
USACE / NAVFAC / AFCEC / NASA UFGS-23 64 10 (August 2008)
Change 3 - 08/15

Preparing Activity: NAVFAC Superseding
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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2016

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DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 64 10

WATER CHILLERS, VAPOR COMPRESSION TYPE

08/08

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SECTION 23 64 10

WATER CHILLERS, VAPOR COMPRESSION TYPE 08/08

NOTE: This guide specification covers the requirements for water chilling equipment.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

PART 1 GENERAL

1.1 REFERENCES

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically
be deleted from this section of the project
specification when you choose to reconcile
references in the publish print process.

The publications listed below form a part of this specification to the
extent referenced. The publications are referred to within the text by the
basic designation only.

AIR-CONDITIONING, HEATING AND REFRIGERATION INSTITUTE (AHRI)

AHRI 450	(2007) Water-Cooled Refrigerant Condensers, Remote Type
AHRI 480	(2007) Refrigerant-Cooled Liquid Coolers, Remote Type
AHRI 550/590 I-P	(2011; Addendum 1 2012; Addendum 2-3 2013) Performance Rating Of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle
AHRI 575	(2008) Method of Measuring Machinery Sound Within an Equipment Space
AHRI 740	(1998) Refrigerant Recovery/Recycling Equipment
ANSI/AHRI 460	(2005) Performance Rating of Remote Mechanical-Draft Air-Cooled Refrigerant Condensers
ANSI/AHRI 495	(2005) Performance Rating of Refrigerant Liquid Receivers

AMERICAN BEARING MANUFACTURERS ASSOCIATION (ABMA)

ABMA 11	(2014) Load Ratings and Fatigue Life for Roller Bearings
ABMA 9	(2015) Load Ratings and Fatigue Life for Ball Bearings

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING
ENGINEERS (ASHRAE)

ANSI/ASHRAE 15 & 34	(2013; Addenda A 2014; ERTA 1 2014; ERTA 2 2015; INT 1 2015; ERTA 3 2015) ANSI/ASHRAE Standard 15-Safety Standard for Refrigeration Systems and ANSI/ASHRAE Standard 34-Designation and Safety Classification of Refrigerants
ASHRAE 64	(2011) Methods of Testing Remote Mechanical-Draft Evaporative Refrigerant Condensers

ASHRAE 90.1 - IP	(2010) Energy Standard for Buildings Except Low-Rise Residential Buildings
ASHRAE 90.1 - SI	(2010) Energy Standard for Buildings Except Low-Rise Residential Buildings
AMERICAN WELDING SOCIETY (AWS)	
AWS Z49.1	(2012) Safety in Welding and Cutting and Allied Processes
ASME INTERNATIONAL (ASME)	
ASME BPVC SEC VIII D1	(2010) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1
ASTM INTERNATIONAL (ASTM)	
ASTM A307	(2014) Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
ASTM A53/A53M	(2012) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM B117	(2011) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM D520	(2000; R 2011) Zinc Dust Pigment
ASTM E84	(2015b) Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM F104	(2011) Standard Classification System for Nonmetallic Gasket Materials
NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)	
NEMA MG 1	(2014) Motors and Generators
NEMA MG 11	(1977; R 2012) Energy Management Guide for Selection and Use of Single Phase Motors
NEMA SM 23	(1991; R 2002) Steam Turbines for Mechanical Drive Service
NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)	
NFPA 37	(2015) Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines
NFPA 54	(2015) National Fuel Gas Code
SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)	
SAE J537	(2011) Storage Batteries

UNDERWRITERS LABORATORIES (UL)

UL 1236

(2015) Standard for Battery Chargers for
Charging Engine-Starter Batteries

1.2 SUBMITTALS

NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

An "S" following a submittal item indicates that the submittal is required for the Sustainability Notebook to fulfill federally mandated sustainable requirements in accordance with Section 01 33 29 SUSTAINABILITY REPORTING.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Water Chiller; G[, [_____]]

Manufacturer's standard catalog data, at least highlighted to show material, size, options, performance charts and curves including full-load and IPLV efficiencies (DOE PL-109-58), etc. in adequate detail to demonstrate compliance with contract requirements. Data shall include manufacturer's recommended installation instructions and procedures. Data shall be adequate to demonstrate compliance with contract requirements as specified within the paragraphs:

- a. Water Chiller
- b. Chiller Components
- c. Refrigerant - Provide MSDS sheets for all refrigerants
- d. Accessories

If vibration isolation is specified for a unit, vibration isolator literature shall be included containing catalog cuts and certification that the isolation characteristics of the isolators provided meet the manufacturer's recommendations.

NOTE: Posted instructions to be used for Army projects only.

[Posted Instructions

Posted instructions, including equipment layout, wiring and control diagrams, piping, valves and control sequences, and typed condensed operation instructions. The condensed operation instructions shall include preventative maintenance procedures, methods of checking the system for normal and safe operation, and procedures for safely starting and stopping the system. The posted instructions shall be framed under glass or laminated plastic and be posted where indicated by the Contracting Officer.

] Verification of Dimensions

A letter including the date the site was visited, conformation of existing conditions, and any discrepancies found.

Manufacturer's Multi-Year Compressor Warranty

Manufacturer's multi-year warranty for compressor(s) in air-cooled water chillers as specified.

Factory Tests

Schedules which identify the date, time, and location for each test. Schedules shall be submitted for both the Chiller Performance Test and the Chiller Sound Test. [The Chiller Performance Test schedule shall also allow the witnessing of the test by a Government Representative.]

System Performance Tests

A schedule, at least [2] [_____] weeks prior to the start of

related testing, for the system performance tests. The schedules shall identify the proposed date, time, and location for each test.

Demonstrations

A schedule, at least [2] [_____] weeks prior to the date of the proposed training course, which identifies the date, time, and location for the training.

Water Chiller - Field Acceptance Test Plan

SD-06 Test Reports

Field Acceptance Testing

Water Chiller - Field Acceptance Test Report

Factory Tests

[Six] [_____] copies of the report shall be provided in bound 216 by 279 mm 8 1/2 by 11 inch booklets. Reports shall certify the compliance with performance requirements and follow the format of the required testing standard for both the Chiller Performance Tests and the Chiller Sound Tests. Test report shall include certified calibration report of all test instrumentation. Calibration report shall include certification that all test instrumentation has been calibrated within 6 months prior to the test date, identification of all instrumentation, and certification that all instrumentation complies with requirements of the test standard. Test report shall be submitted [1] [_____] week after completion of the factory test.

System Performance Tests

[Six] [_____] copies of the report shall be provided in bound 216 by 279 8 1/2 by 11 inch booklets.

SD-07 Certificates

Refrigeration System; G[, [_____]]

Where the system, components, or equipment are specified to comply with requirements of AGA, NFPA, AHRI, ASHRAE, ASME, or UL, [1] [_____] copy of proof of such compliance shall be provided. The label or listing of the specified agency shall be acceptable evidence. In lieu of the label or listing, a written certificate from an approved, nationally recognized testing organization equipped to perform such services, stating that the items have been tested and conform to the requirements and testing methods of the specified agency may be submitted. When performance requirements of this project's drawings and specifications vary from standard AHRI rating conditions, computer printouts, catalog, or other application data certified by AHRI or a nationally recognized laboratory as described above shall be included. If AHRI does not have a current certification program that encompasses such application data, the manufacturer may self certify that his application data complies with project performance requirements in accordance with the specified test standards.

SD-08 Manufacturer's Instructions

Water Chiller - Installation Instruction; G[, [____]]

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G[, [____]]

[Six] [____] complete copies of an operation manual in bound 216 by 279 8 1/2 by 11 inch booklets listing step-by-step procedures required for system startup, operation, abnormal shutdown, emergency shutdown, and normal shutdown at least [4] [____] weeks prior to the first training course. The booklets shall include the manufacturer's name, model number, and parts list. The manuals shall include the manufacturer's name, model number, service manual, and a brief description of all equipment and their basic operating features. [Six] [____] complete copies of maintenance manual in bound 216 by 279 8 1/2 by 11 inch booklets listing routine maintenance procedures, possible breakdowns and repairs, and a trouble shooting guide. The manuals shall include piping and equipment layouts and simplified wiring and control diagrams of the system as installed.

SD-11 Closeout Submittals

Energy Efficient Equipment for Chillers; S

Indoor Air Quality During Construction; S

Ozone Depleting Substances; S

1.3 SAFETY REQUIREMENTS

Exposed moving parts, parts that produce high operating temperature, parts which may be electrically energized, and parts that may be a hazard to operating personnel shall be insulated, fully enclosed, guarded, or fitted with other types of safety devices. Safety devices shall be installed so that proper operation of equipment is not impaired. Welding and cutting safety requirements shall be in accordance with AWS Z49.1.

1.4 DELIVERY, STORAGE, AND HANDLING

Stored items shall be protected from the weather, humidity and temperature variations, dirt and dust, or other contaminants. Proper protection and care of all material both before and during installation shall be the Contractor's responsibility. Any materials found to be damaged shall be replaced at the Contractor's expense. During installation, piping and similar openings shall be capped to keep out dirt and other foreign matter.

1.5 PROJECT REQUIREMENTS

1.5.1 Verification of Dimensions

The Contractor shall become familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing any work.

NOTE: Warranties on Navy construction: Warranties for equipment, materials, or design furnished, or workmanship performed by the Contractor or any subcontractor or supplier, has a duration of one year from the date of final acceptance of the work. An exception is in normal commercial practice longer warranty period for particular construction are given.

An example of a typically longer duration period is the warranty for the chiller refrigeration compressor, is typically good for five years. The Contractor submits to the Contracting Officer all applicable warranties signed and official prior to project closeout.

If a longer than one year warranty duration is desired, it is recommended that the specifier/designer survey the chiller market to determine if the chiller industry normally provides a longer warranty for all of the subject chiller or for any major components.

A warranty duration of longer than a year, and not covered normally by the industry, requires a Level III Contracting Officer's written determination documenting that the extra warranty protection is needed.

1.6 Warranty

In addition to the warranty requirements specification in Division 00, Contract Requirements, the following major components of the chiller shall be covered by a warranty of a duration period of five years: compressor, and [_____].

1.7 MANUFACTURER'S MULTI-YEAR COMPRESSOR WARRANTY

NOTE: This paragraph is to be used only in conjunction with an air-cooled water chiller. If an air-cooled water chiller is not specified, then delete this paragraph.

The designer will be responsible for selecting the length of the warranty, the type (i.e., parts only, or parts and labor), and a response time. Coordinate the selections made with the installation and consider the needs and repair/response capabilities of the user, the criticality of the site, the location of the site in relation to the availability of manufacturer qualified technicians, and cost.

Response time is site/manufacturer dependent although for most sites a 6-hour response time is reasonable. Response time may differ from the response time indicated for items covered under the

standard construction warranty. Designers must be aware that specifying a response time less than 24 hours for warranty service on chillers at remote sites may limit competition.

The Contractor shall provide a [5] [10] year [parts only (excludes refrigerant)][parts and labor (includes refrigerant)] manufacturer's warranty on the chiller compressor(s). This warranty shall be directly from the chiller manufacturer to the Government and shall be in addition to the standard one-year warranty of construction. The manufacturer's warranty shall provide for the repair or replacement of the chiller compressor(s) that become inoperative as a result of defects in material or workmanship within [5] [10] years after the date of final acceptance. When the manufacturer determines that a compressor requires replacement, the manufacturer shall furnish new compressor(s) at no additional cost to the Government. Upon notification that a chiller compressor has failed under the terms of the warranty, the manufacturer shall respond in no more than [6] [24] [_____] hours. Response shall mean having a manufacturer-qualified technician onsite to evaluate the extent of the needed repairs. The warranty period shall begin on the same date as final acceptance and shall continue for the full product warranty period.

1.7.1 Indexed Notebook

NOTE: Where multiple air-cooled water chillers are to be covered by a manufacturer's multi-year warranty, include the following paragraph. This paragraph requires a bound and indexed notebook.

The Contractor shall furnish to the Contracting Officer a bound and indexed notebook containing a complete listing of all water chillers covered by a manufacturer's multi-year warranty. The chiller list shall state the duration of the warranty thereof, start date of the warranty, ending date of the warranty, location of the warranted equipment, and the point of contact for fulfillment of the warranty. This information shall be provided for each chiller and the recorded chiller serial numbers shall identify each chiller. Point of contact shall include the name of the service representative along with the day, night, weekend, and holiday phone numbers for a service call. The completed bound and indexed notebook shall be delivered to the Contracting Office prior to final acceptance of the facility. The Contractor shall furnish with each manufacturer's multi-year warranty the name, address, and telephone number (day, night, weekend, and holiday) of the service representative nearest to the location where the equipment is installed. Upon a request for service under the multi-year warranty, the service representative shall honor the warranty during the warranty period, and shall provide the services prescribed by the terms of the warranty.

