models.

Retain first option in first subparagraph below for chillers using R-123 refrigerant; retain second option for chillers using R-134a refrigerant; or retain third option for chillers using both refrigerants.

Low evaporator [**pressure**] [**temperature**] [**pressure or temperature**]; high condenser pressure.

Low evaporator-fluid temperature.

Retain first three subparagraphs below for oil-lubricated chillers.

Low oil differential pressure.

High or low oil pressure.

High oil temperature.

High compressor-discharge temperature.

Loss of condenser-fluid flow.

Loss of evaporator-fluid flow.

Motor overcurrent.

Motor overvoltage.

Motor undervoltage.

Motor phase reversal.

Motor phase failure.

Sensor- or detection-circuit fault.

Processor communication loss.

Motor controller fault.

Extended compressor surge.

Retain first subparagraph below for chillers using R-123 refrigerant.

Excessive air-leakage detection for chillers using R-123 refrigerant.

<**Insert manually reset safety controls**>.

* + - * 1. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
        2. Security Access: Provide electronic security access to controls through identification and password, with at least three levels of access: view only; view and operate; and view, operate, and service.
        3. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
        4. Communication Port: RS-232 port, USB 2.0 port or higher, or equivalent connection capable of connecting a printer[**and a notebook computer**].

Retain first paragraph below if chiller controls interface with a BAS or DDC system.

* + - * 1. [**BAS**] [**DDC System**] Interface: Factory install hardware and software to enable system to monitor, control, and display chiller status and alarms.

Retain "Hardwired I/O Points" subparagraph below if interface with control system is through hardwired points and minimal interface is required. If extensive interface is required, delete below and retain "Communication Interface" subparagraph below, or retain both subparagraphs if requiring both hardwired and communication interface. Contact manufacturer to confirm options selected are available.

Hardwired I/O Points:

Monitoring: On-off status, [**common trouble alarm**] [**electrical power demand (kilowatts)**] [**electrical power consumption (kilowatt-hours)**] [**power factor**] <**Insert monitoring point**>.

Control: On-off operation, [**chilled-water, discharge temperature set-point adjustment**] [**electrical power demand limit**] <**Insert control point**>.

Retain "Communication Interface" subparagraph below if extensive interface is required and is beyond that that can be provided by hardwired I/O points alone.

Coordinate communication protocol option selected with control system requirements.

Contact manufacturer to confirm communication interface is available.

Communication Interface: [**ASHRAE 135 (BACnet)**] [**LonTalk**] [**Modbus**] [**Industry-accepted, open-protocol**] <**Insert type of interface**> communication interface shall enable control system operator to remotely control and monitor the chiller from an operator workstation.

Control features and monitoring points displayed locally at chiller control panel shall be available through the control system, including, as a minimum, the following:

Revise list below to suit Project. Verify availability of requirements with listed chiller manufacturers. Some requirements listed may be optional; other requirements may not be available from all listed manufacturers.

Start-stop command from remote source.

Unit control source, local, analog, digital or modem.

Chiller control panel start-stop.

Accumulated operating hours.

Accumulated starts.

Compressor motor status.

Unit operation code.

Unit safety fault code.

Unit cycling fault code.

Chilled-water pump status.

Chilled-water flow proof.

Chilled-water entering temperature.

Chilled-water leaving temperature.

Chilled-water leaving temperature set-point adjustment from remote source.

Condenser(s) water entering temperature.

Condenser(s) water leaving temperature.

Evaporator refrigerant pressure.

Condenser(s) refrigerant pressure.

Evaporator refrigerant saturation temperature.

Condenser(s) refrigerant saturation temperature.

Refrigerant discharge temperature.

Refrigerant level.

Refrigerant liquid level set point.

Oil pressure differential.

Oil sump pressure.

Oil pump pressure.

Oil sump temperature.

High-speed thrust bearing proximity position.

High-speed thrust bearing proximity reference.

Motor current percent of full-load amps.

Motor current phase A.

Motor current phase B.

Motor current phase C.

Motor current set-point adjustment from remote source.

Motor bearing shaft end vibration.

Motor bearing opposite shaft end vibration.

Motor bearing shaft end temperature.

Motor bearing opposite shaft end temperature.

Motor average winding temperature.

Variable-frequency controller selection, auto or fixed.

Variable-frequency controller output voltage.

Variable-frequency controller input power, rate.

Variable-frequency controller input power, consumption.

