
USACE / NAVFAC / AFCEA / NASA UFGS-23 66 00.00 20 (July 2006)

Preparing Activity: NAVFAC Superseding
 UFGS-23 66 00.00 20 (April 2006)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2008

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DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 23 66 00.00 20

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07/06

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SECTION 23 66 00.00 20

CENTRAL REFRIGERATION EQUIPMENT FOR AIR CONDITIONING 07/06

NOTE: This guide specification covers the requirements for central refrigeration equipment for built-up air-conditioning systems.

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 and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

NOTE: The following information shall be shown on the projects drawings:

1. Indicate size and locations of cooling tower supports.
2. Locations of water treatment tanks and control panels.
3. Indicate size and routing of refrigerant safety relief discharge piping. Consult ASHRAE 15 "Safety Code for Mechanical Refrigeration."
4. Indicate a cooling tower basin heating system for cooling towers that will be required to operate when outside temperatures are below freezing and the heat generated through the refrigeration process

(with head pressures maintained) will be insufficient to preclude freeze-ups. Either electric immersion heaters or steam or hot water coils may be used for supplemental heating.

5. Design refrigeration systems for air conditioning using energy efficiency in compliance with FEMP/Energy Star requirements specified at www.eren.doe.gov/femp/procurement. Indicate efficiency design parameters for equipment on the drawings.

PART 1 GENERAL

1.1 REFERENCES

NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.

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 AND REFRIGERATION INSTITUTE (ARI)

ARI 450	(1999) Standard for Water-Cooled Refrigerant Condensers, Remote Type
ARI 460	(2005) Performance Rating of Remote Mechanical-Draft Air-Cooled Refrigerant Condensers
ARI 480	(2001) Standard for Refrigerant-Cooled Liquid Coolers, Remote Type
ARI 520	(2004) Performance Rating of Positive Displacement Condensing Units
ARI 550/590	(2003) Standard for Water-Chilling Packages Using the Vapor Compression Cycle
ARI 560	(2000) Absorption Water Chilling and Water Heating Packages

AMERICAN GEAR MANUFACTURERS ASSOCIATION (AGMA)

AGMA 2005	(2003d) Design Manual for Bevel Gears
AGMA 373.04	(1973) Design for Fine-Pitch Wormgearing

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI S1.13 (2005) Methods for the Measurement of
Sound Pressure Levels in Air (ASA 118)

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

ASHRAE 15 (2007; Errata 2007) Safety Code for
Refrigeration

ASME INTERNATIONAL (ASME)

ASME B16.1 (2005) Standard for Gray Iron Threaded
Fittings; Classes 125 and 250

ASME B16.4 (2006) Standard for Gray Iron Threaded
Fittings; Classes 125 and 250

ASME BPVC SEC VIII (2007) Boiler and Pressure Vessel Codes:
Section VIII Rules for Construction of
Pressure Vessels, Division 1

ASME BPVC SEC VIII D1 (2007) Boiler and Pressure Vessel Code;
Section VIII, Pressure Vessels Division 1
- Basic Coverage

ASME PTC 23 (2003) Atmospheric Water Cooling Equipment

ASTM INTERNATIONAL (ASTM)

ASTM A 123/A 123M (2002) Standard Specification for Zinc
(Hot-Dip Galvanized) Coatings on Iron and
Steel Products

ASTM A 153/A 153M (2005) Standard Specification for Zinc
Coating (Hot-Dip) on Iron and Steel
Hardware

ASTM A 48/A 48M (2003) Standard Specification for Gray
Iron Castings

ASTM A 653/A 653M (2007) Standard Specification for Steel
Sheet, Zinc-Coated (Galvanized) or
Zinc-Iron Alloy-Coated (Galvannealed) by
the Hot-Dip Process

ASTM B 117 (2007) Standing Practice for Operating
Salt Spray (Fog) Apparatus

ASTM B 395/B 395M (2002) Standard Specification for U-Bend
Seamless Copper and Copper Alloy Heat
Exchanger and Condenser Tubes

ASTM B 62 (2002) Standard Specification for
Composition Bronze or Ounce Metal Castings

ASTM C 67 (2007) Standard Test Methods for Sampling
and Testing Brick and Structural Clay Tile

ASTM D 1654	(2005) Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
ASTM D 2996	(2001; R 2007e1) Filament-Wound "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe
ASTM D 5864	(2005) Standard Test Method for Determining Aerobic Aquatic Biodegradation of Lubricants or Their Components
ASTM D 596	(2001; R 2006) Reporting Results of Analysis of Water
ASTM D 6081	(1998; R 2004) Aquatic Toxicity Testing of Lubricants: Sample Preparation and Results Interpretation
ASTM E 2129	(2005) Standard Practice for Data Collection for Sustainability Assessment of Building Products
ASTM E 84	(2007) Standard Test Method for Surface Burning Characteristics of Building Materials

COOLING TECHNOLOGY INSTITUTE (CTI)

CTI ATC-105	(2000) Acceptance Test Code
CTI Std-103	(1994) Redwood Lumber Specifications
CTI Std-112	(1997) Pressure Preservative Treatment of Lumber
CTI Std-114	(1996) Douglas Fir Lumber Specifications (Coast Type)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 1	(2000; R 2005) Standard for Industrial Control and Systems General Requirements
NEMA ICS 2	(2000; Errata 2002; R 2005; Errata 2006) Standard for Industrial Control and Systems: Controllers, Contractors, and Overload Relays Rated Not More than 2000 Volts AC or 750 Volts DC: Part 8 - Disconnect Devices for Use in Industrial Control Equipment
NEMA MG 1	(2006; Errata 2007) Standard for Motors and Generators

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 214	(2005) Water-Cooling Towers
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NFPA 255 (2005; Errata 2006) Standard Method of Test of Surface Burning Characteristics of Building Materials

NFPA 70 (2007) National Electrical Code

REDWOOD INSPECTION SERVICE (RIS) OF THE CALIFORNIA REDWOOD ASSOCIATION (CRA)

RIS Grade Use (1998) Redwood Lumber Grades and Uses

SOUTHERN CYPRESS MANUFACTURERS ASSOCIATION (SCMA)

SCMA Spec (1986; Supple. No. 1, Aug 1993) Standard Specifications for Grades of Southern Cypress

U.S. ARMY CORPS OF ENGINEERS (USACE)

EM 1110-2-1424 (1999; Change 1) Lubricants and Hydraulic Fluids

U.S. DEPARTMENT OF AGRICULTURE (USDA)

DOA Bulletin 865 (1944) Timber-Connector Joints; Their Strength and Design

USDA AH 72 (1987) Wood Handbook: Wood as an Engineering Material

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

Energy Star (1992; R 2006) Energy Star Energy Efficiency Labeling System

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS A-A-59223 (Basic; Notice 1) Cooling Towers, Liquid

WEST COAST LUMBER INSPECTION BUREAU (WCLIB)

WCLIB 17 (2000) Standard Grading Rules

WESTERN WOOD PRODUCTS ASSOCIATION (WWPA)

WWPA G-5 (1998) Western Lumber Grading Rules

1.2 RELATED REQUIREMENTS

Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS, applies to this section with the additions and modifications specified herein.

1.3 SUBMITTALS

NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an

item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" 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 projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.] [for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Water chillers; G

Air-cooled condensers, remote-type; G

Cooling towers, including supporting members; G

SD-03 Product Data

Water chillers; G

Submit documentation for **Energy Star** qualifications or meeting FEMP requirements. Indicate Energy Efficiency Rating.

Compressor units; G

Air-cooled condensers, remote-type; G

Water-cooled condensers, remote-type; G

Cooling towers; G

Cooling tower water treatment systems, including chemicals; G

Electric motors and starters; G

[Local/Regional Materials

Submit documentation indicating distance between manufacturing facility and the project site. Indicate distance of raw material origin from the project site. Indicate relative dollar value of local/regional materials to total dollar value of products included in project.]

[Environmental Data]

SD-06 Test Reports

Pressure vessel tests; G

Salt-spray tests; G

Make-up water analysis; G

Start-up and initial operational tests; G

Water analysis; G

Field-assembled cooling towers performance tests; G

Aquatic toxicity

SD-08 Manufacturer's Instructions

Central refrigeration equipment; G

Cooling tower water treatment systems; G

Chemicals; G

Submit an Occupational Safety and Health Act (OSHA) Material Safety Data Sheet for chemicals provided.