1.7.2 Equipment Warranty Tags

At the time of installation, each item of manufacturer's multi-year warranted equipment shall be tagged with a durable, oil- and water-resistant tag, suitable for interior and exterior locations, resistant to solvents, abrasion, and fading due to sunlight. The tag shall be attached with copper wire or a permanent, pressure-sensitive, adhesive backing. The tag shall be installed in an easily noticed location attached

to the warranted equipment. The tag for this equipment shall be similar to the following in format, and shall contain all of the listed information:

MANUFACTURER'S MULTI-YEAR WARRANTY EQUIPMENT TAG
Equipment/Product Covered: _____
Manufacturer:_____Model No.:_____Serial No.:_____
Warranty Period: From _____to _____
Contract No.: _____
Warranty Contact: _____
Name: _____
Address: _____
Telephone: _____
STATION PERSONNEL SHALL PERFORM PREVENTIVE
MAINTENANCE AND OPERATIONAL MAINTENANCE

PART 2 PRODUCTS

NOTE: Job specifications will be written to avoid restrictions on specific types of refrigerant (excluding CFC refrigerants) in order to encourage competitive bidding of available product offerings.

Electric chillers are required to meet performance requirements specified by FEMP. Information on requirements for air-cooled chillers can be found at:

http://www1.eere.energy.gov/femp/technologies/eep_ac_chillers.html

The link for energy requirements for air-cooled chillers is found at:

<http://energy.gov/eere/femp/covered-product-category-air-cooled-electric-chi>

Information on requirements for water-cooled chillers can be found at:

http://www1.eere.energy.gov/femp/technologies/eep_wc_chillers.html

The link for energy requirements for water-cooled chillers is found at:

<http://energy.gov/eere/femp/covered-product-category-water-cooled-electric-c>

These specifications conform to the efficiency requirements as defined in Public Law (PL) 109-58 - "Energy Policy Act of 2005" for federal procurement of energy-efficient products. Equipment selected will have as a minimum the efficiency ratings.

Performance requirements for air-cooled chillers are provided in both kilowatt (kW)/ton and energy efficiency ratio (EER or Btu/watt) units for convenience. When comparing only air-cooled chillers, EER (Btu/watt) is a common metric. When comparing air-cooled and water-cooled chillers, kW/ton is a common metric. Performance requirements for water-cooled chillers are provided in kW/ton.

Equipment having a lower efficiency than FEMP requirements may be specified if the designer determines the equipment to be more life-cycle cost

effective using the life-cycle cost analysis methodology and procedure in 10 CFR 436.

The driving forces in the procurement of higher efficient equipment are Executive Orders 13423 and 13514.

When editing this specification to eliminate a type of chillers technology (oil-free magnetic bearings compressors versus oil-lubricated compressors), the design analysis must include both calculations to demonstrate that the edit is the most LCC effective and manufacturer's literature demonstrating that this edit does not result in a sole-source chiller procurement.

Minimum chiller efficiencies will either be presented in this specification or on the design drawings. Delete chiller efficiencies in the specification if efficiencies are shown on the drawings. If the efficiencies are shown on the drawings, reference the applicable AHRI standard.

Use minimum full load and part load efficiency ratings, located at the following DOE FEMP webpage (http://www1.eere.energy.gov/femp/news/news_detail.html?news_id=18970) to specify electrically driven, air-cooled and water-cooled water chillers

Projects which include vapor-compression type water chillers (this excludes water chillers) will comply with the safety standards defined in ASHRAE 15. Designers will be responsible for thoroughly researching and implementing the ASHRAE 15 safety requirements. For refrigerant-containing parts (excluding piping) located within an indoor space, a designer can use the following 6-step synopsis as a guide in determining "System Application Requirements" from ASHRAE 15.

Step 1. Identify the safety group classification of the refrigerant anticipated to be used in the new water chilling equipment.

Step 2. Identify the occupancy classification of the facility which will house the new water chilling equipment. Occupancies include institutional, public assembly, residential, commercial, large mercantile, industrial, and mixed types.

Step 3. Determine the system probability (high or low) of the new water chilling equipment. Water chillers are typically considered low-probability systems according to ASHRAE 15.

Step 4. Estimate the quantity of refrigerant (grams or pounds) in the largest single water chiller or largest refrigerant circuit of the new equipment. The designer will research catalog data from a

minimum of 2 different water chiller manufacturers in order to get an approximation.

Step 5. Determine the volume (cubic meters or cubic feet) of the indoor space which is planned to house the new water chilling equipment.

Step 6. Identify the "System Application Requirements" from the applicable table in ASHRAE 15 based upon the information identified in the previous steps (e.g., safety group, occupancy, system probability, refrigerant quantity, and indoor space volume). The "System Application Requirements" will dictate applicable refrigerant limitations as well as occupied space or mechanical room requirements. Typically, indoor spaces housing water chilling equipment must meet the mechanical room requirements defined in ASHRAE 15.

ASHRAE 15 refers to a mechanical room as a machinery room, however, the terms are synonymous. On mechanical room design, ASHRAE 15 touches on criteria concerning chiller placement, ventilation design, door and passageway restrictions, refrigerant monitoring, open-flame devices, pressure-relief and purge piping. In addition to mechanical room design, ASHRAE 15 also touches on criteria concerning refrigerant piping, signs, self-contained breathing apparatus (SCBA), and miscellaneous installation restrictions. (SCBAs cannot be considered MCA funded items and are therefore not included in this specification.)

2.1 PRODUCT SUSTAINABILITY CRITERIA

For products in this section, where applicable and to extent allowed by performance criteria, provide and document the following:

2.1.1 Energy Efficient Equipment for Chillers

Provide chillers meeting the efficiency requirements as stated within this section and provide documentation in conformance with Section 01 33 29 SUSTAINABILITY REPORTING paragraph ENERGY EFFICIENT EQUIPMENT.

2.1.2 Ozone Depleting Substances

Chillers must not use CFC-based refrigerants, and must have an Ozone Depletion Potential (ODP) no greater than 0.0, with exception to R-123, in conformance with this section. Provide documentation in conformance with Section 01 33 29 SUSTAINABILITY REPORTING paragraph OZONE DEPLETING SUBSTANCES.

2.2 STANDARD COMMERCIAL PRODUCTS

Materials and equipment shall be standard Commercial cataloged products of a manufacturer regularly engaged in the manufacturing of such products, which are of a similar material, design and workmanship.

These products shall have a two year record of satisfactory field service prior to bid opening. The two year record of service shall include applications of equipment and materials under similar circumstances and of similar size.

Products having less than a two year record of satisfactory field service shall be acceptable if a certified record of satisfactory field service for not less than 6000 hours can be shown. The 6000 hour service record shall not include any manufacturer's prototype or factory testing.

Satisfactory field service shall have been completed by a product that has been, and presently is being sold or offered for sale on the commercial market through the following copyrighted means: advertisements, manufacturer's catalogs, or brochures.

2.3 MANUFACTURER'S STANDARD NAMEPLATES

NOTE: In a salt water environment, substitute acceptable non-corroding metal such as but not limited to nickel-copper, 304 stainless steel, or monel. Aluminum is unacceptable. Nomenclature (or system identification) should be established by the designer.

**Choose first bracketed paragraph for Army projects.
Second bracketed paragraph for Navy projects.**

[Major equipment including chillers, compressors, compressor drivers, condensers, water coolers, receivers, refrigerant leak detectors, heat exchanges, fans, and motors shall have the manufacturer's name, address, type or style, model or serial number, and catalog number on a plate secured to the item of equipment. Plates shall be durable and legible throughout equipment life. Plates shall be fixed in prominent locations with nonferrous screws or bolts.

] [Nameplates are required on major components if the manufacturer needs to provide specific engineering and manufacturing information pertaining to the particular component. Should replacement of this component be required, nameplate information will insure correct operation of the unit after replacement of this component.

] 2.4 ELECTRICAL WORK

NOTE: Where motor starters for mechanical equipment are provided in motor-control centers, the references to motor starters will be deleted.

NOTE: Show the electrical characteristics, motor starter type(s), enclosure type, and maximum rpm on the drawings in the equipment schedule.

Where reduced-voltage motor starters are recommended

by the manufacturer or required otherwise, specify and coordinate the type(s) required in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Reduced-voltage starting is required when full voltage starting will interfere with other electrical equipment and circuits and when recommended by the manufacturer. Where adjustable speed drives (SD) are specified, reference Section 26 29 23 VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS. The methods for calculating the economy of using an adjustable speed drive is described in UFC 3-520-01, "Interior Electrical Systems".

- a. Provide motors, controllers, integral disconnects, contactors, and controls with their respective pieces of equipment, except controllers indicated as part of motor control centers. Provide electrical equipment, including motors and wiring, as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Manual or automatic control and protective or signal devices required for controls and devices specified, but not shown, shall be provided. For packaged equipment, the manufacturer shall provide controllers including the required monitors and timed restart.
- b. For single-phase motors, provide high-efficiency type, fractional-horsepower alternating-current motors, including motors that are part of a system, in accordance with NEMA MG 11.
- c. For polyphase motors, provide squirrel-cage medium induction motors, including motors that are part of a system, and that meet the efficiency ratings for premium efficiency motors in accordance with NEMA MG 1.

NOTE: Bracketed sentence "Motor bearings..." to be used for Army projects only.

- d. Provide motors in accordance with NEMA MG 1 and of sufficient size to drive the load at the specified capacity without exceeding the nameplate rating of the motor. Motors shall be rated for continuous duty with the enclosure specified. Motor duty requirements shall allow for maximum frequency start-stop operation and minimum encountered interval between start and stop. Motor torque shall be capable of accelerating the connected load within 20 seconds with 80 percent of the rated voltage maintained at motor terminals during one starting period. Provide motor starters complete with thermal overload protection and other necessary appurtenances. [Motor bearings shall be fitted with grease supply fittings and grease relief to outside of the enclosure.]
- e. Provide inverter duty premium efficiency motors for use with variable frequency drives.
- [f. Where two-speed or variable-speed motors are indicated, solid-state variable-speed controllers may be provided to accomplish the same function. Use solid-state variable-speed controllers for motors rated 7.45 kW 10 hp or less and variable frequency drives for larger motors.] [Provide variable frequency drives for motors as specified in

Section 26 29 23 VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS

]2.5 SELF-CONTAINED WATER CHILLERS, VAPOR COMPRESSION TYPE

NOTE: Typically, units 1760 kW 500 tons or smaller
are fully assembled and run-tested at the factory.
Units larger than 1760 kW 500 tons are typically
shipped and then assembled, charged, and run-tested
in the field.

Unless necessary for delivery purposes, units shall be assembled, leak-tested, charged (refrigerant and oil), and adjusted at the factory. In lieu of delivery constraints, a chiller may be assembled, leak-tested, charged (refrigerant and oil), and adjusted at the job site by a factory representative. Unit components delivered separately shall be sealed and charged with a nitrogen holding charge. Parts weighing 23 kg 50 pounds or more which must be removed for inspection, cleaning, or repair, such as motors, gear boxes, cylinder heads, casing tops, condenser, and cooler heads, shall have lifting eyes or lugs. Chiller shall be provided with a single point wiring connection for incoming power supply. Chiller's condenser and water cooler shall be provided with [standard] [marine] water boxes with [grooved mechanical] [flanged] [welded] connections.

2.5.1 Scroll, Reciprocating, or Rotary Screw Type

NOTE: These type units are typically available in
capacities of 1406 kW 400 tons or less.

Chiller shall be rated in accordance with AHRI 550/590 I-P. Chiller shall conform to ANSI/ASHRAE 15 & 34. As a minimum, chiller shall include the following components as defined in paragraph CHILLER COMPONENTS.

- a. Refrigerant and oil
- b. Structural base
- c. Chiller refrigerant circuit
- d. Controls package
- e. Scroll, reciprocating, or rotary screw compressor
- f. Compressor driver, [electric motor] [gas-engine]
- g. Compressor driver connection
- h. Water cooler (evaporator)
- i. [Air][Water]-cooled condenser coil
- [j. Heat recovery condenser
-] [k. Receiver
-]

NOTE: Tools to be used for Army projects only.

[1. Tools

]2.5.2 Centrifugal or Rotary Screw Type

NOTE: These type units are typically available in capacities of 703 kW 150 tons or more.

