Facility Design Guidelines: Workplace, Architecture & Engineering

**Centrifugal Chiller**
MasterFormat Section 23-70-00

The guidelines described herein shall be used on all projects, unless USAA’s Project Variance Request process has been used to secure an approved, project-specific variance.

### GENERAL DESCRIPTION

Provide a complete, semi-hermetic, oil free centrifugal compressor, refrigerant, condenser, evaporator, and control systems including integrated variable frequency drive, operating controls and equipment protection. Chiller shall be fully charged with refrigerant. The chiller system, including all pressure vessels shall remain above atmospheric pressure during all operating conditions and during shut down to ensure that non-condensable and moisture do not contaminate the refrigerant and chiller system. **When an air-cooled chiller is required, omit water side guidelines.**

Manufacturer must submit for owner’s review, a life cycle cost analysis using IPLV, full and part load, kW/ton performance data, local electrical utility cost for each load and first cost for the chiller being submitted including any options to qualify for this guideline.

### 1.0 FACTORY ACCEPTANCE TESTING

A. The performance test shall be run with clean tubes in accordance with AHRI 550/590.
B. One representative from both the owner and the engineer shall witness test and each will cover the cost of food, lodging and any other cost related to Factory Acceptance Testing.
C. AHRI Points Test: Factory test each chiller for capacity and efficiency at the four standard AHRI rating points:
   1. 100% load and 85 F entering condenser water temperature (ECWT) and design flow rates.
   2. 75% load and 75 F ECWT and design flow rates.
   3. 50% load and 65 F ECWT and design flow rates.
   4. 25% load and 65 F ECWT and design flow rates.
   5. 25% load and 55 F ECWT and design flow rates.
D. Cold Condenser Water Test: Factory test each chiller for capacity and efficiency at the four standard AHRI rating points:
   1. 100% load and 55 F ECWT and design flow rates.
2. 75% load and 55 F ECWT and design flow rates.
3. 50% load and 55 F ECWT and design flow rates.
4. 25% load and 55 F ECWT and design flow rates.

E. Extended Duration Test: Factory test each chiller for capacity and efficiency at the four standard AHRI rating points for four hours:
   1. 100% load and 85 F (ECWT) and design flow rates.
   2. 75% load and 75 F ECWT and design flow rates.
   3. 50% load and 65 F ECWT and design flow rates.
   4. 25% load and 65 F ECWT and design flow rates.

F. The chiller shall be deemed acceptable if the tests are conducted in conformance with AHRI Standards and the required tolerances are satisfied.

1.2 DELIVERY, STORAGE AND HANDLING

A. Delivery:
   a. Unit shall be delivered to job site fully assembled with all interconnecting refrigerant piping and internal wiring ready for field installation and charged with refrigerant and oil by the Manufacturer.

B. Handling:
   a. Ship unit completely shrink-wrapped on a skid.
   b. Provide additional protective covering over vulnerable components
   c. fit nozzles and open ends with plastic enclosures.

C. Storage:
   a. Unit shall be stored and handled per Manufacturer’s instructions.

D. Rigging:
   a. Comply with manufacturer’s rigging and installation instructions.

1.3 WARRANTY

A. Product Warranty:
   a. Manufacturer shall Warrant all equipment and material of its manufacture against defects in workmanship and material for specified warranty period.
   b. Warranty shall include all part and labor, including refrigerant and oil charge.

B. Maintenance Service during Warranty Period:
   a. All inspections and service of units shall be accomplished by factory trained and authorized servicing technicians.
   b. All labor for leak checking the chiller per the manufacturer's IOM and documentation must be included.
   c. In conjunction with and supporting Factory warranty OEM shall furnish complete factory authorized service and maintenance for applied chillers for the duration of the warranty period.
   d. All work shall be done by manufacturer's commercial warranty agent.
   e. OEM shall provide and report quarterly, semiannual, and annual maintenance in compliance with or better than ASHRAE Standard 180-2008.
f. Include maintenance items as recommended in manufacturer's operating and maintenance data.
g. Submit copy of service call work orders and summary report to the owner, including description of work performed, operating performance status and noted exceptions.