SD-10 Operation and Maintenance Data

Water Chillers, Data Package 3; G

Compressor units, Data Package 3; G

Air-cooled condensers, remote-type, Data Package 3; G

Water-cooled condensers, remote-type, Data Package 3; G

Cooling towers, Data Package 3; G

Cooling tower water treatment systems, Data Package 3; G

Electric motors and starters, Data Package 3; G

Submit in accordance with Section 01 78 23 OPERATION AND
MAINTENANCE DATA.

1.4 QUALITY ASSURANCE

1.4.1 Modifications of References

In the referenced publications, the advisory provisions shall be mandatory; substitute the word "shall" for "should" or "it is recommended" wherever they appear; reference to the "authority having jurisdiction" and "owner" shall be interpreted to mean the Contracting Officer.

1.4.2 Pressure Vessels

Design, fabrication, inspection, and testing of pressure vessels including waterside and refrigerant side of condensers and liquid coolers (evaporators) shall be in accordance with ASME BPVC SEC VIII and ASHRAE 15. The ASME official Code U-Symbol or Code UM-Symbol stamped or marked on the vessels, and the submission of the applicable ASME required manufacturer's data report will be accepted as evidence that pressure vessels comply to ASME rules for construction. Submit results of pressure vessel tests. Provide make-up water analysis in accordance with ASTM D 596.

1.4.3 Personnel Protection

Provide personnel protection from moving parts including fans, pulleys, chains, gears, and couplings. High temperature machinery and piping shall be guarded or covered with insulation.

1.4.4 Electrical Systems

Wiring and components shall conform to NFPA 70.

1.5 CENTRAL REFRIGERATION EQUIPMENT

Provide manufacturer's instruction, including evacuation and charging procedures and posted operating instructions for each piece of refrigeration equipment.

1.6 REFRIGERANTS AND OILS

NOTE: HFC-134a refrigerant is non-ozone depleting, but contributes to global warming. HCFC-123 refrigerant is ozone-depleting (but much less so than R-11), and contributes minimally to global warming. EPA, per the Significant New Alternative Policy rule, reviews refrigerant substitutes on the basis of ozone depletion potential, global warming potential, toxicity, flammability, and exposure potential. Lists of acceptable and unacceptable substitutes are updated several times each year. A chronological list of SNAP updates is available at <http://www.epa.gov/ozone/snap/refrigerants/lists/index.html> or from the stratospheric ozone information hotline at 1 (800) 296-1996. Reducing ozone depletion and global warming potential by reducing or eliminating CFC, HCFC, and Halon use in air conditioning

equipment contributes to the following LEED credits:
EA Prerequisite 3; EA4.

Dehydrate, purge, and charge refrigerant circuit with refrigerant and oil at factory. Factory oil and refrigerant charge shall be full amount required for operation, if within limits permitted by the Department of Transportation; otherwise, a holding charge shall be furnished. Field charging, where only a holding charge is shipped, shall be accomplished without breaking permanent refrigerant connections. Furnish one complete charge of lubricating oil in sealed containers in addition to that placed in system. Assess potential effects of all lubricants on aquatic organisms in accordance with [ASTM D 6081](#) and submit [aquatic toxicity](#) reports. Assess biodegradation in accordance with [ASTM D 5864](#). In accordance with [EM 1110-2-1424](#) Chapter 8, aquatic toxicity shall exceed 1,000 ppm at LL50 and biodegradation shall exceed 60 percent conversion of carbon to carbon dioxide in 28 days. Chillers using R-11, R-12, R-113, R-114, R-115, or R-500 as a refrigerant will not be permitted. Refrigerants shall have an Ozone Depletion Factor (ODF) of [0.05][_____] or less. The ODF shall be in accordance with the "Montreal Protocol On Substances That Deplete The Ozone Layer," September 1987, sponsored by the United Nations Environment Programme. CFCs [and HCFCs] [and Halons]shall not be permitted. Refrigerant shall be an approved alternative refrigerant per EPA's Significant New Alternative Policy (SNAP) listing. [Use HFC-134a refrigerant.] [Use HCFC-123 refrigerant.]

1.7 SUSTAINABLE DESIGN REQUIREMENTS

1.7.1 [Local/Regional Materials](#)

NOTE: Using local materials can help minimize transportation impacts, including fossil fuel consumption, air pollution, and labor.

Use materials or products extracted, harvested, or recovered, as well as manufactured, within a [500][_____] mile [800][_____] kilometer radius from the project site, if available from a minimum of three sources.

1.7.2 [Environmental Data](#)

NOTE: ASTM E 2129 provides for detailed documentation of the sustainability aspects of products used in the project. This level of detail may be useful to the Contractor, Government, building occupants, or the public in assessing the sustainability of these products.

[Submit Table 1 of [ASTM E 2129](#) for the following products: [_____.]

PART 2 PRODUCTS

2.1 SELF-CONTAINED [WATER CHILLERS](#)

Provide complete, packaged water chillers, each mounted on a single welded-steel base. Chillers shall be ready for operation after

installation and field testing. Equipment shall operate within capacity range and speed recommended by the manufacturer. Size equipment based on Design Manual CS from the Air Conditioning Contractors of America; do not oversize. 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. Provide insulation for surfaces subject to sweating including the liquid cooler, suction line piping, water boxes, economizer, and cooling lines. Insulation shall conform to Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.1.1 Centrifugal, Helical Rotary, Water-Cooled

NOTE: Specify applicable ratio after consulting current literature to ensure the most energy-efficient (but still life cycle cost-effective) system is provided. Because most chillers spend over 95 percent of their operating hours at part load, part load performance can be the most important energy efficiency consideration for many applications. Select chiller based on the Integrated Part Load Value (IPLV) when chiller load is variable (i.e., variable ambient temperatures and humidity). The ratios specified shall permit unlimited competition among at least three manufacturers. Per FEMP requirements, power input at full load shall not exceed 0.59 kW/ton0.17 kW/kW for small (150-299 tons525-1049 kW) centrifugal systems, 0.56 kW/ton0.16 kW/kW for large (300-2000 tons1050-7000 kW) centrifugal systems, and 0.64 kW/ton0.16 kW/kW for rotary systems. Power input at part load shall not exceed 0.52 kW/ton0.15 kW/kW for small (150-299 tons525-1049 kW) centrifugal systems, 0.44 kW/ton0.12 kW/kW for large (300-2000 tons 1050-7000 kW) centrifugal systems, and 0.49 kW/ton 0.14 kW/kW for rotary systems. The Energy Policy Act of 2005 requires new buildings to use 30 percent less energy than the ASHRAE 90.1 level. Efficient cooling equipment and components contribute to the following LEED credits: EA Prerequisite 2; EA1.

ARI 550/590. Base capacity and power ratings, at the conditions indicated and specified, on the test requirements of ARI 550/590. Power input shall not exceed [_____] kW/kW kW/ton load at full load capacity. Power input shall not exceed [_____] kW/kW kW/ton load at part load capacity. [Select chiller based on the Integrated Part Load Value (IPLV).]

2.1.1.1 Centrifugal Compressors

Statically and dynamically balanced impellers, either direct or gear driven by an electric motor. Impeller shafts shall be heat-treated alloy steel. Shaft main bearings shall be journal type with bronze or babitted liners or aluminum-alloy, one-piece insert type, or rolling element bearings with an American Bearing Manufacturers Association L10 life greater than 200,000 hours. Casings of cast iron, aluminum, or steel plate shall have split sections with gaskets which are bolted or clamped together. Lubrication systems shall be forced-feed type. An oil pressure differential cutout

interlocked with the compressor starter shall allow compressor to operate only when required oil pressure is provided. Provide for lubrication of bearings and shaft seals prior to starting and on stopping with or without electrical power supply. Speed reducing gears shall be designed to ensure self-alignment, interchangeable parts, proper lubrication and minimum of unbalanced forces. Gear box bearings shall be sleeve type. Provide pressure lubrication with pump and cooler. Gear cases shall be oiltight. Shaft extensions shall be provided with seals to retain oil and exclude dust. Compressors shall operate stably and for indefinite periods of time at any stage of capacity reduction from 100 to 10 percent of full load capacity.