Chiller shall be constructed and rated in accordance with AHRI 550/590 I-P. Chiller shall conform to ANSI/ASHRAE 15 & 34. As a minimum, chiller shall include the following components as defined in paragraph CHILLER COMPONENTS.

- a. Refrigerant and oil
- b. Structural base
- c. Chiller refrigerant circuit
- d. Controls package
- e. Centrifugal or rotary screw compressor
- f. Compressor driver, [electric motor] [gas-engine] [steam turbine]
- g. Compressor driver connection
- h. Water cooler (evaporator)
- i. [Air][Water]-cooled condenser coil

[j. Heat recovery condenser coil

][k. Receiver

] 1. Purge system for chillers which operate below atmospheric pressure

[m. Tools

]2.6 SPLIT-SYSTEM WATER CHILLER, VAPOR COMPRESSION TYPE

NOTE: Typically, units 500 tons or smaller are fully assembled and run-tested at the factory. Units larger than 1760 kW 500 tons are typically shipped and then assembled, charged, and run-tested in the field.

Total chiller system shall be constructed and rated in accordance with AHRI 550/590 I-P. Individual chiller components shall be constructed and rated in accordance with the applicable AHRI standards. Chiller system shall be conform to ANSI/ASHRAE 15 & 34. [The chiller shall be ASHRAE 90.1 - SI ASHRAE 90.1 - IP compliant and meet 10 CFR Part 433, 434 and 435 efficiency performance standards for federal construction. The manufacturer shall provide certification of compliance]. Chiller shall be

assembled, leak-tested, charged (refrigerant and oil), and adjusted at the job site in strict accordance with manufacturer's recommendations. Unit components delivered separately shall be sealed and charged with a nitrogen holding charge. Unit assembly shall be completed in strict accordance with manufacturer's recommendations. Chiller shall operate within capacity range and speed recommended by the manufacturer. Parts weighing 50 pounds or more which must be removed for inspection, cleaning, or repair, shall have lifting eyes or lugs. Chiller shall include all customary auxiliaries deemed necessary by the manufacturer for safe, controlled, automatic operation of the equipment. Chiller's condenser and water cooler shall be provided with [standard] [marine] water boxes with [grooved mechanical] [flanged] [welded] connections. Chillers shall operate at partial load conditions without increased vibration over normal vibration at full load, and shall be capable of continuous operation down to minimum capacity. As a minimum, chiller shall include the following components as defined in paragraph CHILLER COMPONENTS.

- a. Refrigerant and oil
- b. Structural base
- c. Chiller refrigerant circuit
- d. Controls package

[e. Receiver
]

NOTE: Tools to be used for Army projects only.

[f. Tools

]2.6.1 Compressor-Chiller Unit

NOTE: These type units are typically available in
capacities of 1406 kW 400 tons or less.

As a minimum, the compressor-chiller unit shall include the following components as defined in paragraph CHILLER COMPONENTS.

- a. Scroll, reciprocating, or rotary screw compressor
- b. Compressor driver, electric motor
- c. Compressor driver connection
- d. Water cooler (evaporator)

2.6.2 Condensing Unit

NOTE: These type units are typically available in
capacities of 703 kW 150 tons or more.

As a minimum, the condensing unit shall include the following components as

defined in paragraph CHILLER COMPONENTS.

- a. Scroll, reciprocating, or rotary screw compressor
- b. Compressor driver, electric motor
- c. Compressor driver connection
- d. Air or water cooled condenser

2.6.3 Remote Water Cooler (Evaporator)

NOTE: Coil bundles to be used for Army projects only.

2.6.3.1 Shell and Tube Type

Cooler shall be constructed and rated in accordance with AHRI 480. Cooler shall be of the shell-and-coil or shell-and-tube type design. Cooler's refrigerant side shall be designed and factory pressure tested to comply with ANSI/ASHRAE 15 & 34. Cooler's water side shall be designed and factory pressure tested for not less than [1,000] [1,700] [2000] kPa [150] [250] [300] psi. Cooler shell shall be constructed of seamless or welded steel. [Coil bundles shall be totally removable and arranged to drain completely.] Tubes shall be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube shall be individually replaceable. Tubes shall be installed into carbon mild steel tube sheets by rolling. Tube baffles shall be properly spaced to provide adequate tube support and cross flow. Cooler shall be skid-mounted. Refrigerant circuit shall be complete with liquid solenoid valve and expansion device capable of modulating to the minimum step of capacity unloading. For the water side of water cooler, performance shall be based on a water velocity not less than 0.91 m/s 3 fps and not more than 3.7 m/s 12 fps and a fouling factor of 0.00025. [Evaporator shall be provided with electric freeze protection type.]

2.6.3.2 Brazed Plate Type

Cooler shall be constructed and rated in accordance with AHRI 480. Cooler shall be of the brazed plate design. Cooler's refrigerant side shall be designed and factory pressure tested to comply with ANSI/ASHRAE 15 & 34. Cooler's water side shall be designed and factory pressure tested for not less than [1,000] [1,700] [2000] kPa [150] [250] [300] psi. Cooler shell shall be constructed of stainless steel plates brazed together with copper. Refrigerant circuit shall be complete with liquid solenoid valve and expansion device capable of modulating to the minimum step of capacity unloading. For the water side of water cooler, performance shall be based on a water velocity not less than 0.91 m/s 3 fps and not more than 3.7 m/s 12 fps and a fouling factor of 0.00025. [Evaporator shall be provided with electric freeze protection type.]

2.6.4 Remote Air-Cooled Condenser

NOTE: Louvered panels to be used for Army projects only.

Condenser shall be a factory-fabricated and assembled unit, consisting of coils, fans, and condenser fan motors. Condenser shall be constructed and rated in accordance with ANSI/AHRI 460. [Unless the condenser coil is completely protected through inherent design, louvered panel coil guards shall be provided by the manufacturer to prevent physical damage to the coil.] Manufacturer shall certify that the condenser and associated equipment are designed for the submitted condensing temperature. For design conditions, if matched combination catalog ratings matching remote condensers to compressors are not available, the Contractor shall furnish a crossplotting of the gross heat rejection of the condenser against the gross heat rejection of the compressor, for the design conditions to show the compatibility of the equipment furnished.

2.6.4.1 Condenser Casing

Condenser casing shall be aluminum not less than [1.016] [2.032] mm [0.040] [0.080] inch or hot-dip galvanized steel not lighter than 18 gauge. Condensers having horizontal air discharge shall be provided with discharge baffle to direct air upward, constructed of the same material and thickness as the casing.

2.6.4.2 Coil

Condenser coil shall be of the extended-surface fin-and-tube type and shall be constructed of seamless [copper] [or] [aluminum] tubes with compatible [copper] [or] [aluminum] fins. Fins shall be soldered or mechanically bonded to the tubes and installed in a metal casing. Coils shall be circuited and sized for a minimum of 3 degrees C 5 degrees F subcooling and full pumpdown capacity. Coil shall be factory leak and pressure tested after assembly in accordance with ANSI/ASHRAE 15 & 34. [Coil shall be entirely coated with the manufacturer's standard epoxy or vinyl coating.]

2.6.4.3 Fans

NOTE: Belt drives to be used for Army projects only.

Fans shall be centrifugal or propeller type as best suited for the application. Fans shall be direct or V-belt driven. [Belt drives shall be completely enclosed within the unit casing or equipped with a guard.] [When belt drive is provided, an adjustable sheave to furnish not less than 20 percent fan-speed adjustment shall be provided. Sheaves shall be selected to provide the capacity indicated at the approximate midpoint of the adjustment.] Fans shall be statically and dynamically balanced.

2.6.4.4 Condenser Sizing

Size condensers for full capacity at 16.67 degrees C 30 degrees F temperature difference between entering outside air and condensing refrigerant. Subcooling shall not be considered in determining compressor and condenser capacities. For design conditions, submit a cross-plot of net refrigeration effect of compressor to establish net refrigeration effect and compatibility of equipment furnished.

2.6.4.5 Low Ambient Control

Provide factory mounted head pressure control for operation during low

ambient conditions. Head pressure shall be controlled by [fan cycling,]
[fan speed control,] [condenser refrigerant flooding]. Low ambient control
shall permit compressor operation below[4.4 degrees C 40 degrees F][-17.7
degrees C 0 degrees F][[_____] degrees C [_____] degrees F].

2.6.4.6 High Ambient Unloading

Provide unloading capability to allow operation in high ambient conditions [
[_____] degrees C [_____] degrees F] above design conditions.

2.6.5 Remote Water-Cooled Condenser

NOTE: Coil bundles to be used in Army projects only.

Condenser shall be a factory-fabricated and assembled unit constructed and rated in accordance with AHRI 450. Condenser shall be of the shell-and-coil or shell-and-tube type design. Condenser's refrigerant side shall be designed and factory pressure tested to comply with ANSI/ASHRAE 15 & 34. Condenser's water side shall be designed and factory pressure tested for not less than [1,000] [1,700] [2000] kPa [150] [250] [300] psi. Condensers shall be complete with pressure relief valve or rupture disk, water drain connections, refrigerant charging valve, refrigerant valves, liquid-level indicating devices, and stand or saddle. Low pressure refrigerant condenser shall be provided with a purge valve located at the highest point in the condenser to purge non-condensibles trapped in the condenser. Condenser shell shall be constructed of seamless or welded steel. [Coil bundles shall be totally removable and arranged to drain completely.] Tubes shall be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube shall be individually replaceable, except for the coaxial tubes. Tubes shall be installed into carbon mild steel tube sheets by rolling. Tube baffles shall be properly spaced to provide adequate tube support and cross flow. Condenser performance shall be based on water velocities not less than 0.91 m/s 3 fps nor more than 3.7 m/s 12 fps and a fouling factor of [0.00025] [0.0005]. Water-cooled condensers may be used for refrigerant storage in lieu of a separate liquid receiver, if the condenser storage capacity is 20 percent in excess of the fully charged system for remote water cooled condensers. As a minimum, the condenser shall include the following components as defined in paragraph CHILLER COMPONENTS.

- a. Liquid-level indicating devices.
- b. Companion flanges, bolts, and gaskets for flanged water connections.

2.6.6 Remote Evaporatively-Cooled Condenser

Condenser shall be rated and tested in accordance with the requirements of ASHRAE 64. Condenser shall include fans, water pump with suction strainer, electric motor and drive equipment, water eliminators if required, condensing coil, liquid receiver if required, water pan or sump, spray nozzles or water-distribution pan, water strainer, water make-up assembly, bleeder with flow valve of the needle valve type sized for the flow required or a fixed orifice, enclosure with suitable access doors, and air-inlet and outlet openings. No water shall carry over into the unit discharge outlet.

2.6.6.1 Condenser Casing

Enclosure shall be constructed of not lighter than [18 gauge hot-dip galvanized steel] [2.032 mm aluminum] [0.080 inch aluminum], reinforced and braced. Access doors or panels suitably sized and located shall be provided for access to water nozzles or distribution pan, coils, and valves for cleaning, repair, or removal of the item. Access doors or panels shall be gasketed with synthetic rubber, or equivalent gasket material, and locked in place with thumb screws or catches. One-half inch mesh hot-dip galvanized steel or copper air-inlet screens shall be provided on each air inlet.

2.6.6.2 Refrigerant Section

Condenser coil shall be constructed of unfinned copper or steel tubes hot-dip galvanized after fabrication. The receiver shall be welded steel and shall be fitted and tested in accordance with ANSI/AHRI 495. A refrigerant charging valve shall be installed in the liquid line between the receiver cut-off valve and the expansion device. Refrigerant section shall be tested in accordance with ASHRAE 15 for the refrigerant employed in the system.

2.6.6.3 Fans

Fans shall be centrifugal or propeller type as best suited for the application. Fans shall be direct or V-belt driven. Belt drives shall be completely enclosed within the unit casing or equipped with a guard. When belt drive is provided, an adjustable sheave to furnish not less than 20 percent fan-speed adjustment shall be provided. Sheaves shall be selected to provide the capacity indicated at the approximate midpoint of the adjustment. Fans shall be statically and dynamically balanced. Fan motor shall be totally enclosed type or open dripproof and located within an enclosure to be fully protected from the weather.