C. Warranty Period: Two years from date of project Substantial Completion.
   a. Optional- Provide alternate cost to increase warranty to three, four, and five years from date of project Substantial Completion.

PART 2 PRODUCTS

2.0 GENERAL
   A. Manufacturers: Subject to compliance with requirements, manufacturers offering products which may be incorporated in the work, shall be limited to the following:
      1. Trane
      2. York
      3. Carrier
      4. McQuay
   B. General: Provide factory assembled charged, and tested water-cooled packaged centrifugal chiller.
   C. Refrigerant: The chiller shall be pressure tested, evacuated and fully charged with refrigerant and oil.
   D. Capacity Modulation: Provide capacity modulation capable of providing 15% of rated unit capacity, without the need for hot-gas bypass.

2.2 COMPRESSOR

   A. Compressor: The unit shall utilize hermetic or semi-hermetic centrifugal compressors.
      1. The impeller shall be designed for balanced thrust, dynamically balanced, and over-speed tested for smooth, vibration free operation.
      2. Compressor castings shall be designed for 235 psig working pressure and hydrostatically pressure tested at 355 psig for HFC-134a units.
      3. Capacity control shall be achieved by the combined use of variable speed control and mechanical flow regulation to provide fully modulating control from maximum to minimum load. The unit shall be capable of operating with lower temperature cooling tower water during part-load operation in accordance with AHRI standard 550/590. All capacity control devices shall be automatically controlled to maintain a constant leaving chilled water temperature.
      4. The housing will be fully accessible with vertical circular joints, with the complete operating assembly removable form the compressor housing.
   B. Lubrication System: Lubrication oil shall be force fed to all compressor bearings, gears, and rotating surfaces. An oil reservoir, separate from the compressor shall contain a submersible oil pump and oil heater, thermostatically controlled to remove refrigerant from the oil.
C. Motor: The compressor motor shall be a hermetic or semi-hermetic, oil free, permanent magnet type directly coupled to the compressor. The motor shall be bolted to a cast iron adapter plate mounted on the compressor to provide factory alignment of the shaft. Overload/overcurrent transformers will be furnished with all units.

2.3 EVAPORATOR

A. Provide shell and tube type evaporator with 2 pass arrangement, designed, constructed, tested and stamped according to the requirements of the ASME Code, Section VIII. The refrigerant side shall be designed for a minimum of 180 psig.

B. The evaporator shall be flooded type with minimum 0.028 in wall copper tubes rolled into carbon steel tubesheets. The tubes shall be individually replaceable.
   1. A suction baffle eliminator shall be located above the tube bundle to prevent liquid refrigerant carryover to the compressor.
   2. Provide evaporator complete with a refrigerant sight glass.
   3. Evaporator shall be complete with a refrigerant relief device, in accordance ASHRAE 15 requirements.

C. The evaporator shall be equipped with hinged marine waterbox to facilitate removal of the endplate without disconnecting the chilled water piping from the chiller.
   1. Evaporator marine waterbox shall be complete with factory welded, raised face flanged connections, located at 12 o’clock and 3 o’clock. Victaulic flange adapter kits shall not be acceptable.
   2. Internal surfaces of the evaporator heads and water boxes shall be epoxy coated for corrosion protection.
   3. Provide marine water boxes complete with vent and drain connections, complete with ball valve, cap and chain.

D. Evaporator barrel and water boxes shall be fully insulated with two layers of 3/4” thick elastomeric foam. Insulation shall be constructed from sheets, cut and form-fitted to the unit, applied in the factory with pressure sensitive adhesive and vapor proof cement.
   1. Insulation shall be painted in the factory to match color of the chiller.