Variable-frequency controller DC bus voltage.

Variable-frequency controller inverter link current.

Variable-frequency controller output frequency.

Variable-frequency controller internal ambient temperature.

Variable-frequency controller converter heatsink temperature.

Variable-frequency controller harmonic filter installed, true or false.

Harmonic Filter THD at maximum voltage, percent.

Harmonic filter total demand distortion at maximum current, percent.

Harmonic filter total supply kVA.

Anti-recycle time remaining.

Liquid line solenoid.

Pre-rotation vanes position.

Adaptive capacity control valve surge map installed, true or false.

Adaptive capacity control new surge point, true or false.

Adaptive capacity control surge type, pressure differential or current.

Adaptive capacity control surge count.

Adaptive capacity control PRV position.

Adaptive capacity control output frequency.

<**Insert point**>.

Retain "Quick-Start Feature" paragraph below for applications that require rapid chiller operation after a power interruption.

* + - * 1. Quick-Start Feature:

Automatically restore chiller operation up to [**100**] <**Insert number**> percent capacity within [**three**] [**five**] <**Insert number**> minutes after a [**15**] <**Insert number**> -second power interruption.

Quick-start feature shall ensure guide vanes remain open following a power interruption event and quick ramp-up speed logic is employed to facilitate shortest time to deliver chilled water at set-point temperature.

Chiller manufacturer shall provide integral UPS unit(s) with chiller controls if required to keep chiller integral controls operational to comply with requirement.

Chiller manufacturer shall demonstrate chiller start time with the quick-start feature enabled while simulating power fault, power service return, restart time, and capacity control, to produce desired chilled-water temperature at load indicated.

* + - 1. FINISH
         1. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:

Provide at least one coat of primer with a total dry film thickness of at least [**1.5 mils**] [**2 mils**] <**Insert thickness**>.

Options in first subparagraph below are as follows: Carrier provides only one coat with a 2-mils thickness; York provides two coats with a total thickness of 3 mils ; and Daikin and Trane provide two coats with a total thickness of 4 mils.

Provide at least [**one coat**] [**two coats**] of [**alkyd-modified, vinyl enamel**] [**epoxy**] [**polyurethane**] finish with a total dry film thickness of at least [**2 mils**] [**3 mils**] [**4 mils**] <**Insert thickness**>.

Paint surfaces that are to be insulated before applying the insulation.

Paint installed insulation to match adjacent uninsulated surfaces.

Color of finish coat shall be [**manufacturer's standard**] [**custom color selected by Director’s Representative**] <**Insert color description**>.

* + - 1. ACCESSORIES

Retain "Flow Switches," "Vibration Isolation," or "Sound Barrier" paragraphs below to add features furnished by chiller manufacturer.

Thermal-type flow sensors described in "Evaporator," "Condenser," and "Heat-Reclaim Condenser" paragraphs in "Capacities and Characteristics" Article are integral to chiller controls. Retain "Flow Switches" paragraph below if additional flow protection is required by the application. Most applications do not require additional protection.

* + - * 1. Flow Switches:

Chiller manufacturer shall furnish a switch for each evaporator and [**condenser**] [**heat-reclaim condenser**] and verify field-mounting location before installation.

Retain "Paddle Flow Switches or "Pressure-Differential Switches" subparagraph below. Consult listed manufacturers for flow-switch requirements.

Paddle Flow Switches:

Vane operated to actuate a double-pole, double-throw switch, with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.

Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.

Pressure rating equal to pressure rating of heat exchanger.

Construct body and wetted parts of Type 316 stainless steel.

House switch in a NEMA 250, [**Type 4**] <**Insert type**> enclosure constructed of die-cast aluminum.

Vane length to suit installation.

Pressure-Differential Switches:

Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.

Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.

Set Point: Screw type, field adjustable.

Electrical Connections: Internally mounted screw-type terminal blocks.

Switch Enclosure: NEMA 250, [**Type 4**] <**Insert type**>.

Switch Action: Double-pole, double-throw switch, with one pole field wired to the chiller control panel and the other pole field wired to the DDC system for HVAC.

* + - * 1. Vibration Isolation:

Chiller manufacturer shall furnish vibration isolation for each chiller.

Retain "Neoprene Pad" or "Spring Isolator" subparagraph below if vibration isolation is to be furnished by chiller manufacturer. Coordinate requirements with vibration isolation specified in Section 230548 "Vibration and Seismic Controls for HVAC" and Section 230548.13 "Vibration Controls for HVAC."