2.6.6.4 Water Section

Water eliminators shall be constructed of nonferrous metal, of an approved nonmetallic material, or of not lighter than 24 gauge steel, hot-dip galvanized after fabrication. Spray nozzles shall be brass nonclogging type designed to permit easy disassembly, and shall be arranged for easy access. Water pump shall be bronze-fitted centrifugal or turbine type, and may be mounted as an integral part of the evaporative condenser or remotely on a separate mounting pad. Pump suction shall be fully submerged and provided with screened inlet. Water pan or sump shall be constructed of not lighter than 14 gauge steel, hot-dip galvanized after fabrication, or molded acid-resistant glass-fiber-reinforced polyester. Water distribution pan shall be constructed of not lighter than 16 gauge steel, hot-dip galvanized after fabrication. Joints shall be watertight. Water pan or sump shall be provided with drain, overflow, and make-up water connection with stop valve and float valve. A bleed line with a flow valve of the needle type sized for the flow required or fixed orifice shall be provided in the pump discharge line and shall be extended to the nearest drain for continuous discharge.

2.7 CHILLER COMPONENTS

**NOTE: Coordinate the type of chiller components
required with the type of chiller specified in the**

previous paragraphs.

2.7.1 Refrigerant and Oil

NOTE: Chillers shall operate on a refrigerant with an ODP equal to 0. R-134a, R-407C, and R-410A all meet this requirement. The exception is equipment using R-123 which will continue to be produced until January 1, 2020 and will remain acceptable for installation in DoD facilities until then.

On January 1, 2020, R-123 will no longer be allowed.

Choose the bracketed option for Navy projects only.

Refrigerants shall be one of the fluorocarbon gases. Refrigerants shall have number designations and safety classifications in accordance with ANSI/ASHRAE 15 & 34. Refrigerants classified by the EPA as Class 2 shall not be allowed with the exception of R-123. [The ODP shall be in accordance with the "Montreal Protocol On Substances That Deplete The Ozone Layer," September 1987, as amended through 2000, sponsored by the United Nations Environment Programme.]

2.7.2 Structural Base

Chiller and individual chiller components shall be provided with a factory-mounted structural steel base (welded or bolted) or support legs. Chiller and individual chiller components shall be isolated from the building structure by means of [molded neoprene isolation pads.] [vibration isolators with published load ratings. Vibration isolators shall have isolation characteristics as recommended by the manufacturer for the unit supplied and the service intended.]

2.7.3 Chiller Refrigerant Circuit

NOTE: Filter dryers are not needed on chillers which make use of a purge system.

Chiller refrigerant circuit shall be completely piped and factory leak tested. For multicompressor units, not less than 2 independent refrigerant circuits shall be provided. Circuit shall include as a minimum a [combination filter and drier,] combination sight glass and moisture indicator, liquid-line solenoid valve for reciprocating, an electronic or thermostatic expansion valve with external equalizer or float valve, charging ports, compressor service valves for field-serviceable compressors, and superheat adjustment.

2.7.4 Controls Package

NOTE: For large water-cooled chillers (centrifugal or rotary screw), motor starters and disconnects switches which are to be remotely-mounted are not typically supplied by the chiller manufacturer.

Chiller shall be provided with a complete [factory-mounted] [remote-mounted where indicated], prewired electric or microprocessor based operating and safety control system. Controls package shall contain as a minimum a digital display or acceptable gauges, an on-auto-off switch, [motor starters,] [disconnect switches,] power wiring, and control wiring. Controls package shall provide operating controls, monitoring capabilities, programmable setpoints, safety controls, and EMCS interfaces as defined below.

2.7.4.1 Operating Controls

NOTE: For proper startup and head pressure controls, enter the winter design temperature to which the equipment will be subjected. Coordinate this temperature with manufacturers to assure available equipment.

A cooling tower bypass line and modulating control valve should be evaluated and incorporated into a design which requires chiller operation in ambient temperatures less than 13 degrees C 55 degree F.

Chiller shall be provided with the following adjustable operating controls as a minimum.

- a. Leaving chilled water temperature control
- b. Adjustable timer or automated controls to prevent a compressor from short cycling
- c. Automatic lead/lag controls (adjustable) for multi-compressor units
- d. Load limiting
- e. System capacity control to adjust the unit capacity in accordance with the system load and the programmable setpoints. Controls shall automatically re-cycle the chiller on power interruption.
- f. Startup and head pressure controls to allow system operation at all ambient temperatures down to [_____] degrees C F.
- [g. Fan sequencing for air-cooled condenser

]2.7.4.2 Monitoring Capabilities

During normal operations, the control system shall be capable of monitoring and displaying the following operating parameters. Access and operation of display shall not require opening or removing any panels or doors.

- a. Entering and leaving chilled water temperatures
- b. Self diagnostic
- c. Operation status

- d. Operating hours
- e. Number of starts
- f. Compressor status (on or off)
- g. Refrigerant discharge and suction pressures
- h. Magnetic bearing levitation status (if applicable)
- i. Magnetic bearing temperatures (if applicable)
- j. Oil pressure
- [k. Condenser water entering and leaving temperatures
-] [1. Number of purge cycles over the last 7 days

]2.7.4.3 Programmable Setpoints

NOTE: Small sized chillers may not have security setting capabilities.

The control system shall be capable of being reprogrammed directly at the unit. [No parameters shall be capable of being changed without first entering a security access code.] The programmable setpoints shall include the following as a minimum.

- a. Leaving Chilled Water Temperature
- [b. Leaving Condenser Water Temperature
-] [c. Time Clock/Calendar Date

]2.7.4.4 Safety Controls with Manual Reset

Chiller shall be provided with the following safety controls which automatically shutdown the chiller and which require manual reset.

- a. Low chilled water temperature protection
- b. High condenser refrigerant discharge pressure protection
- c. Low evaporator pressure protection
- d. Chilled water flow detection
- e. High motor winding temperature protection
- f. Low oil flow protection if applicable
- g. Magnetic bearing controller (MBC), Internal fault (if applicable)
- h. MBC, High bearing temperature (if applicable)
- i. MBC, Communication fault (if applicable)

j. MBC, Power supply fault (if applicable)

[k. Motor current overload and phase loss protection

]2.7.4.5 Safety Controls with Automatic Reset

Chiller shall be provided with the following safety controls which automatically shutdown the chiller and which provide automatic reset.

a. Over/under voltage protection

b. Chilled water flow interlock

c. MBC, Vibration (if applicable)

d. MBC, No levitation (if applicable)

[e. Phase reversal protection

]2.7.4.6 Remote Alarm

During the initiation of a safety shutdown, a chiller's control system shall be capable of activating a remote alarm bell. In coordination with the chiller, the Contractor shall provide an alarm circuit (including transformer if applicable) and a minimum 100 mm 4 inch diameter alarm bell. Alarm circuit shall activate bell in the event of machine shutdown due to the chiller's monitoring of safety controls. The alarm bell shall not sound for a chiller that uses low-pressure cutout as an operating control.

2.7.4.7 Energy Management Control System (EMCS) Interface

The control system shall be capable of communicating all data to a remote integrated DDC processor through a single shielded cable. The data shall include as a minimum all system operating conditions, capacity controls, and safety shutdown conditions. The control system shall also be capable of receiving at a minimum the following operating commands.

a. Remote Unit Start/Stop

[b. Remote Chilled Water Reset

] [c. Remote Condenser Water Reset

]2.7.5 Compressor(s)

2.7.5.1 Reciprocating Compressor(s)

Rotating parts shall be statically and dynamically balanced at the factory to minimize vibration. Compressors shall be capable of operating at partial-load conditions without increased vibration over the normal vibration at full load operation and shall be capable of continuous operation down to the lowest step of unloading as specified. Compressors of size 7.45 kW 10 horsepower and above shall have an oil lubrication system of the reversible, forced-feed type with oil strainer. Shaft seal in open-type units shall be mechanical type. Piston speed for open-type compressors shall not exceed the manufacturer's recommendation or 6 m/s 1200 fpm, whichever is less. Compressors shall include:

- a. Vertical, V, W, or radial cylinder design
 - b. Oil lubrication
 - c. Integrally cast block of close-grained iron or cast aluminum block with hardened steel cylinder sleeves
 - d. Oil-level bull's eye
 - e. Cast cylinder heads
 - f. Cast-aluminum or forged-steel connecting rods
 - g. Cast iron or forged-steel crankshaft
 - h. Main bearings of the sleeve-insert type
 - i. Crankcase oil heaters controlled as recommended by the manufacturer
 - j. Suction and discharge refrigerant service valves that are flange connected, wrench operated, with cap
 - k. A strainer on the suction side of the compressor
- [1. A hot-gas muffler to reduce vibration and noise from pulsations

2.7.5.2 Scroll Compressor(s)

Compressors shall be of the hermetically sealed design. Compressors shall be mounted on vibration isolators to minimize vibration and noise. Rotating parts shall be statically and dynamically balanced at the factory to minimize vibration. Lubrication system shall be centrifugal pump type equipped with a means for determining oil level and an oil charging valve. Crankcase oil heater shall be provided if standard or if available as an option. If provided, the crankcase oil heater shall be controlled as recommended by the manufacturer.

2.7.5.3 Rotary Screw Compressor(s)

Compressors shall operate stably for indefinite time periods at any stage of capacity reduction without hot-gas bypass. Provision shall be made to insure proper lubrication of bearings and shaft seals on shutdown with or without electric power supply. Rotary screw compressors shall include:

**NOTE: If an open drive (air cooled) motor is used,
 provide mechanical cooling if required to reject the
 additional heat added to the space at the source.
 The additional mechanical cooling should be counted
 into the efficiency calculations for the chiller.**

- a. An open or hermetic, positive displacement, oil-injected design directly driven by the compressor driver. Compressor shall allow access to internal compressor components for repairs, inspection, and replacement of parts.
- b. Rotors shall be solid steel, possessing sufficient rigidity for proper operation.

- c. A maximum rotor operating speed no greater than 3600 RPM. Provide cast iron rotor housing.
- d. Casings of cast iron, precision machined for minimal clearance about periphery of rotors with minimal clearance at rotor tops and rotor ends.
- e. A lubrication system of the forced-feed type that provides oil at the proper pressure to all parts requiring lubrication (if applicable).
- f. Bearing housing shall be conservatively loaded and rated for an L(10) life of not less than 200,000 hours. Shaft main bearings of the sleeve type with heavy duty bushings or rolling element type in accordance with ABMA 9 or ABMA 11.
- g. A differential oil pressure or flow cutout to allow the compressor to operate only when the required oil pressure or flow is provided to the bearings (if applicable).
- h. [A temperature- or pressure-initiated, hydraulically actuated, single-slide-valve, capacity-control system to provide minimum automatic capacity modulation from 100 percent to 15 percent.] [Use a Variable Frequency Drive (VFD) to modulate capacity modulation from 100 percent to 15 percent.]
- i. An oil separator and oil return system to remove oil entrained in the refrigerant gas and automatically return the oil to the compressor (if applicable).
- j. Crankcase oil heaters controlled as recommended by the manufacturer (if applicable).

2.7.5.4 Centrifugal Compressor(s)

NOTE: When centrifugal chillers are used for heat recovery duty, the entering heat recovery condenser water temperature is usually controlled to between 35 and 40 degrees C 95 and 105 degrees F so that the water temperature leaving the heat recovery condenser is high enough to be used as a heat source. Under these conditions, the chiller will be operating at a higher head pressure than normally encountered. At these high head conditions, the centrifugal compressor may surge at part-load conditions of as high as 30 percent to 40 percent depending upon the conditions to which the chiller is subjected. In these cases, the designer should survey the manufacturers to determine at what load the available chillers will surge, at the conditions and loads to be encountered at the site. The bracketed sentences will be removed from the centrifugal chiller paragraph and replaced with the appropriate capacity control requirements. The designer should also consider multiple chillers to satisfy the load and to partition the loading to the chillers such that the heat recovery chiller load is sufficiently high to avoid surge. When examining heat recovery, full consideration should be given to

the effect of 35-40 degrees C 95-105 degree F water and the resulting power requirements of the chiller on the economic benefit of heat recovery.

If an open drive (air cooled) motor is used, provide mechanical cooling if required to reject the additional heat added to the space at the source. The additional mechanical cooling should be counted into the efficiency calculations for the chiller.