2.4 CONDENSER

A. Provide shell and tube type condenser with 2 pass arrangement, designed, constructed, tested and stamped per the requirements of the ASME Code, Section VIII. The water side shall be designed for a minimum of 150 psig.

B. The condenser shall be flooded type with minimum 0.028 in wall copper tubes rolled into carbon steel tubesheets. The tubes shall be individually replaceable.
1. Condenser shall be complete with a refrigerant relief device, in accordance ASHRAE 15 requirements.

C. The condenser shall be equipped with hinged marine waterbox to facilitate removal of the endplate without disconnecting the condenser water piping from the chiller.
   1. Condenser marine waterbox shall be complete with factory welded, raised face flanged connections, located at 12 o’clock and 9 o’clock. Victaulic **flange adapter kits shall not be acceptable**.
   2. Internal surfaces of condenser heads and waterboxes shall be epoxy coated for corrosion protection.
   3. Provide marine water boxes complete with vent and drain connections, complete with ball valve, cap and chain.

2.5 REFRIGERANT


B. Refrigerant flow between the condenser and evaporator shall be controlled by variable orifice or an electronic expansion valve. Refrigerant liquid level in the condenser shall be monitored and the refrigerant flow device shall modulate as necessary to optimize the sub-cooler performance. Liquid line shall be complete with a moisture indicating sight glass.

C. Factory provide, positive shutoff refrigerant isolation valves shall be installed in the compressor discharge line and refrigerant liquid line. These valves shall facilitate isolation and storage of the refrigerant within the condenser, without the need for pump out.

2.6 REFRIGERANT LEAK DETECTION AND MONITORING

A. Refer to Building Automation Integration guidelines.

2.7 POWER AND ELECTRICAL REQUIREMENTS

A. Unit shall be provided with a single point power connection.

B. Starters: A factory installed, unit-mounted VFD shall be provided in lieu of a conventional chiller starter.

C. Controls: No field wiring shall be required. Instead, the chiller shall be provided complete with factory installed control wiring between the controller and the VFD.

D. Conductors: Only copper conductors shall be connected to the compressor. Flexible liquid-tight conduit shall be used for the last 2-3 feet to the chiller to allow for vibration isolation. Flexible metal conduit shall not be permitted.

E. MCA: Furnished chillers shall not exceed scheduled Minimum Circuit Ampacity.
2.8 VARIABLE FREQUENCY DRIVE

A. General: A VFD shall be factory installed on the chiller to vary the compressor motor speed by controlling the frequency and voltage of the electrical power to the motor. The capacity control logic shall automatically adjust motor speed for maximum part-load efficiency by analyzing information fed to it by sensors located throughout the chiller.

1. The VFD efficiency shall be 95% or better at full speed and full load. Fundamental displacement power factor shall be a minimum of 0.95.
2. The VFD shall be Pulse Width Modulation type, utilizing IGBT’s with a displacement power factor of 0.97 or better at all loads and speeds.
3. The VFD shall be unit mounted in a NEMA-1 enclosure with all power and control wiring between the drive and chiller factory installed. Field power wiring shall be a single point connection and electrical lugs for incoming power wiring shall be provided.
4. The VSD shall be complete with circuit breaker and shunt trip, and have a minimum a short circuit withstand rating of 65,000 amps per UL 508. All control circuit voltages shall be physically and electrically isolated from power circuit voltage, equipped with adjustable current limiting and UL approved electronic motor overload protection.
5. The entire chiller package shall be UL listed.

B. VFD and Motor Protection: The chiller VFD shall be complete with protection for the following faults:

1. Output line-to-line short circuit protection
2. Line-to-ground short circuit protection
3. Phase loss at VFD input
4. Phase reversal / Imbalance
5. Over-voltage / Under-voltage
6. Over temperature

C. VFD Cooling: The VFD shall be cooled using air, refrigerant, or condenser water. All cooling connections shall be factory installed.