Neoprene pads are acceptable for most noncritical vibration-sensitive applications if chillers are installed on grade. Spring isolators are common in applications where chillers are installed on elevated floors and isolation of vibration is critical.

Neoprene Pad:

Two layers of 0.375-inch- thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.

Fabricate pads from 40- to [**50**] [**60**] <**Insert number**>-durometer neoprene.

Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig with a 0.12- to 0.16-inch deflection.

Spring Isolator:

Stable in operation and designed for not less than 30 percent reserve deflection beyond actual operating conditions.

Isolators shall be designed so that the Kx/Ky ratio shall be 1.0 or more for stability.

Provide PVC or neoprene-coated springs and hot-dip, galvanized-steel components. Aluminum components shall be etched and painted. Nuts, bolts, and washers shall be zinc electroplated.

Isolators shall be adjustable and with an open spring, having one or more coil springs attached to a top compression plate and a baseplate.

An elastomeric pad with a minimum thickness of 0.25 inch shall be bonded to the baseplate.

Spring assembly shall be removable and fit within a welded-steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation.

Isolated restraining bolts shall not be engaged during normal operation and shall connect the top plate and lower housing to prevent the isolated equipment from rising when drained of fluid.

Isolators shall be selected for a nominal [**1-inch**] [**2-inch**] <**Insert dimension**> deflection.

Integrate seismic restraints in applications that require seismic requirements.

* + - * 1. Sound Barrier:

Retain first subparagraph below to make requirement for sound barrier conditional based on sound performance.

Provide sound barrier only if required to comply with sound requirements indicated.

Furnish removable and reusable sound-barrier covers over the compressor housing, hermetic motor, compressor suction and discharge piping, and condenser shell.

Provide for repeated installation and removal without use of tape or calk.

Inner and outer cover shall consist of a PTFE-impregnated fiberglass cloth enclosing heavy-density, needled fiberglass insulation material with a mass-loaded vinyl acoustic barrier.

Covers shall be double sewn and lock stitched, with edges folded and sewn so no raw cut edges are exposed.

Form covers around control devices, gages, conduit, piping, and supports without degrading sound-barrier performance.

Continuously lap all exposed seams at least 2 inches for better sound containment.

Permanently label each section of cover to indicate its location, description, size, and number sequence.

Randomly place stainless-steel quilting pins to prevent covers from shifting and sagging.

* + - 1. CAPACITIES AND CHARACTERISTICS

If Project has more than one centrifugal chiller, delete this article and schedule centrifugal chillers on Drawings.

* + - * 1. Capacity: <**Insert tons**>.

LEED 2009 Prerequisite EA 2 and LEED v4 Prerequisite "Minimum Energy Performance" require compliance with ASHRAE/IES 90.1. LEED 2009-NC, LEED 2009-CS, and LEED 2009 for Schools Credit EA 1 require efficiency in excess of minimum efficiency required by ASHRAE/IES 90.1. See "Sustainable Design Considerations" Article in the Evaluations for discussion on LEED prerequisites and credits.

* + - * 1. Full-Load Efficiency:

Retain one of five subparagraphs below. First subparagraph is used in ASHRAE/IES 90.1.

COP: <**Insert value**>.

EER: <**Insert value**>.

Power Input/Cooling Output: <**Insert kW/ton**>.

Comply with GS-31.

Comply with FEMP.

* + - * 1. Part-Load Efficiency:

Retain one of four subparagraphs below. Retain first subparagraph if operating conditions reference AHRI standard rating conditions; retain second subparagraph if operating conditions are other than AHRI standard rating conditions.

IPLV: <**Insert value**>.

NPLV: <**Insert value**>.

Comply with GS-31.

Comply with FEMP.

* + - * 1. Evaporator:

Pressure Rating: <**Insert psig**>.

Number of Passes: [**One**] [**Two**] [**Three**].

Fluid Type: [**Water**] <**Insert fluid type**>.

Design Fluid Flow Rate: <**Insert gpm**>.

Minimum Fluid Flow Rate: <**Insert gpm**>.

Entering-Fluid Temperature: <**Insert deg F**>.

Leaving-Fluid Temperature: <**Insert deg F**>.

Fluid-Pressure Drop: <**Insert feet of head**>.

Fluid Velocity: <**Insert fps**>.

Fouling factor units in "Fouling Factor" subparagraph below are consistent with AHRI 550/590; first option is based on AHRI 550/590 standard rating.