2.1.1.2 Helical Rotary Compressors

Positive displacement, oil-injected type, and driven by an electric motor. Rotors shall be solid steel, Society of Automotive Engineers Grade 1141 or 1144. Shaft main bearings shall be either sleeve-design type with leaded bronze or steel-backed babbitt; or frictionless bearing design, ball or roller type. Housings and covers shall be high-grade, cast iron or aluminum pressure castings. Lubrication systems shall lubricate rotors, bearings, shaft seal as well as rotor sealing and cooling. Provide an oil safety cutout interlocked with the compressor starter to allow compressor to operate only when oil system is operational. Provide for lubrication of bearings and shaft seals on shutdown with or without electrical power supply. Compressors shall operate stably and for indefinite periods of time at any stage of capacity reduction from 100 to 10 percent of full load capacity.

2.1.1.3 Condensers

NOTE: The selection of the double-tube bundle is a design function where a steady demand exists for low grade rejected heat. Where this demand does not exist or where the heat recovery cannot be justified, the single-tube bundle should be used. When marine water boxes are requested by the activity, use the second bracketed sentence and delete the first bracketed sentence. If not requested, use the first bracketed sentence and delete the second bracketed sentence.

[Shell-and-tube construction shall permit tubes to be cleaned from each end by removing water box cover plates or head and minimum amount of water piping.] [Shell-and-tube construction with water boxes having side mounted piping connections and cover plates to permit tubes to be cleaned from each end without removing connected piping.] Refrigerant side design pressure shall comply with **ASHRAE 15**. Water side design pressure shall not be less than **1034 kPa (gage) 150 psig**. Tubes shall be fabricated of seamless copper tubing, with plan or integral fins and shall be individually replaceable and rolled or brazed into copper or steel tube sheets. Base performance on a water velocity not less than **0.91 meter per second (m/s) 3 feet per second (fps)** nor more than **3.66 m/s 12 fps** and a fouling factor of 0.00075. Condensers shall be [single] [double]-tube bundle type.

2.1.1.4 Liquid Coolers (Evaporators)

Removable copper tube, bundle type constructed of seamless copper tubing

rolled or brazed into copper or steel tube sheets with baffles and tube supports of copper; or liquid cooler shall be fabricated of seamless copper tubing, plain or with integral fins, individually replaceable and rolled or brazed into copper or steel tube sheets with tube supports of copper or steel plate. Refrigerant side design pressure shall comply with ASHRAE 15. Water side design pressure shall not be less than 1034 kPa (gage) 150 psig. Liquid cooler feed control shall feed liquid cooler at all levels of capacity from 100 percent down to minimum required operating level. Base performance on a water side velocity not less than 0.91 m/s 3 fps nor more than 3.66 m/s 12 fps, and fouling factor of 0.00025.

2.1.1.5 Purge Systems

If chiller operates at refrigerant pressures below 101.34 kPa(gage) 14.7 psig, provide a purge system and connect to main refrigeration system. Purge systems shall automatically remove air, water vapor, and noncondensable gases from refrigeration system and condense, separate, and return to system refrigerant present. Provide an oil separator, if required by manufacturer. Purge systems shall provide a warning to signal operator at occurrence of excessive purging, indicating abnormal air leakage into unit. Purge systems shall not discharge to occupied areas, or create a potential hazard to personnel.

2.1.1.6 Evacuation or Pump-Out Systems

When a positive refrigerant is used and basic chiller unit will not permit pumpdown storage and isolation of entire charge within basic unit, provide a manually started and stopped evacuation or pump-out system, consisting of a condensing unit and a receiver of sufficient capacity to store entire refrigerant charge of largest water-chilling system or unit. When designed to permit pumpdown of entire refrigerant charge and isolation of entire refrigerant charge within basic unit, a separate evacuation or pump-out shall not be required. Receivers shall be provided with rupture members and dual relief valves, piping, and controls so that the evacuation or pump-out system may be provided without temporary piping or wiring.

2.1.1.7 Controls, Control Panels, and Gages

NOTE: Specify required time delay for type and size
of unit after consulting current literature.

NOTE: Include sentence in brackets if centrifugal
chillers are specified.

Provide an automatic capacity-reduction system for stable operation from 100 to 10 percent of full load capacity. Provide modulating, chilled-water controls with adjustable throttling range, a means of calibration, and a means of adjusting chilled-water temperature control point. Provide a time delay of not less than [_____] minutes to prevent compressor restart when a compressor is shut down by the operating controls. Provide a demand limiter to minimize amperage draw. [Provide controls to restart chiller automatically if power is interrupted for three seconds or less.] Provide a control panel complete with compressor operating control, start-stop switch, and the following gages and protective devices:

a. Gages:

- (1) Evaporator pressure
- (2) Condenser pressure
- (3) Oil pump pressure
- (4) Elapsed running time meter

b. Protection Devices With Manual Reset:

- (1) Low oil temperature lockout
- (2) Low refrigerant temperature cutout
- (3) Low temperature chilled-water or refrigerant cutout
- (4) High-pressure cutout
- (5) Low oil pressure cutout or low oil flow cutout
- (6) High oil or bearing temperature cutout
- (7) High motor winding temperature cutout
- (8) Compressor motor overload cutout
- (9) Low chilled water flow cutout
- (10) Low condenser water flow cutout

2.1.1.8 Signal Lights

Provide signal lights or other visual "failed" indications for specified protective devices. Provide a minimum 100 mm 4 inch alarm bell and alarm circuit to actuate the bell in event of machine cutout on protective devices except when low pressure cutout is used as an operating control.

2.1.1.9 Electric Motors and Starters

Provide variable speed, polyphase, induction electric motors conforming to NEMA MG 1. Motors 3/4 kW 1 hp and larger shall meet NEMA Premium Efficiency requirements. Fan motors less than 3/4 kW 1 hp shall meet NEMA High Efficiency requirements. Provide motors suitable for use with the indicated electrical power characteristics and the type of starter provided. Provide reduced voltage, closed-transition type motor starter conforming to NEMA ICS 1 and NEMA ICS 2. Provide phase failure, phase reversal, over voltage and under voltage protection.

2.1.2 Reciprocating, Helical Rotary, Scroll, Air-Cooled

NOTE: Specify applicable ratio after consulting current literature to ensure the most energy-efficient (but still life cycle cost-effective) system is provided. Because most chillers spend over 95 percent of their operating hours at part load, part load performance can be the

most important energy efficiency consideration for many applications. Select chiller based on the Integrated Part Load Value (IPLV) when chiller load is variable (i.e., variable ambient temperatures and humidity). The ratios specified shall permit unlimited competition among at least three manufacturers. Per FEMP requirements, power input at full load shall not exceed 0.34 kW/kW 1.23 kW/ton. Power input at part load shall not exceed 0.25 kW/kW 0.90 kW/ton for reciprocating systems, 0.27 kW/kW 0.98 kW/ton for helical rotary systems, or 0.24 kW/kW 0.86 kW/ton for scroll systems.

ARI 550/590. Base capacity and power ratings, at the conditions indicated and specified, on the test requirements of ARI 550/590. Power input shall not exceed [_____] kW/kW kW/ton load at full load capacity. Power input shall not exceed [_____] kW/kW kW/ton load at part load capacity. [Select chiller based on the Integrated Part Load Value (IPLV).] For multicompressor units, not less than two independent refrigerant circuits shall be provided. Chillers shall be capable of operating at partial-load conditions without increased vibration over normal vibration at full load operation, and shall be capable of continuous operation down to minimum capacity.

2.1.2.1 Casings

Aluminum not less than one mm 0.040 inch in nominal thickness or steel not lighter than 18 gage (1.31 mm 0.0516 inch) in nominal thickness. Provide condensers having horizontal air discharge with discharge baffles to direct air upward, constructed of same material and thickness as casing. Provide wire screens or louvers over exposed condenser coil fins not protected by casing.

2.1.2.2 Reciprocating Compressors

Provide with forced-feed lubrication, crankcase heater, hot-gas muffler and suction strainer. Cylinder unloading devices shall be unloaded when compressor starts. Piston speed for open compressors shall not exceed recommendations of manufacturer or 5.1 m/s 1000 feet per minute (fpm), whichever is less.

2.1.2.3 Helical Rotary Compressors

Positive displacement, oil injected type, and driven by an electric motor. Rotors shall be solid steel, Society of Automotive Engineers Grade 1141 or 1144. Shaft main bearings shall be either sleeve-design type with leaded bronze or steel-backed babbitt; or frictionless bearing design, ball or roller type. Housings and covers shall be high-grade cast-iron pressure castings. Lubrication systems shall lubricate rotors, bearings, shaft seal as well as rotor sealing and cooling. Provide an oil safety cutout interlocked with the compressor starter to allow compressor to operate only when oil management system is operational. Provide for lubrication of bearings and shaft seals on shutdown with or without electric power supply.