D. VFD Harmonics: The VFD shall be provided in accordance with IEEE Standard 519-1992. Each VFD shall require an active harmonic filter with a maximum of 5% total harmonic distortion.

E. VFD Metering: The chiller display shall include real-time VFD performance information, including but not limited to the following:

1. Output frequency and voltage
2. Input kVA, 3-phase input current and 3-phase output current
3. kW and kWh
4. Input voltage THD and Input current TDD

2.9 SOUND CRITERIA
A. Sound levels shall meet the maximum scheduled sound levels. If chiller does not meet sound levels, chiller manufacturer shall provide additional attenuation features.

B. Provide acoustical sound power or sound pressure level data in decibels (dB) at the eight (8) octave band center frequencies. A-weighted sound data alone is not acceptable.

C. Provide all sound power or sound pressure level data at 100%, 75%, 50%, and 25% load.

D. Acoustical performance ratings shall be in accordance with AHRI Standard 370.

2.10 CONTROLLER

A. The unit shall have a microprocessor-based control system consisting of a large VGA touch-screen operator interface and a unit controller.

B. The touch-screen shall display the unit operating parameters, accept setpoint changes (multi-level password protected) and be capable of resetting faults and alarms. The following parameters shall be displayed on the home screen and also as trend curves on the trend screen:
   1. Entering and leaving chilled and condenser water temperatures
   2. Evaporator and condenser saturated refrigerant pressures
   3. Percent of 100% speed (per compressor)
   4. Percent of 100 rated load amps for entire unit
   5. Operating hours
   6. Number of compressor starts
   7. Oil reservoir temperature
   8. Percent motor current

C. In addition to the trended items above, all other important real-time operating parameters shall also be shown on the touch-screen. These items shall be displayed on a chiller graphic showing each component. At a minimum, the following critical areas must be monitored:
   1. Compressor actual speed, maximum speed, percent speed
   2. Evaporator water in and out temperatures, refrigerant pressure and temperature
   3. Condenser water in and out temperatures, refrigerant pressure and temperature
   4. Liquid line temperature
   5. Chilled water setpoint
   6. Compressor and unit state and input and output digital and analog values

D. A fault history shall be displayed using an easy to decipher, color coded set of messages that are date and time stamped. The alarm history shall be downloadable from the unit’s USB port. An operating and maintenance manual specific for the unit shall be viewable on the screen and downloadable.
E. All setpoints shall be viewable and changeable (multi-level password protected) on the touch screen and include setpoint description and range of set values.

F. Automatic corrective action to reduce unnecessary cycling shall be accomplished through preemptive control of low evaporator or high discharge pressure conditions to keep the unit operating through abnormal transient conditions.

G. The information communicated between the BAS and the factory mounted unit controllers shall include the reading and writing of data to allow unit monitoring, control and alarm notification as specified in the unit sequence of operation and the unit points list.

H. All communication from the chiller unit controller as specified in the points list shall be via standard BACnet® objects. Proprietary BACnet® objects shall not be allowed. BACnet® communications shall conform to the BACnet® protocol (ANSI/ASHRAE135-2001). A BACnet® Protocol Implementation Conformance Statement (PICS) shall be provided along with the unit submittal.

2.11 ACCESSORIES AND OPTIONS

A. Flow Switch: Provide differential pressure switch, in lieu of thermal dispersion or paddle flow switch.

B. Communications Interface: Provide BACnet/IP or Modbus TCP interface via Ethernet, for communication to the BAS (Siemens).
   1. Remote Input/Outputs: Provide hardwired communications points for use by the BAS.
   2. Provide each chiller with hardware required for interface with the manufacturer provided system monitoring interface.