Centrifugal compressors shall be single or multistage, having dynamically balanced impellers, either direct or gear driven by the compressor driver. Impellers shall be over-speed tested at 1.2 times the impeller-shaft speed. Impeller shaft shall be heat-treated alloy steel with sufficient rigidity for proper operation at any required operating speed. Compressors shall be variable speed and may have either oil-free, frictionless magnetic bearing drives or oil-lubricated bearing drives. Centrifugal compressors shall include:

- a. Shaft main bearings that are either oil lubricated, oil free ceramic or frictionless magnetic levitated. The oil lubricated bearings shall be the rolling element type in accordance with ABMA 9 or ABMA 11, journal type with bronze or babbitt liners, or of the aluminum-alloy one-piece insert type. Oil lubricated or oil free ceramic bearings shall be rated for an L(10) life of not less than 200,000 hours. Frictionless main shaft bearings shall be provided with radial and axial magnetic levitated bearings (combination permanent and electro magnets) to levitate the shaft thereby eliminating metal to metal contact and thus eliminating friction and the need for oil. The active magnetic bearings shall be equipped with an automatic vibration reduction and balancing system. Each bearing position shall be sensed by position sensors and provide real time positioning of the rotor shaft, controlled by on-board digital electronics. In the event of a power failure, the magnetic bearings will remain in operation throughout the compressor coast-down using a reserve power supply. Provide mechanical bearings with an oil lubrication system, designed for emergency touchdowns, as a backup to the magnetic bearings.
- b. Casing of cast iron, aluminum, or steel plate with split sections gasketed and bolted or clamped together.
- c. Lubrication system of the forced-feed type that provides oil at the proper pressure to all parts requiring lubrication.
- d. Provisions to ensure proper lubrication of bearings and shaft seals prior to starting and upon stopping with or without electric power supply (if applicable). On units providing forced-feed lubrication prior to starting, a differential oil pressure cutout interlocked with the compressor starting equipment shall allow the compressor to operate only when the required oil pressure is provided to the bearings (if applicable).
- e. Oil sump heaters controlled as recommended by the manufacturer.
- f. Temperature-or pressure-actuated prerotation vane or suction damper to provide automatic capacity modulation from 100 percent capacity to 10 percent capacity. If operation to 10 percent capacity cannot be achieved without providing hot-gas bypass, then the Contractor shall

indicate in the equipment submittal the load percent at which hot gas bypass is required.

2.7.6 Compressor Driver, Electric Motor

NOTE: If an open drive (air cooled) motor is used,
provide mechanical cooling if required to reject the
additional heat added to the space at the source.
The additional mechanical cooling should be counted
into the efficiency calculations for the chiller.

Motors, starters, [variable speed drives], wiring, etc. shall be in accordance with paragraph ELECTRICAL WORK. Motor starter shall be [unit mounted] [remote mounted] as indicated with starter type, wiring, and accessories coordinated with the chiller manufacturer.

2.7.7 Compressor Driver, Gas-Engine

NOTE: Natural gas-engine drives are used in
conjunction with either reciprocating, rotary, or
centrifugal type compressors.

The decision to use a heavy duty industrial type engine as compared to a standard automotive type engine will be based strictly on an economic comparison. The standard automotive type engines have a much lower initial cost, but they must be replaced and/or overhauled much more often. Also note that typically, standard automotive type engines are only available for chillers with a capacity of 1760 kW 500 tons or less.

Guidance to Project Designers: When specifying natural gas-engine drive chillers, close coordination with the DPW (customer) must be exercised. The designer should inform the DPW that preventive maintenance and periodical overhaul of the gas-engine drives is essential to ensure continued operation, and that energy demand savings are realized. While the initial cost of gas-engine drives is much lower than other types, gas-engine drives require more frequent maintenance and overhaul.

Gas-engine compressor driver shall operate on natural gas and be in accordance with NFPA 37 and NFPA 54. Engine shall be designed for stationary applications and include all ancillaries necessary for operation. Engine shall be a manufacturer's standard production model and be specifically designed for chiller operation. Engine shall include as a minimum a [heavy duty industrial] [standard automotive] grade block, starting system, lubrication system, coolant system, engine heat exchanger, [engine cooling radiator,] fuel supply system, electronic ignition, and controls package. Engine shall be [naturally aspirated], [supercharged,] or [turbocharged] and include appropriate air filters. Engine shall be 2- or 4-stroke-cycle and compression-ignition type. Engine shall be vertical

in-line, V- or opposed-piston type, with a solid cast block or individually cast cylinders. Engine shall have a minimum of 2 cylinders. Opposed-piston type engines shall have not less than 4 cylinders. Engine block shall have a coolant drain port.

NOTE: For pneumatic start systems size air receiver tank and compressor per manufacturer's recommendations.

2.7.7.1 Starting System

NOTE: Specify either an electric or pneumatic type starting system. Electric type system will be used for most applications. For installations where a compressed air system exists or is to be installed, a pneumatic starting system should be considered.

Engine starting system shall be the [electric] [pneumatic] type and be of sufficient capacity, at the maximum temperature specified, to crank the engine without damage or overheating. [Electric starting system shall operate on a [24] [____]-volt DC system utilizing a negative circuit ground. A starting battery system shall be provided and shall include the battery, corrosion resistant battery rack, intercell connectors, spacers, automatic battery charger with overcurrent protection, metering and relaying. Battery shall be in accordance with SAE J537. Battery charger shall conforming to UL 1236 and be the current-limiting type with overcurrent protection.] [Pneumatic starting system shall be as specified in Section 22 00 00 PLUMBING, GENERAL PURPOSE, for a working pressure of 1.03 MPa 150 psi.]

2.7.7.2 Lubrication System

Engine shall be provided with a pressurized oil lubrication system. System shall include a lubrication oil pump that is engine driven. One full-flow filter shall be provided for each pump. Filters shall be readily accessible and capable of being changed without disconnecting the piping or disturbing other components. System pressure shall be regulated as recommended by the engine manufacturer. A pressure relief valve shall be provided on the crankcase. Crankcase breathers shall be piped to the outside. System shall be readily accessible for servicing such as draining, refilling, and overhauling.

2.7.7.3 Coolant System

Engine shall include an automatic engine jacket water cooling system. Water shall be circulated through the system with an engine-driven circulating pump. [System coolant shall use a combination water and ethylene-glycol sufficient for freeze protection at the minimum temperature specified.]

NOTE: If engine heat exchanger is used the cooling tower must be sized to include heat rejected from both engine and chiller.

[2.7.7.4 Engine Heat Exchanger

Engine heat exchanger shall be of the shell-and-tube type construction and be in accordance with ASME BPVC SEC VIII D1. Shell material shall be carbon steel. Tubes shall be seamless copper or copper-nickel. Tubes shall be individually replaceable. Unit's waterside working pressure shall be rated for not less than 1,000 kPa 150 psig and factory tested at 150 percent of design working pressure. Water connections larger than 75 mm 3 inches shall be ASME Class 1500 flanged. Unit shall be provided with gasketed removable covers, drains, and vents.

] [2.7.7.5 Engine Cooling Radiator

NOTE: An engine cooling radiator will be needed to satisfy an engine's cooling requirements if cooling tower water or heat recovery is not used.

Heat exchanger may be factory coated with corrosive resistant film, provided that correction measures are taken to restore the heat rejection capability of the radiator to the initial design requirement via oversizing, or other compensating methods. Internal surfaces shall be compatible with liquid fluid coolant used. Materials and coolant are subject to approval by the Contracting Officer. Heat exchangers shall be the pressure type incorporating a pressure valve, vacuum valve and a cap. Caps shall be designed for pressure relief prior to removal. Each heat exchanger and the entire cooling system shall be capable of withstanding a minimum pressure of 48 kPa 7 psi and shall be protected with a strong grille or screen guard. Each heat exchanger shall have at least 2 tapped holes; one shall be equipped with a drain cock, the rest shall be plugged.

] 2.7.7.6 Fuel Supply System

Engine fuel supply system shall be factory mounted. System shall include as a minimum a solenoid shut-off valve, a gas pressure regulator, and carburetors (including a throttle body assembly) or fuel injectors.

2.7.7.7 Controls Package

The controls for the gas-engine shall be incorporated into the overall controls package for the water chiller. The engine controls shall be capable of monitoring, displaying, and controlling, as applicable, the following conditions.

- a. Coolant-fluid inlet and outlet temperatures
- b. Lubricating-oil inlet and outlet temperatures and pressures
- c. Engine run-time hours
- d. Engine current status mode (on/off)
- e. Engine speed
- f. Percent engine load
- g. Engine jacket temperature

2.7.7.8 Exhaust Piping

Exhaust piping shall be ASTM A53/A53M Schedule 40 seamless black iron, exhaust piping installation shall be per the engine manufacturer's recommendations, except as modified herein. Horizontal sections of exhaust piping shall be sloped downward away from the engine to a drip leg for collection of condensate with drain valve and cap. Changes in direction shall be long radius. Exhaust piping and mufflers shall be insulated in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS. Vertical exhaust piping shall be provided with a hinged, gravity-operated, self-closing, rain cover.

2.7.7.9 Exhaust Muffler

Engine shall be provided with a chamber type exhaust muffler. The muffler shall be of welded steel and designed for [outside] [inside] [vertical] [horizontal] mounting. Eyebolts, lugs, flanges, or other items shall be provided as necessary for support in the location and position indicated. Pressure drop through the muffler shall not exceed the recommendations of the engine manufacturer. Outside mufflers shall be zinc coated or painted with high temperature [_____] degrees resisting paint. The muffler and exhaust piping together shall reduce the noise level to less than [_____] dBA at a distance of 22.9 m 75 feet from the end of the exhaust piping with the chiller operating at 100 percent of rated output capacity. The muffler shall have a drain valve, nipple, and cap at the low-point of the muffler.

2.7.7.10 Exhaust System Connections

Flexible connectors shall be provided at the exhaust piping connection to the engine. An expansion joint shall be provided in the exhaust piping at the muffler connection. Flexible connectors and expansion joints shall have flanged connections. Flexible sections shall be made of convoluted seamless tube without joints or packing. Expansion joints shall be the bellows type. Expansion and flexible elements shall be stainless steel suitable for engine exhaust gas at 649 degrees C 1200 degrees F. Flexible connectors and expansion joints shall be capable of absorbing vibration from the engine and compensation for thermal expansion and contraction.

2.7.8 Compressor Driver, Steam Turbine

Steam turbine shall conform to NEMA SM 23 and be suitable for direct connection to the compressor. Turbine shall have a capacity 10 percent greater than the compressor brake horsepower requirement at full-load condition. Steam strainer shall be either internally mounted or installed in connecting piping. Turbine shall include sentinel warning valve, forced-feed lubrication, oil cooler, oil reservoir, oil relief valve, oil piping, oil-pressure gauge, tachometer, and gland-seal piping if a condensing turbine is used. If a non-condensing turbine is used, provision shall be made for drain piping. The turbine shall be suitable for automatic control. An overspeed trip governor shall be provided to shut off the steam supply at 115 percent of design speed. Provision shall be made to stop the turbine upon operation of the compressor safety devices and upon power failure by the use of a solenoid trip on the emergency overspeed governor. Turbine shall be governed by a pneumatically controlled hydraulic governor during automatic operation and with a manual control effective during failure of the air supply. Pneumatic valve shall be actuated by a temperature controller with its sensing element in contact with the chilled water. Turbine shall be designed to operate at the steam

pressure and exhaust conditions indicated. If the turbine is a condensing type, a surface-type steam condenser complete with single-stage air ejector, inter- and after-condenser, electric-driven dual condensate pumps, atmospheric relief valve, and expansion joint shall be furnished.

2.7.9 Compressor Driver Connections

NOTE: Delete the first set of brackets if a large water-chilling package is specified. Delete the second set of brackets if a condensing and compressing unit or a small water-chilling package is used.

[Each compressor shall be driven by a V-belt drive or direct connected through a flexible coupling, except that flexible coupling is not required on hermetic units. V-belt drives shall be designed for not less than 150 percent of the driving motor capacity. Flexible couplings shall be of the type that does not require lubrication.] [Each machine driven through speed-increasing gears shall be so designed as to assure self-alignment, interchangeable parts, proper lubrication system, and minimum unbalanced forces. Bearings shall be of the sleeve or roller type. Gear cases shall be oil tight. Shaft extensions shall be provided with seals to retain oil and exclude all dust.

2.7.10 Water Cooler (Evaporator)

NOTE: The standard performance fouling factor per AHRI is 0.000018 m²(degrees C)/W 0.0001 h(ft²)(degrees F)/Btu.

Cooler shall be of the shell-and-coil or shell-and-tube type design. Cooler shell shall be constructed of seamless or welded steel. Coil bundles shall be totally removable and arranged to drain completely. Tubes shall be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube shall be individually replaceable. Tubes shall be installed into carbon mild steel tube sheets by rolling. Tube baffles shall be properly spaced to provide adequate tube support and cross flow. Performance shall be based on a water velocity not less than 0.91 m/s 3 fps nor more than 3.7 m/s 12 fps and a fouling factor of [0.000018 m²(degrees C)/W (0.0001 h(ft²)(degrees F)/Btu)] [0.000044 m²(degrees C)/W (0.00025 h(ft²)(degrees F)/Btu)] [0.000088 m²(degrees C)/W (0.0005 h(ft²)(degrees F)/Btu)] [0.0001 h(ft²)(degrees F)/Btu] [0.00025 h(ft²)(degrees F)/Btu] [0.0005 h(ft²)(degrees F)/Btu].