2.1.2.4 Scroll Compressors

Three-dimensional, compliant, hermetically sealed design. Compressors shall be mounted on vibration isolators. Rotating parts shall be factory

balanced. Main bearings shall be rolling-element type. Lubrication systems shall be centrifugal pump type including oil level sight glass and oil charging valve.

2.1.2.5 Condenser Coils

NOTE: Research project location conditions to determine the environmental effects on finned tube coils. The research should include a survey of existing similar equipment. Prepare project specifications based on the conclusions of the research. Consideration should be given to the following combinations based on past experience of these materials in dealing with the local conditions.

1. Copper tube and aluminum fins, coated
2. Copper tube and copper fins, coated
3. Aluminum tube and aluminum fins, coated
4. Aluminum tube and aluminum fins, uncoated
5. Copper tube and copper fins, uncoated
6. Copper tube and aluminum fins, uncoated.

Extended-surface fin-and-tube type. Condenser coils shall be constructed of [copper tubes and aluminum fins] [copper tubes and copper fins] [aluminum tubes and aluminum fins]. Fins shall be hydraulically or mechanically bonded to tubes and installed in a metal casing. Coils shall be circuited and sized for a minimum of **minus 15 degrees C 5 degrees F** subcooling and full pumpdown capacity. Indoor and outdoor coils shall be matched and from same manufacturer. Use a low sensible heat ratio for more moisture removal. [Provide a coating as specified in the paragraph entitled "Coatings for Finned Tube Coils." Coils to be coated shall be part of the manufacturer's standard product for the capacities and ratings indicated and specified. Fins shall be plate type.]

2.1.2.6 Fans

Statically and dynamically balanced. For V-belt drive fans, provide adjustable sheaves. Provide fans with vibration isolation devices to minimize vibration transmission.

2.1.2.7 Liquid Coolers (Evaporators)

NOTE: Insert winter design temperature that the equipment will be subjected to.

Tubes shall be seamless copper. Refrigerant side design pressure shall comply with **ASHRAE 15**. Water side design pressure shall not be less than **1034 kPa (gage) 150 psig**. On direct-expansion units, each refrigerant circuit shall be complete with liquid solenoid valve and expansion device capable of modulating to minimum capacity. For the water side of liquid

cooler, the performance shall be based on a water velocity ranging from 0.91 to 3.66 m/s 3 to 12 fps with a fouling factor of 0.00025. Cooler shall be provided with an electrical heating cable for freeze-up protection to [____] degrees C degrees F ambient.

2.1.2.8 Controls, Control Panels, and Gages

NOTE: Specify required time delay for type and size
of unit after consulting current literature.

NOTE: Specify lowest percent of full capacity
required. Check for availability before inserting
number in blank.

NOTE: Insert winter design temperature that the
equipment will be subjected to.

Provide a control panel fitted with a discharge pressure gage, suction pressure gage, separate high pressure cutout with manual reset, separate low pressure cutout, low water temperature cutout with manual reset, compressor operating control, and manual off-auto switch. Provide oil pressure gage and low-oil-pressure cutout switch with manual reset for chillers with positive displacement type oil pumps. Provide signal lights or other visual "failed" indications for high pressure, low pressure, and oil pressure protection devices. Multicompressor units shall be provided with a lead/lag selector switch. Provide a timer to prevent compressors from short cycling whenever stopped by safety controls. Time delay shall be not less than [____] minutes. A pumpdown cycle of the nonrecycling start type shall be provided for each compressor 70 kW 20 tons or larger. Provide a minimum 100 mm 4 inch alarm bell and alarm bell circuit to actuate bell in event of machine cutout on protective devices, except when low-pressure cutout is used as an operating control. Provide system capacity control to adjust chiller output to a minimum of [____] percent of full load capacity without cycling operating compressor and to automatically recycle system on power interruption. Provide start-up and head pressure controls to allow for system operation at all ambient temperatures down to [____] degrees C degrees F.

2.1.2.9 Electric Motors and Starters

Provide variable speed induction electrical motors conforming to NEMA MG 1. Motors 3/4 kW 1 hp and larger shall meet NEMA Premium Efficiency requirements. Fan motors less than 3/4 kW 1 hp shall meet NEMA High Efficiency requirements. Fan motor bearings shall be permanently lubricated. Compressor starters shall be [across-the-line magnetic] [reduced-voltage] type conforming with NEMA ICS 1 and NEMA ICS 2. Provide phase failure, over voltage and low voltage protection.

2.1.3 Reciprocating, Helical Rotary, Scroll, Water-Cooled

NOTE: Specify applicable ratio after consulting
current literature to ensure the most

energy-efficient (but still life cycle
cost-effective) system is provided. Because most chillers spend over 95 percent of their operating hours at part load, part load performance can be the most important energy efficiency consideration for many applications. Select chiller based on the Integrated Part Load Value (IPLV) when chiller load is variable (i.e., variable ambient temperatures and humidity). The ratios specified shall permit unlimited competition among at least three manufacturers. Per FEMP requirements, power input at full load shall not exceed 0.18 kW/kW0.64 kW/ton for small (less than 525 kW150 tons) rotary and scroll systems, and 0.17 kW/kW0.61 kW/ton for medium (525-1050 kW150-300 tons) rotary and scroll systems. Power input at part load shall not exceed 0.15 kW/kW0.55 kW/ton for small (less than 525 kW150 tons) rotary and scroll systems, and 0.14 kW/kW0.51 kW/ton for medium (525-1050 kW150-300 tons) rotary and scroll systems.

ARI 550/590. Base capacity and power ratings, at the conditions indicated and specified, on the test requirements of ARI 550/590. Power input shall not exceed [_____] kW/kW kW/ton load at full load capacity. Power input shall not exceed [_____] kW/kW kW/ton load at part load capacity. [Select chiller based on the Integrated Part Load Value (IPLV).] For multicompressor units, not less than two independent refrigerant circuits shall be provided. 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.

2.1.3.1 Reciprocating Compressors

Provide with forced-feed lubrication, crankcase heater, hot-gas muffler, and suction strainer. Cylinder unloading devices shall be unloaded when compressor starts. Piston speed for open compressor shall not exceed recommendations of manufacturer or 5 m/s 1000 fpm, whichever is less.

2.1.3.2 Helical Rotary Compressors

Shall be positive displacement, oil-injected type, and driven by an electric motor. Rotors shall be solid steel, Society of Automotive Engineers Grade 1141 or 1144. Shaft main bearings shall be either sleeve-design type with leaded bronze or steel-backed babbitt; or frictionless bearing design, ball or roller type. Housings and covers shall be high-grade, cast-iron or aluminum pressure castings. Lubrication system shall lubricate rotors, bearings, shaft seal as well as rotor sealing and cooling. Provide an oil safety cutout interlocked with the compressor starter to allow compressor to operate only when the oil system is operational. Provide for lubrication of bearings and shaft seals on shutdown with or without electrical power supply.

2.1.3.3 Scroll Compressors

Three-dimensional, compliant, hermetically sealed design. Compressors shall be mounted on vibration isolators. Rotating parts shall be factory balanced. Main bearings shall be rolling-element type. Lubrication systems shall be centrifugal pump type including oil level sight glass and

oil charging valve.

2.1.3.4 Condensers

NOTE: The selection of the double-tube bundle is a design function where a steady demand exists for low grade rejected heat. Where this demand does not exist or where the heat recovery cannot be justified, the single-tube bundle should be used.

Water-cooled condensers shall have shell-and-tube construction, permitting tubes to be cleaned from each end by removing water box cover plates or head and a minimum amount of water piping. Refrigerant side design pressure shall comply with ASHRAE 15. Water side design pressure shall not be less than 1034 kPa (gage) 150 psig. Tubes shall be fabricated of seamless copper tubing, plan or with integral fins, and shall be individually replaceable and rolled or brazed into copper or steel tube sheets. Base performance on a water velocity not less than 0.91 m/s 3 fps nor more than 3.66 m/s 12 fps and a fouling factor of 0.00075. Condenser shall be [single] [double]-tube bundle type.