Fouling Factor: [**0.0001 sq. ft. x h x deg F/Btu**] [**0.00025 sq. ft. x h x deg F/Btu**] [**0.0005 sq. ft. x h x deg F/Btu**] <**Insert value**>.

* + - * 1. Condenser:

Pressure Rating: <**Insert psig**>.

Number of Passes: [**One**] [**Two**] [**Three**].

Fluid Type: [**Water**] <**Insert fluid type**>.

Design Fluid Flow Rate: <**Insert gpm**>.

Minimum Fluid Flow Rate: <**Insert gpm**>.

Entering-Fluid Temperature: <**Insert deg F**>.

Leaving-Fluid Temperature: <**Insert deg F**>.

Fluid-Pressure Drop: <**Insert feet of head**>.

Fluid Velocity: <**Insert fps**>.

Fouling factor units in "Fouling Factor" subparagraph below are consistent with AHRI 550/590; first option is based on AHRI 550/590 standard rating.

Fouling Factor: [**0.00025 sq. ft. x h x deg F/Btu**] [**0.0005 sq. ft. x h x deg F/Btu**] [**0.001 sq. ft. x h x deg F/Btu**] <**Insert value**>.

Retain "Heat-Reclaim Condenser" paragraph below if heat-reclaim condenser is required.

* + - * 1. Heat-Reclaim Condenser:

Pressure Rating: <**Insert psig**>.

Number of Passes: [**One**] [**Two**] [**Three**].

Fluid Type: [**Water**] <**Insert fluid type**>.

Design Fluid Flow Rate: <**Insert gpm**>.

Minimum Fluid Flow Rate: <**Insert gpm**>.

Entering-Fluid Temperature: <**Insert deg F**>.

Leaving-Fluid Temperature: <**Insert deg F**>.

Fluid-Pressure Drop: <**Insert feet of head**>.

Fluid Velocity: <**Insert fps**>.

Fouling factor units in "Fouling Factor" subparagraph below are consistent with AHRI 550/590; first option is based on AHRI 550/590 standard rating.

Fouling Factor: [**0.0001 sq. ft. x h x deg F/Btu**] [**0.00025 sq. ft. x h x deg F/Btu**] [**0.0005 sq. ft. x h x deg F/Btu**] <**Insert value**>.

* + - * 1. Compressor:

Number of Compressors: [**One**] [**Two**] <**Insert number**>.

Retain options in first two subparagraphs below for dual-compressor units.

[**First**]Compressor Rated-Load Amperes: <**Insert number**> A.

[**First**]Compressor Locked-Rotor Amperes: <**Insert number**> A.

Retain both subparagraphs below for dual-compressor units. Copy and repeat two subparagraphs below as required for additional compressors.

Second Compressor Rated-Load Amperes: <**Insert number**> A.

Second Compressor Locked-Rotor Amperes: <**Insert number**> A.

Retain "Chiller Control Electrical Requirements" paragraph below only if chiller is not provided with a single-point electrical power connection.

* + - * 1. Chiller Control Electrical Requirements:

Power Connections: [**Integral**] [**Field**].

Power Input: <**Insert number**> kW.

Minimum Circuit Ampacity: <**Insert number**> A.

Maximum Overcurrent Protection Device: <**Insert number**> A.

Volts: [**120**] <**Insert number**>-V ac.

Phase: [**Single**] [**Three**].

Hertz: 60.

* + - * 1. Chiller Electrical Requirements:

Power Input: <**Insert number**> kW.

Power Factor: [**0.90**] [**0.95**] <**Insert value**>.

Minimum Circuit Ampacity: <**Insert number**> A.

Maximum Overcurrent Protection Device: <**Insert number**> A.

Volts: [**208**] [**240**] [**480**] [**600**] [**2300**] [**4160**] <**Insert number**>-V ac.

Phase: Three.

Hertz: 60.

* + - * 1. Noise Rating: [**85**] <**Insert number**> -dBA sound power level when measured according to AHRI 575. Provide factory-installed sound treatment if necessary to achieve performance indicated.
      1. PACKAGED REFRIGERANT-RECOVERY UNITS

Retain this article to require chiller manufacturer to furnish a package refrigerant-recovery unit. Consult Director’s Representative regarding chiller service requirements and need for unit.