2.7.11 Air-Cooled Condenser Coil

NOTE: Standard coil construction is copper tubes with aluminum fins. For excessively corrosive atmospheres, either copper tubes with copper fins or aluminum tubes with aluminum fins should be considered. For additional corrosion protection, specify the manufacturer's standard epoxy or vinyl coating.

Condenser coil shall be of the extended-surface fin-and-tube type and shall be constructed of seamless [copper] [or] [aluminum] tubes with compatible [copper] [or] [aluminum] fins. Fins shall be soldered or mechanically bonded to the tubes and installed in a metal casing. Coils shall be circuited and sized for a minimum of 3 degrees C 5 degrees F subcooling and full pumpdown capacity. Coil shall be factory leak and pressure tested after assembly in accordance with ANSI/ASHRAE 15 & 34. [Coil shall be entirely coated with the manufacturer's standard epoxy or vinyl coating.]

2.7.12 Water-Cooled Condenser Coil

**NOTE: The standard performance fouling factor per
AHRI is 0.000044 m2 (degrees C)/W0.00025
h(ft2)(degrees F)/Btu for condenser.**

Condenser shall be of the shell-and-coil or shell-and-tube type design. Condenser's refrigerant side shall be designed and factory pressure tested to comply with ANSI/ASHRAE 15 & 34. Condenser's water side shall be designed and factory pressure tested for not less than [1,000] [1,700] [2000] kPa [150] [250] [300] psi. Condensers shall be complete with refrigerant relief valve/rupture disc assembly, water drain connections, and refrigerant charging valve. Low pressure refrigerant condenser shall be provided with a purge valve located at the highest point in the condenser to purge non-condensibles trapped in the condenser. Condenser shell shall be constructed of seamless or welded steel. Coil bundles shall be totally removable and arranged to drain completely. Tubes shall be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube shall be individually replaceable, except for the coaxial tubes. Tube baffles shall be properly spaced to provide adequate tube support and cross flow. Performance shall be based on water velocities not less than 0.91 m/s 3 fps nor more than 3.7 m/s 12 fps and a fouling factor of [0.000044 m2(degrees C)/W (0.00025 h(ft2)(degrees F)/Btu)] [0.000088 m2(degrees C)/W (0.0005 h(ft2)(degrees F)/Btu)] [0.00025 h(ft2)(degrees F)/Btu)] [0.0005 h(ft2)(degrees F)/Btu]. Water-cooled condensers may be used for refrigerant storage in lieu of a separate liquid receiver, if the condenser storage capacity is 5 percent in excess of the fully charged system for single packaged systems.

2.7.13 Heat Recovery Condenser Coil

**NOTE: The designer will conduct feasibility studies
to determine if a heat recovery condenser is an
economical addition to the system. Heat recovery
condensers generally come in two sizes. The smaller
of the two is generally sized to reject the
superheat to the domestic water. The larger is
sized to reject the same amount of heat as the
standard condenser. The drawings will indicate the
heat rejection capacity of the heat recovery
condenser and the temperatures of the water to which
it must reject the heat.**

Condenser shall be of the shell-and-coil or shell-and-tube type design and shall not be a part of the standard condenser. Condenser shall be provided

and installed by the chiller manufacturer. Condenser's refrigerant side shall be designed and factory pressure tested to comply with ANSI/ASHRAE 15 & 34. Condenser's water side shall be designed and factory pressure tested for not less than [1,000] [1,700] [2000] kPa [150] [250] [300] psi. Condenser shall have performance characteristics as indicated on the drawings. Condenser shell shall be constructed of seamless or welded steel. Coil bundles shall be totally removable and arranged to drain completely. Tubes shall be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube shall be individually replaceable, except for the coaxial tubes. Tube baffles shall be properly spaced to provide adequate tube support and cross flow. Performance shall be based on water velocities not less than 0.91 m/s 3 fps nor more than 3.7 m/s 12 fps and a fouling factor of [0.00025] [0.0005].

2.7.14 Receivers

Receiver shall bear a stamp certifying compliance with ASME BPVC SEC VIII D1 and shall meet the requirements of ANSI/ASHRAE 15 & 34. Inner surfaces shall be thoroughly cleaned by sandblasting or other approved means. Each receiver shall have a storage capacity not less than 20 percent in excess of that required for the fully-charged system. Each receiver shall be equipped with inlet, outlet drop pipe, drain plug, purging valve, relief valves of capacity and setting required by ANSI/ASHRAE 15 & 34, and two bull's eye liquid-level sight glasses. Sight glasses shall be in the same vertical plane, 90 degrees apart, perpendicular to the axis of the receiver, and not over 75 mm 3 inches horizontally from the drop pipe measured along the axis of the receiver. In lieu of bull's eye sight glass, external gauge glass with metal glass guard and automatic closing stop valves may be provided.

2.7.15 Chiller Purge System

NOTE: Refrigeration systems which operate below atmospheric pressure (i.e., R-123 machines) will require a refrigerant purge piping system. Indicate the routing of the piping on the drawings. Require the Contractor to delete the piping if a purge system is not required for the type of chiller that is to be provided. Indicate that it will be the Contractor's responsible to size the piping based upon the chiller manufacturer's recommendations. Purge discharge piping may be connected to the pressure-relief piping on the chiller side of the piping's vibration isolators.

Chillers which operate at pressures below atmospheric pressure shall be provided with a purge system. Purge system shall automatically remove air, water vapor, and non-condensable gases from the chiller's refrigerant. Purge system shall condense, separate, and return all refrigerant back to the chiller. An oil separator shall be provided with the purge system if required by the manufacturer. Purge system shall not discharge to occupied areas, or create a potential hazard to personnel. Purge system shall include a purge pressure gauge, number of starts counter, and an elapsed time meter. Purge system shall include lights or an alarm which indicate excessive purge or an abnormal air leakage into chiller.

NOTE: Tools to be used for Army projects only.

[2.7.16 Tools

One complete set of special tools, as recommended by the manufacturer for field maintenance of the system, shall be provided. Tools shall be mounted on a tool board in the equipment room or contained in a toolbox as directed by the Contracting Officer.

]2.8 ACCESSORIES

2.8.1 Refrigerant Leak Detector

NOTE: Refrigerant leak detectors will be provided as required by the "System Application Requirements" in ASHRAE 15.

When a detector is required, the location will be indicated on the drawings. Detectors are best located between the refrigeration system and the room exhaust. Sampling points from a detector will be located a maximum of 18 inches above the finished floor since all commonly-used refrigerants are heavier than air.

As a rule of thumb, the distance between any refrigeration system and a refrigerant sampling point should not exceed 15.24 m 50 feet. In order to meet the recommended 15.24 m 50 foot distance, a mechanical room can be provided with either multiple detectors each with single sampling points or with one detector that has the capability of monitoring at multiple sampling points. If multiple sampling points are required, enter the number in the appropriate blank below.

Per ASHRAE 15, when a detector senses refrigerant it must activate an alarm and initiate the room ventilation system. In regards to alarms, as a minimum, indicate that the detector will energize a light on or near the detector as well as a second light installed on the outside wall next to the mechanical room entrance. The exterior light will be provided with a sign that warns personnel entering the mechanical room of a refrigerant release and that a SCBA is required to enter. If applicable to the installation, include an audible alarm on the exterior of the mechanical room. Include the electrical design for the alarm system on the drawings.

As an additional item, ASHRAE 15 states that open-flame devices (i.e., boilers, etc.) cannot be installed in the same area as a refrigeration system, unless either combustion air for the open-flame device is ducted straight from outside to the device; or the alarm relay from the detector is

used to automatically shutdown the combustion process in the event of refrigerant leakage. Indicate all applicable alarm controls on the drawings.

Delete the information in the last bracketed sentences if an EMCS is not applicable to the design.

Detector shall be the continuously-operating, halogen-specific type. Detector shall be appropriate for the refrigerant in use. Detector shall be specifically designed for area monitoring and shall include [a single sampling point] [[_____] sampling points] installed where indicated. Detector design and construction shall be compatible with the temperature, humidity, barometric pressure and voltage fluctuations of the operating area. Detector shall have an adjustable sensitivity such that it can detect refrigerant at or above 3 parts per million (ppm). Detector shall be supplied factory-calibrated for the appropriate refrigerant(s). Detector shall be provided with an alarm relay output which energizes when the detector detects a refrigerant level at or above the TLV-TWA (or toxicity measurement consistent therewith) for the refrigerant(s) in use. The detector's relay shall be capable of initiating corresponding alarms and ventilation systems as indicated on the drawings. Detector shall be provided with a failure relay output that energizes when the monitor detects a fault in its operation. [Detector shall be capable with the facility's energy management and control system (EMSS). The EMCS shall be capable of generating an electronic log of the refrigerant level in the operating area, monitoring for detector malfunctions, and monitoring for any refrigerant alarm conditions.]

2.8.2 Refrigerant Relief Valve/Rupture Disc Assembly

NOTE: ASHRAE 15 requires refrigeration systems to be protected with a pressure-relief device that will safely relieve pressure due to fire or other abnormal conditions. A relief valve/rupture disc assembly is the optimum solution. The rupture disc will provide visual indication of a release while also providing immediate shutoff once a safe pressure is achieved.

Designer will indicate on the drawings the location of each new relief valve/rupture disc assembly as well as the routing and size of corresponding pressure-relief piping. The routing and size of new pressure-relief piping will be per ASHRAE 15.

The assembly shall be a combination pressure relief valve and rupture disc designed for refrigerant usage. The assembly shall be in accordance with ASME BPVC SEC VIII D1 and ANSI/ASHRAE 15 & 34. The assembly shall be provided with a pressure gauge assembly which will provide local indication if a rupture disc is broken. Rupture disc shall be the non-fragmenting type.

2.8.3 Refrigerant Signs

Refrigerant signs shall be a medium-weight aluminum type with a baked

enamel finish. Signs shall be suitable for indoor or outdoor service. Signs shall have a white background with red letters not less than 13 mm 0.5 inches in height.

2.8.3.1 Installation Identification

Each new refrigerating system shall be provided with a refrigerant sign which indicates the following as a minimum:

- a. Contractor's name.
- b. Refrigerant number and amount of refrigerant.
- c. The lubricant identity and amount.
- d. Field test pressure applied.

2.8.3.2 Controls and Piping Identification

Refrigerant systems containing more than 50 kg 110 lb of refrigerant shall be provided with refrigerant signs which designate the following as a minimum:

- a. Valves or switches for controlling the refrigerant flow [, the ventilation system,] and the refrigerant compressor(s).
- b. Pressure limiting device(s).

2.8.4 Refrigerant Recovery/Recycle System

NOTE: A refrigerant recovery/recycle system will not be specified if the designer determines that on site staff will not be responsible for chiller teardown or major service. If the designer determines the on site staff will be responsible for chiller teardown or major service, the designer shall investigate whether another recovery/recycle system is available to maintenance personnel before specifying a new system. The recovery/recycle system is an expensive item and all alternatives to providing a new system should be investigated.

If a refrigerant recovery/recycle system is specified, the recovery/recycle system shall be tested and listed to conform to the requirements of AHRI 740 for refrigerant recovery/recycle systems by a recognized national testing laboratory. The system shall include separate storage vessel(s) capable of storing the entire refrigerant charge of the largest chiller.

The recovery/recycle unit shall be portable. Chiller mounting or floor mounting of the system is expensive and therefore is discouraged.

A manually initiated refrigerant recovery/recycle system shall be provided, consisting of a motor-driven, air- or water-cooled, reciprocating

condensing unit and a receiver of sufficient capacity to store the entire refrigerant charge of the largest water-chilling system. For refrigerants with atmospheric pressure boiling temperature below 20 degrees C 68 degrees F the receiver shall be sized so that it is no more than 80 percent full at 32 degrees C 90 degrees F. For refrigerants with atmospheric pressure boiling temperature above 20 degrees C 68 degrees F, the receiver shall be sized so that it is no more than 90 percent full at 32 degrees C 90 degrees F. The recovery/recycle system condensing unit shall be assembled as a complete unit and meet the requirements of ANSI/ASHRAE 15 & 34. The system components shall be portable and shall include all valves, connections, and controls required for operation. Receiver and relief devices shall conform to the requirements of ASME BPVC SEC VIII D1. The recovery/recycle system shall be tested and listed to conform to AHRI 740 for refrigerant recovery/recycle systems by a recognized national testing laboratory. For refrigerants with atmospheric pressure boiling temperature below 20 degrees C 68 degrees F, the recovery/recycle unit shall have an AHRI 740 vapor refrigerant recovery rate of no less than 8.5 kg/minute 17.0 lb/minute. For refrigerants with atmospheric pressure boiling temperature above 20 degrees C 68 degrees F, the recovery/recycle unit shall have an AHRI 740 vapor refrigerant recovery rate of no less than 1.0 kg/minute 2.2 lb/minute.