2.1.3.5 Liquid Coolers (Evaporators)

Tubes shall be seamless copper. On direct-expansion-type units, each refrigerant circuit shall be complete with liquid solenoid valve and expansion device capable of modulating to minimum capacity. For the water side of liquid cooler, performance shall be based on a water velocity not less than 0.91 m/s 3 fps nor more than 3.66 m/s 12 fps and a fouling factor of 0.00025.

2.1.3.6 Controls, Control Panels, and Gages

NOTE: Specify required time delay for type and size of unit after consulting current literature.

NOTE: Specify lowest percent of full capacity required. Check for availability before inserting number in blank.

Provide a control panel fitted with a discharge pressure gage, suction pressure gage, separate high pressure cutout with manual reset, separate low pressure cutout, low water temperature cutout with manual reset, compressor operating control, and manual off-auto switch. Provide oil pressure gage and low-oil-pressure cutout switch with manual reset for chillers with positive displacement type oil pumps. Provide signal lights or other visual "failed" indications for high pressure, low pressure, and oil pressure protection devices. Multicompressor units shall be provided with a lead/lag selector switch. Provide a timer to prevent compressors from short cycling whenever stopped by safety controls. Time delay shall be not less than [_____] minutes. A pumpdown cycle of the nonrecycling start type shall be provided for each compressor 70 kW 20 tons or larger. Provide a minimum 100 mm 4 inch alarm bell and alarm bell circuit to actuate bell in event of machine cutout on protective devices, except when

low-pressure cutout is used as an operating control. Provide system capacity control to adjust chiller output to a minimum of [_____] percent of full load capacity without cycling operating compressor and to automatically recycle system on power interruption. Provide start-up and head pressure controls to allow for system operation at all ambient temperatures down to [_____] degrees C degrees F.

2.1.3.7 Motors and Starters

Provide [across-the-line magnetic] [reduced voltage] type motor starters conforming with NEMA ICS 1 and NEMA ICS 2. Provide phase failure, over voltage and low voltage protection. Provide induction electric motors conforming with NEMA MG 1. Motors shall be variable speed. Motors 3/4 kW 1 hp and larger shall meet NEMA Premium Efficiency requirements. Fan motors less than 3/4 kW 1 hp shall meet NEMA High Efficiency requirements.

2.1.4 Absorption Chillers[/Heaters]

NOTE: Absorption chillers should be considered for demand shedding and thermal balancing of the total system.

Absorption chiller[/heater] shall be designed, constructed, tested, and rated in accordance with ARI 560 and shall meet the requirements of ASHRAE 15. Unit shall be capable of operating automatically and continuously between 10 percent and 100 percent of full load. Unit shall include:

1. Absorber
2. Condenser
3. Evaporator
4. Generator - low stage generator for single-effect units and low and high stage generator for double-effect units
5. Solution heat exchangers
6. Pumps for solution and refrigeration recirculation
7. Controls
 - a. Low temperature cut-out
 - b. Provisions for interlocks to prevent or stop operation of the chiller package upon failure of chilled water flow
 - c. Means for electrically protecting pump motors included in the package against thermal overload
 - d. Chilled water[/heating] temperature controller
 - e. Instrument panel
 - f. Burner controls and [gas] [oil] train safeties per UL Standards 795 Oil for Heating Equipment and 726 Oil for Direct-Fired Water

Chilling-Heating Units]

8. Anticrystallization or automatic decrystallization equipment

9. Miscellaneous

- a. Absorbent charge
- b. Means for removing non-condensables from the chiller
- c. Interconnecting piping, base and supports
- d. Installations and operating instructions
- e. Nameplate

2.1.4.1 Capacity Criteria

NOTE: The following is a list of appropriate minimum full load ratings to be used for units covered by ARI 560. These values or higher values will be entered into the specification where indicated, and placed on the drawings. The designer should contact manufacturers to determine what is available before specifying values.

	Full Load COP	Heating Efficiency
Direct Fired, Double Effect	1.00	80 percent
Indirect Fired, Single Effect	0.70	
Indirect Fired, Double Effect	1.20	

Unit shall have a minimum Coefficient of Performance (COP) of [_____] at full load rating in accordance with ARI 560. Unit shall have a minimum [Integrated Part Load Value (IPLV)] [Application Part Load Value (APLV)] of [_____] COP in accordance with ARI 560.

2.1.4.2 Absorber, Evaporator, Condenser, & Generator

NOTE: Although a double effect absorption water chiller[/heater] costs more, than a single effect absorption water chiller an engineering economic study made in accordance with Life Cycle Costing technique may indicate substantial savings in energy, resulting in the lower cost alternative over the projected useful life of the facility. When this determination is made, the item within the brackets will be used, provided the cost of the project can be kept within the allotted funds. The use of double effect absorption will be considered if high pressure steam (or hot water) is available. No new heat generating plant will be constructed to serve the double effect units; this restriction is the same as currently in effect for ordinary

absorption units. If steam or hot water is not available, a direct fired absorption chiller[/heater] may be installed. If hot water is required, a Life Cycle Cost analysis shall be performed to determine if a direct fired absorption chiller/heater is more economical than a separate chiller and boiler. The inapplicable pressure depending, upon steam or hot water, will be deleted.

The absorber, evaporator, condenser, and generator shall comply with the requirements of ASHRAE 15. The absorption unit shall be of the shell-and-tube type construction. The absorber, evaporator, and condenser shall be suitable for not less than [1,000] [1,700] kPa [150] [250] psig waterside working pressure. The generator shall have a heating medium of [steam] [hot water] and have a suitable working pressure of [1,000] [1,700] kPa [150] [250] psig. The absorption unit may be enclosed in one or two shells with removable water boxes or heads. Condenser tubes shall be copper or copper-nickel. Generator tubes shall be copper-nickel. Absorber and evaporator tubes shall be either copper or copper-nickel. Tube ends shall be rolled into or silver brazed to tube sheets. All copper or copper-nickel tubes shall be seamless and be in accordance with ASTM B 395/B 395M. The liquid cooler, within the evaporator, shall be seamless and be in accordance with ASTM B 395/B 395M. The liquid cooler, within the evaporator, shall be designed, constructed, tested, and certified in accordance with ASME BPVC SEC VIII D1. [For double effect absorption chiller[/heaters], first stage concentrator tubes shall be titanium and the steam circuit shall comply with ASME BPVC SEC VIII D1. The header for the double effect unit shall be designed for a steam working pressure of 1,000 kPa 150 psig and factory tested at 150 percent of design working pressure. Double effect absorption chillers[/heaters] shall be equipped with capacity modulation to control solution flow entering and leaving the first stage concentrator.]

2.1.4.3 Tube Bundles

NOTE: The selection of the double-tube bundle is a design function where a steady demand exists for low grade rejected heat. Where this demand does not exist or where the heat recovery cannot be justified, the single-tube bundle should be used.

Provide sufficient clearance between tubes and an adequate number of support sheets, with tubes fitted in the sheets, to prevent chafing of tubes or crevice corrosion due to uneven tube expansion, vibration, or pulsation. Holes in tube sheets shall not have sharp corners. Each tube shall be removable, in one piece, through holes individually provided for it in tube and support sheets. Water velocities through cooler, condenser, and absorber tubes shall range from less than 0.91 to 3.66 m/s 3 to 12 fps. Condenser shall be [single] [double]-tube bundle type.

2.1.4.4 Heads

Provide removable, welded-steel or cast-iron heads for external steam and water connections to permit access to tubes for inspection and cleaning. Design and test water spaces for a working pressure of not less than 1034

kPa (gage) 150 psig. Water spaces that are not subject to the ASME Code, due to size or other limitations, shall be tested at a pressure of not less than 1.5 times the working pressure.

2.1.4.5 Purge System

Provide chiller with an automatically or manually controlled purge system consisting of a motor driven, jet type, or viscosity type, high vacuum pump with separators, pipe connections, and controls. Provide positive protection against return air to unit when evacuator is not in operation.

2.1.4.6 Crystallization

Provide for automatic decrystallization or anti-crystallization, in accordance with manufacturer's standard. If decrystallization is used, provide and arrange for supplemental heating elements if required for automatic operation.

2.1.4.7 Refrigerant and Absorber

Absorber unit shall be fully charged with water and a nontoxic absorber after installation. Refrigerant and inhibitors shall not generate films that would reduce machine efficiency by coating tubes. The corrosion inhibitor shall not cause the solution to be classified as hazardous waste under the Resource Conservation and Recovery Act.