* + - * 1. Packaged portable unit consisting of compressor, air- or water-cooled condenser, recovery system, tank pressure gages, filter dryer, and valving that allows for switching between liquid- and vapor-recovery mode.
        2. Refrigerant-recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest chiller furnished.
        3. Units shall have lockable casters that permit rolling unit into position before locking position in place.
        4. Review chiller layout and provide refrigerant hoses of sufficient length to permit positioning of unit near chiller without compromising service access and safety.
        5. Water-cooled units shall have water hoses of sufficient length and pressure rating to permit positioning unit near chiller while connecting to closest field water source.
        6. Terminate hoses with quick-connect fittings and mating adapters.
        7. Unit shall have a power cord terminated with NEMA-rated plug suitable for unit power requirements.

Quantity of mating receptacle(s) shall be as required by application. [**Refer to Drawings for requirements**] <**Insert requirements**>.

Power cord shall be of sufficient length and rating to permit positioning unit near chiller while connecting to closest field power source. Power cord shall be not less than <**Insert length**> long.

* + - 1. HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM

Retain this article to require chiller manufacturer to furnish a brush-cleaning system. Brush-cleaning systems are used in applications with poor water quality. Consult water-treatment expert to evaluate need. Consult Director’s Representative.

* + - * 1. Factory-provided, field-installed, brush-cleaning system on each chiller [**condenser**] <**Insert heat exchanger**> for tube cleaning and improved heat transfer.
        2. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.
        3. System shall consist of a brush inserted into each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow, to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.
        4. Components:

Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed 0.025 inch.

Basket: Single-piece polypropylene basket with neck OD to press fit ID of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.

Four-Way Valve:

Construct valve body of carbon steel, with internal sealing parts of hard rubber and Type 304 stainless steel.

Configure valve with parallel flow connections to minimize field installation of piping.

Construct to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, at a system working pressure equal to that of condenser.

Pipe connections shall be flanged.

Valve manufacturer shall test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operating conditions of maximum differential pressure.

Hydrostatically test to 1.5 times the design working pressure.

Design the valve to cause no more than 0.5-psig pressure drop at design flow conditions.

Provide valve with valve-mounted indicating/warning light, which shall light before the valve begins rotation.

Retain one of two "Valve Actuator" subparagraphs below.

Valve Actuator: Mount electric actuator to operate valve.

Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.

Position Switches: Factory mount microswitches on the valve to indicate the complete turn of valve in both normal and reverse flow.

Control Panel: Factory or field mount a control panel on chiller. Control panel shall include the following features:

NEMA 250, [**Type 1**] [**Type 4**] [**Type 4x**] [**Type 12**] enclosure.

Timer to automatically initiate the cleaning cycle over a 24-hour period.

Manual override of preset cleaning cycle.

Visual indication of "Power On," "Diverter Position," "Normal Flow," "Reverse Flow," and "Valve Malfunction," indicating a slow turn or incomplete valve turn.

For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.

Flow switch bypass.

Unloading signal to chiller.

* + - 1. SOURCE QUALITY CONTROL

Not all manufacturers perform run tests of chillers. Consult manufacturers for availability.

* + - * 1. Perform functional [**run**]tests of chillers before shipping.

Retain "Factory Performance Testing" paragraph below for factory performance testing. Factory performance tests added cost. Consult Director’s Representative to confirm need for performance testing. Consult listed manufacturers for estimated cost of testing.

* + - * 1. Factory Performance Testing:

Factory performance test chillers, before shipping, according to AHRI 550/590.

Test the following conditions:

Design conditions indicated.

Retain one of first three subparagraphs below for part-load performance testing. Limit testing to only conditions required to validate chiller performance. Each test point adds cost and requires time to stabilize operation on test stand. Excessive testing provides little benefit and value to Director’s Representative.

Reduction in capacity from design to minimum load in steps of [**10**] [**25**] [**33**] <**Insert number**> with condenser fluid at design conditions.

Reduction in capacity from design to minimum load in steps of [**10**] [**25**] [**33**] <**Insert number**> with varying entering condenser-fluid temperature from design to minimum conditions in [**5 deg F**] <**Insert temperature**> increments.

At [**one**] [**two**] [**three**] [**four**] [**five**] [**10**] <**Insert number**> point(s) of varying part-load performance to be selected by Director’s Representative at time of test.

Retain first subparagraph below to witness testing.

Allow [**Director’s Representative**] <**Insert entity**> access to place where chillers are being tested. Notify Director’s Representative in writing at least [**30**] <**Insert number**> days in advance of testing.

Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

Retain "Factory Sound Testing" paragraph below for factory sound testing. Factory sound tests add cost and may not be available from some manufacturers. Consult Director’s Representative to confirm need for testing.

* + - * 1. Factory Sound Testing:

For chillers located indoors, rate sound power level according to AHRI 575.

Factory sound test chillers, before shipping, according to AHRI 575.

Test the following conditions:

Design conditions indicated.

Chiller operating at calculated worst-case sound condition.

Limit testing to only conditions required to validate chiller performance. Each test point adds cost and requires time to stabilize operation on test stand. Excessive testing provides little benefit and value to Director’s Representative.

At [**one**] [**two**] [**three**] [**four**] [**five**] <**Insert number**> point(s) of varying part-load performance to be selected by Director’s Representative at time of test.

Retain first subparagraph below to witness testing.

Allow [**Director’s Representative**] <**Insert entity**> access to place where chillers are being tested. Notify Director’s Representative in writing at least [**30**] <**Insert number**> days in advance of testing.

Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

Retain first paragraph below for chillers using R-134a refrigerant.

* + - * 1. Factory test and inspect evaporator [**and condenser**] [**, condenser, and heat-reclaim condenser**] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

Retain first paragraph below for chillers using R-123 refrigerant.

* + - * 1. Factory test and inspect evaporator [**and condenser**] [**, condenser and heat-reclaim condenser**] according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test fluid side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Pressure proof test refrigerant side of heat exchangers to a minimum of 45 psig. Vacuum and pressure test for leaks.

Retain "Eddy Current Testing" for applications that require field testing of tubes during chiller life cycle. Consult Director’s Representative regarding need for eddy current testing.

* + - * 1. Eddy Current Testing:

Perform factory testing of evaporator and condenser tubes of each chiller to ensure tube quality and longevity.

Submit test report, including, as a minimum:

List of equipment used and equipment settings.

Test data reports and accompanying strip charts of calibrations.

Identify tubes with significant defects and typical indications.

Statistical summary of defect indications.

Recommendations concerning tube condition, tube replacement, tube removal for evaluation, and future frequency of testing.

Approval by an American Society for Nondestructive Testing, Level III eddy current technician.

Retain "Director’s Representative Travel Expenses" paragraph below if travel expenses are to be included. Consult Director’s Representative.

* + - * 1. Director’s Representative Travel Expenses:

Include cost associated with Director’s Representative travel expenses to witness factory testing. Total value attributed to travel expenses shall be clearly indicated.

Expenses shall include roundtrip coach airfare, out-of-town hotel accommodations, out-of-town meals (breakfast, lunch, dinner), out-of-town ground transportation, and all associated taxes and fees.

Exclude other incidental expenses not indicated.

Include travel expenses for [**one**] [**two**] <**Insert number**> Director’s Representative representative(s) with origin of <**Insert city, state, country**>.

1. EXECUTION
   * + 1. EXAMINATION
          1. Examine chillers before installation. Reject chillers that are damaged.
          2. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, control and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.

Chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and control and electrical connections.

* + - * 1. Proceed with installation only after unsatisfactory conditions have been corrected.
      1. CHILLER INSTALLATION

Retain first paragraph below for mounting chillers on concrete bases.

* + - * 1. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.

Retain first paragraph below for mounting chillers on a structural-steel support structure.

* + - * 1. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

Retain first paragraph below if chillers are to be installed on a support structure other than a concrete base. Indicate design of support structure on Drawings.

* + - * 1. Install chillers on support structure indicated.
        2. Equipment Mounting:

Retain first subparagraph below to require equipment to be installed on cast-in-place concrete equipment bases.

Install chillers on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

Retain one of two subparagraphs below if vibration isolation and seismic-control devices are not furnished with chillers. Retain first for projects in seismic areas; retain second for projects not in seismic areas. Indicate vibration isolation and seismic-control device type and minimum deflection in supported equipment schedule on Drawings.

Comply with requirements for vibration isolation and seismic-control devices specified in Section 230548 "Vibration and Seismic Controls for HVAC."

Comply with requirements for vibration isolation devices specified in Section 230548.13 "Vibration Controls for HVAC."

* + - * 1. Maintain manufacturer's recommended clearances for service and maintenance.
        2. Maintain clearances required by governing code.
        3. Chiller manufacturer's factory-trained service personnel shall charge chiller with refrigerant and fill with oil if not factory installed.
        4. Install separate devices furnished by manufacturer and not factory installed.