2.8.5 Automatic Tube Brush Cleaning System

**NOTE: Delete this paragraph unless specifically
required by the onsite staff.**

2.8.5.1 Brush and Basket Sets

One brush and basket set (one brush and two baskets) shall be furnished for each condenser tube. Brushes shall be made of nylon bristles, with titanium wire. Baskets shall be polypropylene.

2.8.5.2 Flow-Diverter Valve

Each system shall be equipped with one flow-diverter valve specifically designed for the automatic tube brush cleaning system and have parallel flow connections. The flow-diverter valve shall be designed for a working pressure of [1,000] [1,700] [2000] kPa [150] [250] [300] psig. End connections shall be flanged. Each valve shall be provided with an electrically operated air solenoid valve and position indicator.

2.8.5.3 Control Panel

The control panel shall provide signals to the diverter valve at a preset time interval to reverse water flow to drive the tube brushes down the tubes and then signal the valve to reverse the water flow to drive the brushes back down the tubes to their original position. The controller shall have the following features as a minimum:

- a. Timer to initiate the on-load cleaning cycle.
- b. Manual override of preset cleaning cycle.
- c. Power-on indicator.
- d. Diverter-position indicator.

- e. Cleaning-cycle-time adjustment
- f. Flow-switch bypass.

2.8.6 Gaskets

Gaskets shall conform to ASTM F104 - classification for compressed sheet with nitrile binder and acrylic fibers for maximum 371 degrees C 700 degrees F service.

2.8.7 Bolts and Nuts

Bolts and nuts, except as required for piping applications, shall be in accordance with ASTM A307. The bolt head shall be marked to identify the manufacturer and the standard with which the bolt complies in accordance with ASTM A307.

2.9 FABRICATION

2.9.1 Factory Coating

**NOTE: For equipment to be installed outdoors,
adequate protection will be specified.
Manufacturers must submit evidence that unit
specimen have passed the specified salt spray fog
test. A 125 hour test will be specified in a
noncorrosive environment and a 500 hour test will be
specified in a corrosive environment.**

Unless otherwise specified, equipment and component items, when fabricated from ferrous metal, shall be factory finished with the manufacturer's standard finish, except that items located outside of buildings shall have weather resistant finishes that will withstand [125] [500] hours exposure to the salt spray test specified in ASTM B117 using a 5 percent sodium chloride solution. Immediately after completion of the test, the specimen shall show no signs of blistering, wrinkling, cracking, or loss of adhesion and no sign of rust creepage beyond 3 mm 1/8 inch on either side of the scratch mark. Cut edges of galvanized surfaces where hot-dip galvanized sheet steel is used shall be coated with a zinc-rich coating conforming to ASTM D520, Type I.

2.9.2 Factory Applied Insulation

Chiller shall be provided with factory installed insulation on surfaces subject to sweating including the water cooler, suction line piping, economizer, and cooling lines. Insulation on heads of coolers may be field applied, however it shall be installed to provide easy removal and replacement of heads without damage to the insulation. Where motors are the gas-cooled type, factory installed insulation shall be provided on the cold-gas inlet connection to the motor per manufacturer's standard practice. Factory insulated items installed outdoors are not required to be fire-rated. As a minimum, factory insulated items installed indoors shall have a flame spread index no higher than 75 and a smoke developed index no higher than 150. Factory insulated items (no jacket) installed indoors and which are located in air plenums, in ceiling spaces, and in attic spaces shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Flame spread and smoke developed

indexes shall be determined by ASTM E84. Insulation shall be tested in the same density and installed thickness as the material to be used in the actual construction. Material supplied by a manufacturer with a jacket shall be tested as a composite material. Jackets, facings, and adhesives shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50 when tested in accordance with ASTM E84.

2.10 FACTORY TESTS

2.10.1 Chiller Performance Test

NOTE: Currently, most chiller manufacturers do not have the ability to factory performance test anything other than water-cooled chillers (centrifugal or rotary screw) which have flooded evaporators. In addition, most testing facilities are only setup to test chillers 300 tons or larger in capacity. The ability to performance test small DX systems (water- or air-cooled) is almost non-existent.

Chiller performance testing is a very expensive requirement and should be carefully evaluated before including it into a job specification. The AHRI certification program has gone a long way in recent years of assuring chiller performance as specified. The need for a performance test will be evaluated against the customer's requirements and the criticality of the installation. When a chiller performance test is not required, ensure that paragraph SUBMITTALS is edited to remove the requirements for factory tests in SD-03 and SD-06.

If a performance test is deemed necessary to assure that the capacity and efficiencies specified will be met, then include this paragraph. Testing should only be specified on water-cooled chillers between 1054 and 5622 kW 300 and 1600 tons. Tests may be specified for smaller chillers in critical applications where the tests are felt justified, however, the designer must determine in the design stage if such tests are available. In no case should a test be required on more than one unit of multiple, identical capacities.

The AHRI testing of chillers allows a deviation to chiller capacity of up to 5 percent at full load. Load calculations should consider this tolerance.

The Contractor and proposed chiller manufacturer shall be responsible for performing the chiller factory test to validate the specified full load capacity, full load EER, and [IPLV] [NPLV] in accordance with AHRI 550/590 I-P except as indicated. [The chiller factory test shall be performed in the presence of a Government representative.] The Contractor and chiller manufacturer shall provide to the Government a certified chiller factory test report in accordance with AHRI 550/590 I-P to confirm that the chiller performs as specified. Tests shall be conducted in an

AHRI certified test facility in conformance with AHRI 550/590 I-P procedures and tolerances, except as indicated. At a minimum, chiller capacity shall be validated to meet the scheduled requirements indicated on the drawings. Tolerance or deviation shall be in strict accordance with AHRI 550/590 I-P. Stable operation at minimum load of 10 percent of total capacity shall be demonstrated during the factory test.

2.10.1.1 Temperature Adjustments

Temperature adjustments shall adhere to AHRI 550/590 I-P to adjust from the design fouling factor to the clean tube condition. Test temperature adjustments shall be verified prior to testing by the manufacturer. There shall be no exceptions to conducting the test with clean tubes with the temperature adjustments per AHRI 550/590 I-P. The manufacturer shall clean the tubes, if necessary, prior to testing to obtain a test fouling factor of 0.0000.

2.10.1.2 Test Instrumentation

The factory test instrumentation shall be per AHRI 550/590 I-P and the calibration shall be traceable to the National Institute of Standards and Technology.

2.10.1.3 Test Report

A certified test report of all data shall be forwarded to the Government for approval prior to project acceptance. Calibration curves and information sheets for all instrumentation shall be provided.

2.10.1.4 Equipment Adjustments

If the equipment fails to perform within allowable tolerances, the manufacturer shall be allowed to make necessary revisions to his equipment and retest as required. [The manufacturer shall assume all expenses incurred by the Government to witness the retest.]

2.10.2 Chiller Sound Test

NOTE: Require factory sound tests for chiller applications where sound levels are a critical issue. Typically, factory sound tests are only performed on large centrifugal and rotary screw machines. As a minimum if a factory sound test is not deemed necessary, indicated the maximum allowable sound level requirements for all applicable chiller components on the drawings.

In the paragraph below, select 85 decibels if military personnel (90 decibels for civilian personnel) will operate the equipment without hearing protection. Other decibel requirements may be specified if hearing protection is provided.

Chillers shall be sound tested at the factory prior to shipment to confirm the sound pressure level specified herein. Tests and data shall be conducted and measured in strict accordance with AHRI 575 at the full load system operating conditions. The chiller sound pressure level, in decibels

(dB), with a reference pressure of 20 micropascals, shall not exceed [85] [90] [_____] dB, A weighted. Ratings shall be in accordance with AHRI 575. No reduction of entering condenser water temperature or raising of leaving chilled water temperature shall be allowed. A minimum of 75 percent of the sound data points shall be taken along the length of the machine, and established as the minimum percentage of total possible points used to determine sound levels. In the event that the chiller does not meet the dBA sound pressure level, the manufacturer shall, at his expense, provide sufficient attenuation to the machine to meet the specified value. This attenuation shall be applied in such a manner that it does not hinder the operation or routine maintenance procedures of the chiller. The attenuation material, adhesives, coatings, and other accessories shall have surface burning characteristics as determined by ASTM E84.

2.11 SUPPLEMENTAL COMPONENTS/SERVICES

2.11.1 Chilled and Condenser Water Piping and Accessories

Chilled and condenser water piping and accessories shall be provided and installed in accordance with Section 23 64 26 CHILLED, CHILLED-HOT, AND CONDENSER WATER PIPING SYSTEMS.

2.11.2 Refrigerant Piping

Refrigerant piping for split-system water chillers shall be provided and installed in accordance with Section 23 23 00 REFRIGERANT PIPING.

2.11.3 Cooling Tower

Cooling towers shall be provided and installed in accordance with Section 23 65 00 COOLING TOWERS.

2.11.4 Temperature Controls

NOTE: Modify this paragraph as required to coordinate the central equipment controls with the air-side system controls. In projects where this section of the specifications is intended to produce control equipment for existing air-side systems, this paragraph will be rewritten to secure controls to match existing controls and to properly integrate the specified controls into the existing temperature control system.

A sequence of control, a schematic of controls, and a ladder diagram should be included on the drawings for each cooling tower fan, chilled water pump, condenser water pump, etc. in order to define the overall system operation.

Chiller control packages shall be fully coordinated with and integrated [into the temperature control system specified in Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM and Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC Section 23 09 23.13 20 BACnet DIRECT DIGITAL CONTROL SYSTEMS FOR HVAC] [into the existing air-conditioning system].

PART 3 EXECUTION

3.1 CONSTRUCTION-RELATED SUSTAINABILITY CRITERIA

For construction activities in this section, provide and document the following:

3.1.1 Indoor Air Quality During Construction

Provide documentation showing that after construction ends, and prior to occupancy, new filters were installed in conformance with Section 01 33 29 SUSTAINABILITY REPORTING paragraph INDOOR AIR QUALITY DURING CONSTRUCTION.

3.2 INSTALLATION

Installation of water chiller systems including materials, installation, workmanship, fabrication, assembly, erection, examination, inspection, and testing shall be in accordance with the manufacturer's written installation instructions, including the following:

[1. Water chiller - installation instructions

]3.2.1 Connections to Existing Systems

Notify the Contracting Officer in writing at least 15 calendar days prior to the date the connections are required. Obtain approval before interrupting service. Furnish materials required to make connections into existing systems and perform excavating, backfilling, compacting, and other incidental labor as required. Furnish labor and tools for making actual connections to existing systems.

3.2.2 Refrigeration System

3.2.2.1 Equipment

NOTE: Determine in the initial stages of design the approximate distances required for maintenance clearances of all new equipment. The maintenance clearances will be used in determining the final layout of the equipment.

For installations where noise and vibration transmission to the building must be reduced, the maximum tolerable transmissibility, in percent, should be determined and the blank filled in with the appropriate value. When it is not necessary to specify the percent of transmissibility, the item in the brackets will be deleted and brackets removed. Recommended transmissibility in percentages are: 10 percent for equipment mounted in very critical areas; 10 to 20 percent for critical areas; and 20 to 40 percent for noncritical areas. The drawings should be checked to ensure that all structural and equipment connection factors and the conditions surrounding the equipment to be provided with the vibration isolation units favorably influence the effectiveness of the isolators. Where many items of equipment require different transmission values,

based on the equipment location, the specification
may be revised to indicate the appropriate values on
the drawings.