2.1.4.8 Absorption Unit Pumps

Pumps as required, but not including chilled-water and condenser-water pumps, shall be provided as part of the liquid chilling plant and be factory mounted. Pumps shall be hermetic type provided with suction and discharge stop valves, when required by the manufacturer, and be complete with piping, fittings, and other required devices. Magnetic across-the-line starter with overhead protection shall be provided in the control panel for each pump.

2.1.4.9 Cleaning Brushes

Furnish chiller with two brushes, having jointed rods, suitable for cleaning evaporator and condenser tubes.

2.1.4.10 Charging and Testing

Unless fully assembled, tested, evacuated, and charged at factory, components shall be dried and sealed to prevent corrosion of internal surfaces prior to field assembly. Assemble, test, evacuate, and charge units under supervision of manufacturer's representative. Periodic tests shall be readily made on the concentration of the inhibitor and lithium bromide solution with a field test kit furnished by manufacturer, or as recommended by manufacturer.

2.2 SPLIT-SYSTEM WATER CHILLERS, REMOTE CONDENSER

NOTE: Specify applicable ratio after consulting current literature to ensure the most energy-efficient (but still cost-effective) system is provided. Because most chillers spend over 95 percent of their operating hours at part load, part

load performance can be the most important energy efficiency consideration for many applications. Select chiller based on the Integrated Part Load Value (IPLV) when chiller load is variable (i.e., variable ambient temperatures and humidity). The ratios specified shall permit unlimited competition among at least three manufacturers.

ARI 550/590. Base capacity and power ratings, at the conditions indicated and specified, on the test requirements of ARI 550/590. Size equipment based on Design Manual CS from the Air Conditioning Contractors of America; do not oversize. Power input shall not exceed [_____] kW/kW kW/ton load at full load capacity. Power input shall not exceed [_____] kW/kW kW/ton load at part load capacity. [Select chiller based on the Integrated Part Load Value (IPLV).] For multicompressor units, not less than two independent refrigerant circuits shall be provided. 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. Provide insulation for surfaces subject to sweating including the liquid cooler, suction line piping, water boxes, economizer, and cooling lines. Insulation shall conform to Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

2.2.1 Reciprocating Compressors

Provide with forced feed lubrication, crankcase heater, hot-gas muffler, and suction strainer. Cylinder-unloading devices shall be unloaded when compressor starts. Piston speed for open compressor shall not exceed recommendations of manufacturer or 5 m/s 1000 fpm, whichever is less.

2.2.2 Helical Rotary Compressors

Positive displacement, oil-injected type, and driven by an electric motor. Rotors shall be solid steel, Society of Automotive Engineers Grade 1141 or 1144. Shaft main bearings shall be either sleeve-design type with leaded bronze or steel-backed babbit; or frictionless bearing design, ball or roller type. Housings and covers shall be high-grade, cast-iron or aluminum pressure castings. Lubrication system shall lubricate rotors, bearings, shaft seal as well as rotor sealing and cooling. Provide an oil safety cutout interlocked with the compressor starter to allow compressor to operate only when the oil system is operational. Provide for lubrication of bearings and shaft seals on shutdown with or without electrical power supply.

2.2.3 Scroll Compressors

Three-dimensional, compliant, hermetically sealed design. Compressors shall be mounted on vibration isolators. Rotating parts shall be factory balanced. Main bearings shall be rolling-element type. Lubrication systems shall be centrifugal pump type including oil level sight glass and oil charging valve.

2.2.4 Liquid Coolers (Evaporators)

Tubes shall be seamless copper. On direct-expansion-type units, each refrigerant circuit shall be complete with liquid solenoid valve and expansion device capable of modulating to minimum capacity. For the water side of liquid cooler, performance shall be based on a water velocity not

less than 0.91 m/s 3 fps and not more than 3.66 m/s 12 fps and a fouling factor of 0.00025.

2.2.5 Controls, Control Panels, and Gages

NOTE: Specify required time delay for type and size
of unit after consulting current literature.

NOTE: Specify lowest percent of full capacity
required. Check for availability before inserting
number in blank.

Provide a control panel fitted with a discharge pressure gage, suction pressure gage, separate high pressure cutout with manual reset, separate low pressure cutout, low water temperature cutout with manual reset, compressor operating control, and manual off-auto switch. Provide oil pressure gage and low-oil-pressure cutout switch with manual reset for chillers with positive displacement type oil pumps. Provide signal lights or other visual "failed" indications for high pressure, low pressure, and oil pressure protection devices. Multicompressor units shall be provided with a lead/lag selector switch. Provide a timer to prevent compressors from short cycling whenever stopped by safety controls. Time delay shall be not less than [_____] minutes. Pumpdown cycle of the nonrecycling start type shall be provided for each compressor 70 kW 20 tons or larger. Provide a minimum 100 mm 4 inch alarm bell and alarm bell circuit to actuate bell in event of machine cutout on protective devices, except when low-pressure cutout is used as an operating control. Provide system capacity control to adjust chiller output to a minimum of [_____] percent of full load capacity without cycling operating compressor and to automatically recycle system on power interruption. Provide start-up and head pressure controls to allow for system operation at all ambient temperatures down to [_____] degrees C degrees F.

2.2.6 Motors and Starters

Provide [across-the-line magnetic] [reduced voltage] type motor starters conforming with NEMA ICS 1 and NEMA ICS 2. Provide phase failure, over voltage and low voltage protection. Provide induction electric motors conforming with NEMA MG 1. Motors shall be variable speed. Motors 3/4 kW 1 hp and larger shall meet NEMA Premium Efficiency requirements. Fan motors less than 3/4 kW 1 hp shall meet NEMA High Efficiency requirements.

2.2.7 Factory Charging

Dehydrate, purge, and charge refrigerant circuit with refrigerant and oil at factory. Factory oil and refrigerant charge shall be full amount required for operation, if within limits permitted by the Department of Transportation; otherwise, a holding charge shall be furnished. Field charging, where only a holding charge is shipped, shall be accomplished without breaking permanent refrigerant connections.

2.3 COMPRESSOR UNITS

ARI 520. Provide factory-assembled compressor units driven by electric motors. Provide with valves, refrigerant piping, instruments and controls.

Provide standard equipment, optional equipment, and accessories specified in [ARI 520](#). Entire unit shall be mounted on a welded steel base. Provide initial charge of refrigerant grade lubricating oil. Compressors shall operate at partial load conditions without increase in vibration over that normally experienced at full load; and shall be capable of continuous operation down to lowest step of unloading as specified.

2.3.1 Reciprocating Compressors

Compressors shall have integrally cast housing of close-grained iron with oil-level bull's eye, cast cylinder heads, cast-aluminum or forged-steel connecting rods, and cast-iron or forged-steel crankshaft. Main bearings shall be sleeve-insert type. Provide forced-feed, positive-displacement type lubrication systems with oil strainer and reversible oil pump. Shaft seals in open-type units shall be mechanical type. Suction and discharge valves shall be flange connected, wrench operated, rising stem, with cap. Rotating parts shall be factory statically and dynamically balanced. Provide crankcase oil heaters and controls. Piston speed for open-type compressors shall not exceed manufacturer's recommendation or 5 m/s 1000 fpm, whichever is less. Provide a hot-gas muffler.

2.3.2 Helical Rotary Compressors

Positive displacement, oil-injected and driven by an electric motor. Rotors shall be solid steel, Society of Automotive Engineers Grade 1141 or 1144. Shaft main bearings shall be either sleeve-design type with leaded bronze or steel-backed babbit; or frictionless bearing design, ball or roller type. Housing and covers shall be high-grade, cast-iron or aluminum pressure castings. Lubrication system shall lubricate rotors, bearings, shaft seal as well as rotor sealing and cooling. Provide an oil safety cutout interlocked with the compressor starter to allow compressor to operate only when the oil system is operational. Provide for lubrication of bearings and shaft seals on shutdown with or without electrical power supply.

2.3.3 Scroll Compressors

Three-dimensional, compliant, hermetically sealed design. Compressors shall be mounted on vibration isolators. Rotating parts shall be factory balanced. Main bearings shall be rolling-element type. Lubrication systems shall be centrifugal pump type including oil level sight glass and oil charging valve.

2.3.4 Controls

NOTE: Specify lowest percent of full capacity
required. Check for availability before inserting
number in blank.

NOTE: Specify required time delay for type and size
of unit after consulting current literature.