Chillers shipped in multiple major assemblies shall be field assembled by chiller manufacturer's factory-trained service personnel.

* + - 1. HEAT-EXCHANGER, BRUSH-CLEANING SYSTEM INSTALLATION

Retain this article for installation of heat-exchanger, brush-cleaning system. Coordinate with "Heat-Exchanger, Brush-Cleaning System" Article.

* + - * 1. Install brush-cleaning system control panel adjacent to chiller control panel.
        2. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
        3. Install field electric power, as required, to each system control panel and electric actuated valve.
        4. Install pneumatic piping with pressure regulator and isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.
        5. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
        6. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.
      1. PACKAGED REFRIGERANT-RECOVERY UNIT INSTALLATION

Retain this article for installation of packaged refrigerant-recovery unit. Coordinate with "Packaged Refrigerant-Recovery Units" Article.

* + - * 1. Install field electric power as required for unit furnished. Install power connections at multiple locations as recommended by chiller manufacturer for unit to service chillers indicated. Install receptacle(s) furnished with unit.
        2. Install field water source as required for unit furnished. Install connections at multiple locations as recommended by chiller manufacturer for unit to service chillers indicated. Terminate connections with valves.
        3. Install quick-connect adapters furnished with unit.
        4. Functionally test unit for proper operations with field connections to power and water, as applicable.
      1. PIPING CONNECTIONS

Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified for piping systems. If Drawings are explicit enough, these requirements may be reduced or omitted.

* + - * 1. Comply with requirements for piping specified in Section 232113 "Hydronic Piping," Section 232116 Hydronic Piping Specialties," and Section 232300 "Refrigerant Piping." Drawings indicate general arrangement of piping, fittings, and specialties.
        2. Where installing piping adjacent to chillers, allow space for service and maintenance.
        3. Evaporator-Fluid Connections:

Connect to evaporator inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage.

Connect to evaporator outlet with shutoff valve, balancing valve,[**flexible connector,**] thermometer, plugged tee with shutoff valve and pressure gage,[**flow meter,**] and drain connection with valve.

Make connections to chiller with a [**flange**] [**mechanical coupling**] [**flange or mechanical coupling**].

* + - * 1. Condenser-Fluid Connections:

Connect to condenser inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage.

Connect to condenser outlet with shutoff valve, balancing valve,[**flexible connector,**] thermometer, plugged tee with shutoff valve and pressure gage,[**flow meter,**] and drain connection with valve.

Make connections to chiller with a [**flange**] [**mechanical coupling**] [**flange or mechanical coupling**].

Retain "Heat-Reclaim Condenser-Fluid Connections" paragraph below for chiller equipped with a heat-reclaim condenser.

* + - * 1. Heat-Reclaim Condenser-Fluid Connections:

Connect to condenser inlet with shutoff valve, [**strainer,**] [**flexible connector,**] thermometer, and plugged tee with pressure gage.

Connect to condenser outlet with shutoff valve, balancing valve,[**flexible connector,**] thermometer, plugged tee with shutoff valve and pressure gage,[**flow meter,**] and drain connection with valve.

Make connections to chiller with a [**flange**] [**mechanical coupling**] [**flange or mechanical coupling**].

* + - * 1. Refrigerant-Pressure Relief Device Connections:

For chillers installed indoors, extend [**vent piping**] [**separate vent piping for each chiller**] to the outdoors without valves or restrictions.

Comply with ASHRAE 15.

Connect to chiller pressure relief device with flexible connector and dirt leg with drain valve.

* + - * 1. For chillers equipped with a purge system, extend [**purge vent piping**] [**separate purge vent piping for each chiller**] to the outdoors. Comply with ASHRAE 15 and ASHRAE 147.
        2. Connect each chiller drain connection with a drain valve, which is full size of drain connection. [**Connect drain pipe to drain valve with union, and extend drain pipe to terminate over floor drain.**]
        3. Connect each chiller water box vent connection with an [**automatic**] [**or**] [**manual**] vent, which is full size of vent connection.
      1. ELECTRICAL POWER CONNECTIONS
         1. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
         2. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
         3. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection. Nameplate shall be laminated phenolic layers of black with engraved white letters at least 1/2 inch high. Locate nameplate where easily visible.
      2. CONTROLS CONNECTIONS
         1. Install control and electrical power wiring to field-mounted control devices.
         2. Connect control wiring between chillers and other equipment to interlock operation as required to provide a complete and functioning system.