Refrigeration equipment and the installation thereof shall conform to ANSI/ASHRAE 15 & 34. Necessary supports shall be provided for all equipment, appurtenances, and pipe as required, including frames or supports for compressors, pumps, cooling towers, condensers, water coolers, and similar items. Compressors shall be isolated from the building structure. If mechanical vibration isolators are not provided, vibration absorbing foundations shall be provided. Each foundation shall include isolation units consisting of machine and floor or foundation fastenings, together with intermediate isolation material. Other floor-mounted equipment shall be set on not less than a 150 mm 6 inch concrete pad doweled in place. Concrete foundations for floor mounted pumps shall have a mass equivalent to three times the weight of the components, pump, base plate, and motor to be supported. In lieu of concrete pad foundation, concrete pedestal block with isolators placed between the pedestal block and the floor may be provided. Concrete pedestal block shall be of mass not less than three times the combined pump, motor, and base weights. Isolators shall be selected and sized based on load-bearing requirements and the lowest frequency of vibration to be isolated. Isolators shall limit vibration to [_____] percent at lowest equipment rpm. Lines connected to pumps mounted on pedestal blocks shall be provided with flexible connectors. Foundation drawings, bolt-setting information, and foundation bolts shall be furnished prior to concrete foundation construction for all equipment indicated or required to have concrete foundations. Concrete for foundations shall be as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE. Equipment shall be properly leveled, aligned, and secured in place in accordance with manufacturer's instructions.

3.2.2.2 Field Refrigerant Charging

- a. Initial Charge: Upon completion of all the refrigerant pipe tests, the vacuum on the system shall be broken by adding the required charge of dry refrigerant for which the system is designed, in accordance with the manufacturer's recommendations. Contractor shall provide the complete charge of refrigerant in accordance with manufacturer's recommendations. Upon satisfactory completion of the system performance tests, any refrigerant that has been lost from the system shall be replaced. After the system is fully operational, service valve seal caps and blanks over gauge points shall be installed and tightened.
- b. Refrigerant Leakage: If a refrigerant leak is discovered after the system has been charged, the leaking portion of the system shall immediately be isolated from the remainder of the system and the refrigerant shall be pumped into the system receiver or other suitable container. The refrigerant shall not be discharged into the atmosphere.
- c. Contractor's Responsibility: The Contractor shall, at all times during the installation and testing of the refrigeration system, take steps to prevent the release of refrigerants into the atmosphere. The steps shall include, but not be limited to, procedures which will minimize the release of refrigerants to the atmosphere and the use of refrigerant recovery devices to remove refrigerant from the system and store the refrigerant for reuse or reclaim. At no time shall more than

85 g 3 ounces of refrigerant be released to the atmosphere in any one occurrence. Any system leaks within the first year shall be repaired in accordance with the specified requirements including material, labor, and refrigerant if the leak is the result of defective equipment, material, or installation.

3.2.2.3 Oil Charging

Except for factory sealed units, two complete charges of lubricating oil for each compressor crankcase shall be furnished. One charge shall be used during the performance testing period, and upon the satisfactory completion of the tests, the oil shall be drained and replaced with the second charge.

3.2.3 Mechanical Room Ventilation

For mechanical rooms which are intended to house refrigeration equipment, designers will use ASHRAE 15 to determine applicable design criteria. Delete this paragraph if a mechanical room is not applicable to the design.

In summary, ASHRAE 15 allows the use of either natural or mechanical ventilation systems, however natural ventilation is allowed only in certain limited applications. Natural ventilation is allowed only when "a refrigerant system is located outdoors more than 6.1 m 20 feet from building openings and is enclosed by a penthouse, lean-to or other open structure", otherwise mechanical ventilation is required.

The amount of ventilation air required for a mechanical room will be determined based upon the ventilation equations in ASHRAE 15. In order to use these equations, a designer must approximate the mass of refrigerant (kgs or lbs) expected in the largest system located in the mechanical room. Refrigerant quantities will be determined based upon a minimum of 2 different system manufacturers.

a. For a natural ventilation system, ASHRAE 15 provides an equation for sizing the amount of free opening area required.

b. For a mechanical ventilation system, ASHRAE 15 requires both normal and alarm ventilation. Normal ventilation will be sized to cover personnel ventilation requirements (2.5 l/s/m² 0.5 cfm/ft²) and heat buildup requirements if applicable. Alarm ventilation will be sized based upon the equations in ASHRAE 15. Both the normal and alarm ventilation rates can be achieved using the same ventilation system (e.g., multi-speed exhaust fans), however, individual systems are preferred. For the alarm ventilation, exhaust intakes will be located near the equipment and close to the finished floor. Most commonly used refrigerants are heavier-than-air and subsequently sink to the floor. Also per ASHRAE 15,

air supply and exhaust ducts to the mechanical room
will serve no other area within a facility.
Discharge air from a mechanical ventilation system
will be to the outdoors.

Mechanical ventilation systems shall be in accordance with Section 23 00 00
AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM.

3.2.4 Field Applied Insulation

Field installed insulation shall be as specified in Section 23 07 00
THERMAL INSULATION FOR MECHANICAL SYSTEMS, except as defined differently
herein.

3.2.5 Field Painting

Painting required for surfaces not otherwise specified, and finish painting
of items only primed at the factory are specified in Section 09 90 00
PAINTS AND COATINGS.

3.3 MANUFACTURER'S FIELD SERVICE

The services of a factory-trained representative shall be provided for
[_____] days. The representative shall advise on the following:

a. Hermetic machines:

- (1) Testing hermetic water-chilling unit under pressure for
refrigerant leaks; evacuation and dehydration of machine to an
absolute pressure of not over 300 micrometers.
- (2) Charging the machine with refrigerant.
- (3) Starting the machine.

b. Open Machines:

- (1) Erection, alignment, testing, and dehydrating.
- (2) Charging the machine with refrigerant.
- (3) Starting the machine.

3.4 CLEANING AND ADJUSTING

Equipment shall be wiped clean, with all traces of oil, dust, dirt, or
paint spots removed. Temporary filters shall be provided for all fans that
are operated during construction, and new filters shall be installed after
all construction dirt has been removed from the building. System shall be
maintained in this clean condition until final acceptance. Bearings shall
be properly lubricated with oil or grease as recommended by the
manufacturer. Belts shall be tightened to proper tension. Control valves
and other miscellaneous equipment requiring adjustment shall be adjusted to
setting indicated or directed. Fans shall be adjusted to the speed
indicated by the manufacturer to meet specified conditions. At least one
week before the official equipment warranty start date, all condenser coils
on air-cooled water chillers and split-system water chillers shall be
cleaned in accordance with the chiller manufacturer's instructions. This

work covers two coil cleanings. The condenser coils shall be cleaned with an approved coil cleaner by a service technician, factory trained by the chiller manufacturer. The condenser coil cleaner shall not have any detrimental affect on the materials or protective coatings on the condenser coils. Testing, adjusting, and balancing shall be as specified in Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC.

3.5 FIELD ACCEPTANCE TESTING

3.5.1 Test Plans

- a. Manufacturer's Test Plans: Within [120][_____] calendar days after contract award, submit the following plans:

[(1) Water chiller - field acceptance test plan

Field acceptance test plans shall be developed by the chiller manufacturer detailing recommended field test procedures for that particular type and size of equipment. Field acceptance test plans developed by the installing Contractor, or the equipment sales agency furnishing the equipment, will not be acceptable.

The Contracting Officer will review and approve the field acceptance test plan for each of the listed equipment prior to commencement of field testing of the equipment. The approved field acceptance tests of the chiller and subsequent test reporting.

-] b. Coordinated testing: Indicate in each field acceptance test plan when work required by this section requires coordination with test work required by other specification sections. Furnish test procedures for the simultaneous or integrated testing of tower system controls which interlock and interface with controls factory prewired or external controls for the equipment provided under [Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC][Section 23 09 53.00 20, SPACE TEMPERATURE CONTROL SYSTEMS] [Section 23 09 23.13 20, BACnet DIRECT DIGITAL CONTROL SYSTEMS FOR HVAC].
- c. Prerequisite testing: Chillers for which performance testing is dependent upon the completion of the work covered by Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC must have that work completed as a prerequisite to testing work under this section. Indicate in each field acceptance test plan when such prerequisite work is required.
- d. Test procedure: Indicate in each field acceptance test plan each equipment manufacturers published installation, start-up, and field acceptance test procedures. Include in each test plan a detailed step-by-step procedure for testing automatic controls provided by the manufacturer.

Each test plan shall include the required test reporting forms to be completed by the Contractor's testing representatives. Procedures shall be structured to test the controls through all modes of control to confirm that the controls are performing with the intended sequence of control.

Controller shall be verified to be properly calibrated and have the proper set point to provide stable control of their respective

equipment.

- e. Performance variables: Each test plan shall list performance variables that are required to be measured or tested as part of the field test.

Include in the listed variables performance requirements indicated on the equipment schedules on the design drawings. Chiller manufacturer shall furnish with each test procedure a description of acceptable results that have been verified.

Chiller manufacturer shall identify the acceptable limits or tolerance within which each tested performance variable shall acceptably operate.

- f. Job specific: Each test plan shall be job specific and shall address the particular cooling towers and particular conditions which exist in this contract. Generic or general preprinted test procedures are not acceptable.
- g. Specialized components: Each test plan shall include procedures for field testing and field adjusting specialized components, such as hot gas bypass control valves, or pressure valves.

3.5.2 Testing

- a. Each water chiller system shall be field acceptance tested in compliance with its approved field acceptance test plan and the resulting following field acceptance test report submitted for approval:

[(1) Water chiller - field acceptance test report

-] b. Manufacturer's recommended testing: Conduct the manufacturer's recommended field testing in compliance with the approved test plan. Furnish a factory trained field representative authorized by and to represent the equipment manufacturer at the complete execution of the field acceptance testing.
- c. Operational test: Conduct a continuous 24 hour operational test for each item of equipment. Equipment shutdown before the test period is completed shall result in the test period being started again and run for the required duration. For the duration of the test period, compile an operational log of each item of equipment. Log required entries every two hours. Use the test report forms for logging the operational variables.
 - d. Notice of tests: Conduct the manufacturer's recommended tests and the operational tests; record the required data using the approved reporting forms. Notify the Contracting Officer in writing at least 15 calendar days prior to the testing. Within 30 calendar days after acceptable completion of testing, submit each test report for review and approval.
 - e. Report forms: Type data entries and writing on the test report forms. Completed test report forms for each item of equipment shall be reviewed, approved, and signed by the Contractor's test director. The manufacturer's field test representative shall review, approve, and sign the report of the manufacturer's recommended test. Signatures shall be accompanied by the person's name typed.

- f. Deficiency resolution: The test requirements acceptably met; deficiencies identified during the tests shall be corrected in compliance with the manufacturer's recommendations and corrections retested in order to verify compliance.

3.6 SYSTEM PERFORMANCE TESTS

3.6.1 General Requirements

Before each refrigeration system is accepted, tests to demonstrate the general operating characteristics of all equipment shall be conducted by a registered professional engineer or an approved manufacturer's start-up representative experienced in system start-up and testing, at such times as directed. Tests shall cover a period of not less than [48] [_____] hours for each system and shall demonstrate that the entire system is functioning in accordance with the drawings and specifications. Corrections and adjustments shall be made as necessary and tests shall be re-conducted to demonstrate that the entire system is functioning as specified. Prior to acceptance, service valve seal caps and blanks over gauge points shall be installed and tightened. Any refrigerant lost during the system startup shall be replaced. If tests do not demonstrate satisfactory system performance, deficiencies shall be corrected and the system shall be retested. Tests shall be conducted in the presence of the Contracting Officer. Water and electricity required for the tests will be furnished by the Government. Any material, equipment, instruments, and personnel required for the test shall be provided by the Contractor. Field tests shall be coordinated with Section 23 05 93 TESTING, ADJUSTING, AND BALANCING FOR HVAC.

3.6.2 Test Report

The report shall document compliance with the specified performance criteria upon completion and testing of the system. The report shall indicate the number of days covered by the tests and any conclusions as to the adequacy of the system. The report shall also include the following information and shall be taken at least three different times at outside dry-bulb temperatures that are at least 3 degrees C 5 degrees F apart:

- a. Date and outside weather conditions.
- b. The load on the system based on the following:
 - (1) The refrigerant used in the system.
 - (2) Condensing temperature and pressure.
 - (3) Suction temperature and pressure.
 - (4) Running current, voltage and proper phase sequence for each phase of all motors.
 - (5) The actual on-site setting of all operating and safety controls.
 - (6) Chilled water pressure, flow and temperature in and out of the chiller.
 - (7) The position of the [capacity-reduction gear] [gas supply control valve] [fuel oil supply valve] at machine off, one-third loaded, one-half loaded, two-thirds loaded, and fully loaded.

3.7 DEMONSTRATIONS

Contractor shall conduct a training course for the operating staff as designated by the Contracting Officer. The training period shall consist

of a total [_____] hours of normal working time and start after the system is functionally completed but prior to final acceptance tests. The field posted instructions shall cover all of the items contained in the approved operation and maintenance manuals as well as demonstrations of routine maintenance operations.

-- End of Section --