Provide a control panel fitted with a discharge pressure gage, suction pressure gage, separate high pressure cutout with manual reset, separate low pressure cutout, compressor operating control, and manual off-auto

switch. Provide oil pressure gage and low-oil-pressure cutout switch with manual reset for compressors with positive displacement type oil pumps. Provide signal lights or other visual "failed" indications for high pressure, low pressure, and oil pressure protection devices. Multicompressor units shall be provided with a lead/lag selector switch. Provide a timer to prevent compressors from short cycling whenever stopped by safety controls. Time delay shall be not less than [_____] minutes. A pumpdown cycle of the nonrecycling start type shall be provided for compressors 70 kW 20 tons or larger. Provide a minimum 100 mm 4 inch alarm bell and alarm bell circuit to actuate bell in event of machine cutout on protective devices, except when low-pressure cutout is used as an operating control. Provide system capacity control to adjust output to a minimum of [_____] percent of full load capacity without cycling operating compressor and to automatically recycle system on power interruption.

2.3.5 Electric Motors and Starters

Provide variable speed polyphase induction motors conforming to NEMA MG 1. Provide [across-the-line magnetic] [reduced voltage] motor starters conforming to NEMA ICS 1 and NEMA ICS 2. Provide phase failure, over voltage and under voltage protection. Motors 3/4 kW 1 hp and larger shall meet NEMA Premium Efficiency requirements. Fan motors less than 3/4 kW 1 hp shall meet NEMA High Efficiency requirements.

2.4 AIR-COOLED CONDENSERS, REMOTE-TYPE

Factory-assembled, design-tested, and rated in conformance with ARI 460. Condensers shall be ready for operation after installation and field testing.

2.4.1 Condenser Casings

Aluminum not less than one mm 0.040 inch in nominal thickness or steel not lighter than 18-gage (1.31 mm 0.0516 inch) in nominal thickness. Provide condensers having horizontal air discharge with discharge baffles to direct air upward, constructed of same material and thickness as casing. Provide wire screens or louvers over exposed condenser coil fins not protected by the casing.

2.4.2 Capacity and Cross-Plot

Size condensers for full capacity at 17 degree C 30 degrees F temperature difference between entering outside air and condensing refrigerant. Entering dry-bulb, outside design air temperature shall be based on [_____] degrees C degrees F. For design conditions, submit a cross-plot of net refrigeration effect of condenser against net refrigeration effect of compressor to establish net refrigeration effect and compatibility of equipment furnished. Subcooling shall not be considered in determining compressor and condenser capacities.

2.4.3 Condenser Coils

NOTE: Research project location conditions to determine the environmental effects on finned tube coils. The research should include a survey of existing similar equipment. Prepare project specifications based on the conclusions of the research. Consideration should be given to the

following combinations based on past experience of these materials in dealing with the local conditions.

1. Copper tube and aluminum fins, coated
2. Copper tube and copper fins, coated
3. Aluminum tube and aluminum fins, coated
4. Aluminum tube and aluminum fins, uncoated
5. Copper tube and copper fins, uncoated
6. Copper tube and aluminum fins, uncoated.

Extended-surface fin-and-tube type. Condenser coils shall be constructed of [copper tube and aluminum fins] [copper tube and copper fins] [aluminum tube and aluminum fins]. Fins shall be hydraulically or mechanically bonded to 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. Indoor and outdoor coils shall be matched and from same manufacturer. Use a low sensible heat ratio for more moisture removal. [Provide a coating as specified in the paragraph entitled "Coatings for Finned Tube Coils." Coils to be coated shall be part of the manufacturer's standard product for the capacities and ratings indicated and specified. Fins shall be the plate fin type.]

2.4.4 Fans

For V-belt drive fans, provide adjustable sheave. Fans shall be statically and dynamically balanced. Provide fans with vibration isolation devices to minimize vibration transmission.

2.4.5 Electric Motors and Starters

Provide variable speed polyphase induction motors conforming to NEMA MG 1. Motor bearings shall be permanently lubricated. Provide across-the-line magnetic motor starters conforming with NEMA ICS 1 and NEMA ICS 2. Provide phase failure over voltage and low voltage protection. Motors 3/4 kW 1 hp and larger shall meet NEMA Premium Efficiency requirements. Fan motors less than 3/4 kW 1 hp shall meet NEMA High Efficiency requirements.

2.4.6 Condenser Controls

NOTE: Insert winter design temperature that the equipment will be subjected to.

Provide start-up and head pressure controls to allow for system operation at all ambient temperatures down to [_____] degrees C degrees F.

2.5 WATER-COOLED CONDENSERS, REMOTE-TYPE

Provide shell-and-coil or shell-and-tube type constructed, tested, and rated in accordance with ARI 450. Refrigerant side design pressure shall comply with ASHRAE 15. Water side design pressure shall be not less than 1034 kPa (gage) 150 psig.

2.5.1 Shell-and-Coil Condensers

Fabricate with seamless or welded steel shell and welded head. Water shall flow through the coil which shall be nonferrous metal, plain or integral finned, and arranged to drain completely. Coil joints shall be brazed or silver soldered. Entire bundle shall be removable.

2.5.2 Shell-and-Tube Condensers

Fabricate with seamless or welded steel shell, steel tube sheets, and cast-iron or steel water boxes. Tubes shall be nonferrous metal, plain or integral finned, and shall be expanded full diameter into reamed and grooved holes, silver soldered or brazed. Provide intermediate tube supports for lengths of straight tubing between supports every 0.91 meter 3 feet for copper tubes, and every 1.22 meters 4 feet for brass tubes. Tubes shall fit in the support to prevent chafing due to vibration or pulsations.

2.5.3 Accessories

Provide condensers with the following accessories:

- a. Purge connections;
- b. Relief devices;
- c. Refrigerant valves;
- d. Liquid-level indicating devices;
- e. Companion flanges, bolts, and gaskets for flanged water connections;
- f. Stands or saddles; and
- g. Water drain connections.

2.5.4 Performance

Base performance on water velocities not less than 0.91 m/s 3 fps nor more than 3.66 m/s 12 fps and fouling factor of 0.0005. Water-cooled condensers may be provided for refrigerant storage in lieu of a separate liquid receiver, provided that condenser storage capacity is 20 percent in excess of fully charged system.

2.5.5 Condenser Controls

[When refrigerant discharge pressure decreases, a pressure controller shall modulate a three-way valve to mix leaving condenser water.] [When water temperature leaving condenser decreases, cooling tower fan shall be de-energized.] Controls shall be set for a saturated refrigerant condensing temperature of 40 degrees C 105 degrees F.

2.6 LIQUID COOLERS, REMOTE-TYPE

Direct expansion flooded type; constructed, tested, and rated in conformance with ARI 480. Refrigerant side design pressure shall comply with ASHRAE 15. Water side design pressure shall be not less than 1034 kPa (gage) 150 psig. Tubes shall be seamless copper. On direct expansion

units, each refrigerant circuit shall be complete with liquid solenoid valve and expansion device capable of modulating to minimum step of capacity unloading. For water side of liquid cooler, performance shall be based on a water velocity ranging from 0.91 to 3.66 m/s 3 to 12 fps with a fouling factor of 0.00025.

2.7 COOLING TOWERS

NOTE: Research project location conditions to determine the environmental effects on finned tube coils. The research should include a survey of existing similar equipment. Prepare project specifications based on the conclusions of the research. Consideration should be given to the following combinations based on past experience of these materials in dealing with the local conditions.

1. Copper tube and aluminum fins, coated
2. Copper tube and copper fins, coated
3. Aluminum tube and aluminum fins, coated
4. Aluminum tube and aluminum fins, uncoated
5. Copper tube and copper fins, uncoated
6. Copper tube and aluminum fins, uncoated.

Research the project location atmospheric and water conditions to determine there effects on cooling tower materials. The research should include a survey of existing towers. Base material selection on life cycle cost analysis. Factory-assembled wood cooling towers may be a restrictive product (i.e., three manufacturers may not exist). Level 1, Contracting Officer, approval is required if it is established conclusively that no option other than a factory-assembled wood cooling tower will serve the purpose, and less than three manufacturers exist.

Selecting a cooling tower on a higher design ambient wet bulb temperature will provide a more efficient tower. An induced draft tower is more efficient than a forced draft tower, and variable speed fans are more efficient than 2-speed or single-speed fans.