C. Variable Flow Control: Chiller shall be capable of supporting variable water flowrates.

D. Vibration Isolation: Chiller shall be provided with neoprene pads sized to support the chiller’s operating weight. Isolation pads shall consist of a heavy gauge galvanized plate sandwiched between two-layers of 1/2" thick ribbed neoprene pads, located at the corners of the chiller, unless otherwise noted.

E. Energy efficient hot gas by-pass system will be supplied for operation down to 10% of design load. The hot gas by-pass shall be completely factory piped and wired. It will consist of a hot gas valve, external electric operator and linkage, and a solid-state sensing control. This control will measure entering and leaving chilled water temperature to indicate load and measure refrigerant condensing temperature to indicate head. These signals shall be compared to a adjustable point to activate the hot gas valve. Hot gas will be actuated only when necessary and in only the amount required for stable and efficient chiller operation.

2.12 FACTORY START-UP
A. Factory start-up services shall be provided for as long a time as necessary to ensure proper operation of the unit, but in no case for less than two 8-hour days.

B. Following the successful start-up, the chiller technician shall return to the site to support the commissioning effort. This effort will likely occur during off-hours and will extended well beyond a normal 8-hour workday.

**PART 3 EXECUTION**

A. General: Install chillers in accordance with manufacturer’s installation instructions.

B. Support: Install chillers on housekeeping pad, with specified vibration isolation.

C. Electrical Wiring: Install electrical devices furnished by manufacturer in conformance with the requirements of Division-26.

D. Controls: Coordinate field installed automatic temperature controls with Division-23 section "Building Automation System Guidelines."

E. Start up: Provide the services of the manufacturer’s factory trained service representative to start up all chillers. Start-up by any organization other than the manufacturer is unacceptable.

F. Field Tests: Test controls and chiller operation. Replace damaged or malfunctioning controls and equipment. Field tests during chiller installation and start-up tests shall not be considered as fulfilling requirements of commissioning tests.

G. Refrigerant Pressure Relief: Refrigerant pressure relief piping shall be extended, where required, to a discharge point that is a minimum of twenty feet from any building opening (i.e. windows, ventilation openings, doors, etc.)

**3.2 COMMISSIONING, TESTING AND VERIFICATION**

A. System Commissioning Tests: Meet the requirements of Division-01 “General Commissioning” and Division-23 Sections “HVAC Commissioning”.

B. Preparation: Before the scheduled commissioning tests, the Contractor and/or the manufacturer’s representative shall have prepared the chillers in accordance with the recommendations of the manufacturer for start-up and operations.

C. Operational Control Test:

1. Manufacturer’s certified representative shall fully participate in the chiller site acceptance testing. Include a minimum of (1) 12 hour day on site to support the commissioning effort

2. Demonstrate proper functioning of the entire operational control of the chiller. Included in the verifications, but not limited to, are oil pumps, liquid line solenoid valves, crankcase heaters, thermal expansion valves, chilled water and condenser water flow switches, and adjustable temperature controllers.
3. The chillers must demonstrate stable operation without excess vibration and noise. Each step of the multi-step control (cylinder unloading and/or compressor staging) must be verified.

4. Demonstrate proper operation of remote control of starting, stopping and resetting of the unit.

D. Safety Control Tests:
1. Demonstrate proper functioning of all safety cutouts.
2. Demonstrate that manual resetting is required to restart for all safety cutouts.
3. Demonstrate proper operation of interlocking between chillers and chilled water pumps.
4. Variables to activate safety control actions may be simulated.
5. All safety control tests must be verified by electric signals at the compressor motor starters or actual stopping of the compressors.

E. Running and Warning Indicators Test:
1. Demonstrate proper functioning of all indicating lights (where applicable).
2. Testing of running and warning indicators (where applicable) may be performed concurrently with safety control tests.

3.3 TRAINING OF PERSONNEL

A. Training: Provide the services of the manufacturer’s technical representative for one 8-hour day to instruct personnel in the operation and maintenance of mag chillers. Schedule training with owner, providing at least thirty days’ notice.