Retain first paragraph below to connect chillers to control system for remote monitoring and control.

* + - * 1. Connect control wiring between chiller control interface and [**DDC control system**] <**Insert system description**> for remote monitoring and control of chillers. Comply with requirements in [**Section 230923 "Direct Digital Control (DDC) System for HVAC."**] <**Insert Section.**>
        2. Install nameplate on face of chiller control panel indicating the control equipment designation serving chiller and the I/O point designation for each control connection. Nameplate shall be laminated phenolic layers of black with engraved white letters at least 0.5 inch high.
      1. STARTUP SERVICE
         1. Engage a Company Field Advisor per OGS Spec Section 014216 to perform startup service.

Complete installation and startup checks according to manufacturer's written instructions.

Verify that refrigerant charge is sufficient and chiller has been leak tested.

Verify that pumps are installed and functional.

Verify that thermometers and gages are installed.

Operate chiller for run-in period.

Retain first subparagraph below for oil-lubricated chillers.

Check bearing lubrication and oil levels.

Verify that refrigerant pressure relief device is vented outside.

Verify proper motor rotation.

Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.

Verify and record performance of fluid flow and low-temperature interlocks for evaporator[**and condenser**] [**, condenser, and heat-reclaim condenser**].

Verify and record performance of chiller protection devices.

Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

* + - * 1. Inspect field-assembled components, equipment installation, piping, controls and electrical connections for proper assembly, installation, and connection.
        2. Visually inspect chiller for damage before starting. Repair or replace damaged components, including insulation. Do not start chiller until damage that is detrimental to operation has been corrected.
        3. Prepare test and inspection startup reports.
      1. WARRANTY PERIOD TESTING

Retain this article for applications requiring field testing and analysis to validate proper equipment operation. Consult Director’s Representative regarding need for testing and testing requirements.

* + - * 1. Within [**one**] <**Insert number**> month(s) of warranty period expiration, perform testing, analysis, and reporting indicated for each chiller.
        2. Eddy Current Testing:

Solicit services of a third-party testing agency, specializing in such analysis, to perform testing of evaporator and condenser tubes, to ensure tube quality and longevity.

Submit test report to Director’s Representative, including, as a minimum:

List of equipment used and equipment settings.

Test data reports and accompanying strip charts of calibrations.

Identify tubes with significant defects and typical indications.

Statistical summary of defect indications.

Recommendations concerning tube condition, tube replacement, tube removal for evaluation, and future frequency of testing.

Approval by an American Society for Nondestructive Testing, Level III eddy current technician.

Retain "Oil Analysis" paragraph below for oil-lubricated chillers only.

* + - * 1. Oil Analysis:

Take oil sample and solicit services of a third-party testing agency, specializing in such analysis, to perform oil analysis.

Submit analysis results and recommendations to Director’s Representative.

* + - * 1. Refrigerant Analysis:

Take refrigerant sample and solicit services of a third-party testing agency, specializing in such analysis, to perform refrigerant analysis.

Submit analysis results and recommendations to Director’s Representative.

* + - * 1. Site Access and Scheduling:

Contact Director’s Representative to schedule testing at least 30 days in advance of testing.

Make mutually agreeable schedule adjustments to accommodate Director’s Representative's request for testing.

Review, with Director’s Representative, requirements for visitors in advance of testing.

Comply with Director’s Representative requirements for visitors while on-site.

* + - 1. DEMONSTRATION
         1. Engage a Company Field Advisor per OGS Spec Section 014216 to train Facility’s maintenance personnel to adjust, operate, and maintain chillers.[**Video record the training sessions and provide electronic copy to Director’s Representative.**]

Instructor shall be factory trained and certified.

Retain one of first two subparagraphs below. Retain first subparagraph to require training that lasts eight hours or less. Retain second paragraph to require training exceeds eight hours.

Provide not less than [**eight**] <**Insert number**> hours of training.

Provide not less than [**16**] <**Insert number**> hours of training spread across consecutive days, not to exceed [**eight**] <**Insert number**>hours per day.

Train personnel in operation and maintenance and to obtain maximum efficiency in plant operation.

Provide instructional videos showing general operation and maintenance that are coordinated with operation and maintenance manuals.

Obtain Director’s Representative sign-off that training is complete.

Facility’s maintenance personnel training shall be held at Project site.

END OF SECTION 236416