Fire Safety: Design cooling towers having wood fill with heat responsive devices and remote controls to flood entire normal water distribution system in case of fire in dry cells of cooling towers. Indicate heat responsive devices under fan decks, distribution basins, or in other locations where necessary for activation. Where heat responsive devices are inaccessible, provide controls to test the system. Operation of heat responsive devices shall activate building fire alarm system, stop cooling tower fans, and provide both audible and

visual signals on the air conditioning central control panel. Remote controls to flood normal water distribution system shall be quick action type. The design shall conform to the requirements of NFPA 214 "Water-Cooling Towers."

2.7.1 Fire Safety

Towers shall conform to NFPA 214. Fire hazard rating for plastic impregnated materials shall not exceed 25. Plastics shall not drip or run during combustion. Determine ratings by ASTM E 84 or NFPA 255.

2.7.2 Enclosures

Enclosures shall meet tower manufacturer's recommendations.

2.7.3 Supporting Members

Where supporting members are indicated, verify their size and locations to ensure the adequacy of the support systems. Provide modifications to tower supports, steel members, and vibration isolation units for particular tower to be furnished.

2.7.4 Factory-Assembled Towers

Cooling towers shall be factory-assembled type, conforming to FS A-A-59223 with the following requirements:

- a. Type I, Induced Mechanical Draft.
- b. Constructed of [zinc-coated steel] [stainless steel] [wood] [fiberglass-reinforced plastic]. No asbestos-cement materials will be permitted.
- c. Hardware shall be [cadmium plated] [zinc-coated] [stainless steel] except nails shall be [silicon bronze] [commercial bronze] [stainless steel].
- d. Vibration cutout switch shall be provided and interlocked with the fan motor.
- e. Fill or contact surfaces shall be [polyvinyl chloride (PVC) formed sheets] [zinc-coated steel] [wood]. No plasticized cellulose materials will be permitted.
- f. Field performance test is not required.
- [g. Fifteen-percent increase in design structural loading shall be included for ice or snow load.]
- [h. Air inlet and discharge terminations shall have flanged or lipped projections for connecting ductwork.]
- [i. Fan motor shall be 2-speed.]

2.7.5 Field-Assembled Cooling Towers

Induced-draft, counterflow or crossflow type, and either spray-filled or

wetted-surface type. Field-assembled towers shall include those where a majority of assembly work is done at the project location.

2.7.5.1 Sound Power Levels

NOTE: Choose one of the following options.

NOTE: Specify sound power levels after considering location and application of cooling tower. Delete first paragraph if project includes Section 15070, "Mechanical Sound, Vibration, and Seismic Control." Delete second paragraph if project does not include Section 15070, "Mechanical Sound, Vibration, and Seismic Control."

[Sound power levels (in decibels with a reference pressure of 0.0002 microbar) of the cooling tower shall not exceed the maximum permitted decibel levels for the designated octave band as set forth in the following tables. Base the sound power level data for the cooling tower on tests conducted in accordance with ANSI S1.13.

Octave Band (in Hz)	63	125	250	500	1000	2000	4000	8000
Sound Power Level in dB	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]	[_____]
	[_____]							

[Sound level criteria shall conform to Section 22 05 48.00 20 MECHANICAL SOUND VIBRATION AND SEISMIC CONTROL.]

2.7.5.2 Design

Notching structural members is permissible only if the members are increased proportionately in size to provide equivalent strength. Towers shall be designed and constructed to withstand a wind pressure of not less than 1437 Pa 30 pound force per square foot (psf) on external surfaces. Fan decks shall be designed to withstand a live load of not less than 2874 Pa 60 psf in addition to the concentrated or distributed loads of equipment mounted on the fan decks. [A 15-percent increased loading shall be included for ice or snow load.] Design data for wood towers shall conform to applicable requirements of the CTI Std-103, CTI Std-114, USDA AH 72 and DOA Bulletin 865.

2.7.5.3 Identification Markings

Identification shall be permanently and legibly marked directly on the tower or on a corrosion-resisting metal plate securely attached to the tower at the source of manufacture. Identification shall include the manufacturer's model and serial number, name, and trademark and be readily identifiable to the manufacturer.

2.7.5.4 Woods

Redwood shall conform to RIS Grade Use. Red cypress shall conform to

SCMA Spec. Douglas fir and hemlock shall conform to **WCLIB 17**. Wood grades shall conform to **WWPA G-5**. Redwood and red cypress shall be clear of all heart grade, except for structural framing members and inner casings of double-cased towers, which may be select heart grade. Douglas fir and hemlock grades shall be similar to redwood and red cypress grades. Plywood shall be in accordance with Douglas Fir Plywood Association Standards or CTI Standards and shall be marine type, pressure treated, with B-grade face and back and C-grade inner plies. Protect cut edges.

2.7.5.5 Wood Treatment

Douglas fir and west coast hemlock used in the construction cooling towers shall have a preservative treatment in accordance with **CTI Std-112**. Wood exposed as the result of notching, cutting, or drilling shall be saturated with the preservative.

2.7.5.6 Fiberglass-Reinforced Plastics

Provide corrosion-proof, fire-retardant plastics in tower construction. Plastics shall be manufacturer's standard commercial material and shall meet conditions specified herein. Components manufactured of polystyrene will not be permitted.

2.7.5.7 Hardware

Cadmium-plated, stainless steel (Type 304), or zinc-coated steel. Angle brackets and similar parts shall be cast iron or zinc-coated steel. Zinc coatings shall conform to **ASTM A 153/A 153M** and **[ASTM A 123/A 123M]** **[ASTM A 653/A 653M]**, as applicable, and shall have an extra heavy coating of not less than **0.76 kg per square meter** **2.5 ounces per square foot** of surface. Nails shall be silicon bronze, commercial bronze, or stainless steel. Subject hardware to a salt-spray fog test in accordance with **ASTM B 117**. No signs of corrosion shall be evident after 1,000 hours continuous exposure to a 5 percent salt spray.

2.7.5.8 Basins

[Wood] [Concrete] construction and have capacity so that air will not be entrained in outlets when operating, and no water will overflow on shutdown. Basin may be rectangular, flat-bottom type, V-bottom type, or shallow-pan type with deep storage sump. Provide each flat-bottom basin with one or more steel, cast-iron, or concrete outlet sumps of such size and depth as to prevent cavitation and air entrainment under operating conditions. If a single outlet is indicated, and the Contractor elects to provide two or more sumps, additional header piping of same size as outlet pipe shown shall be provided. Provide outlets with removable screens. Screens shall consist of **13 mm 1/2 inch** mesh, zinc-coated steel wire fastened to **32 by 32 by 4.76 mm 1.25 by 1.25 by 3/16 inch** angle frames of zinc-coated steel. Total screen area below operating water line shall be not less than **0.0929 square meter one square foot** for each **25.24 L/s 400 gpm** of specified tower capacity. Individual sections of screens shall not weigh over **45.40 kg 100 pounds**. Provide each basin with an overflow to carry off excess flow due to incorrect adjustment of float, and a valved drain connection. Pipe overflow and drain connections to nearest sewer drain. Provide basins with a float-controlled, makeup water valve, located so as to discharge not less than **50 mm 2 inches** or two pipe diameters, whichever is greater, above top of basin. Hose bibb of **20 mm 3/4 inch** nominal size shall be provided near tower casing. Connect makeup valve and hose bibb as indicated.

2.7.5.9 Wood Basins

Fabricate wood basins of 40 mm 1.5 inch tongue and groove wood, caulked with cotton wicking and mastic, or 20 mm 3/4 inch or heavier plywood with plywood battens. Sides shall be through bolted to bottom whenever feasible and to battens at joints and corners. Sides may be same material as bottoms or of two layers of 10 mm 3/8 inch plywood.

2.7.5.10 Concrete Basins

Concrete shall be 20 MPa 2,500 psi class in accordance with Section 03 30 00 CAST-IN-PLACE CONCRETE, reinforced as indicated.

2.7.5.11 Casings

Fabricate from double-sheathed wood, or fiberglass-reinforced plastic. Wood sheathing shall be not less than 15 mm 1/2 inch tongue and groove. Partitions between cells shall be single-sheathed wood and shall extend from fan deck to bottom of fill except for down flow towers, which shall extend to top of fill.

2.7.5.12 Fan Decks

Fabricate from plywood a minimum of 29 mm 1.125 inches thick. Fan decks shall be designed to support a 293 kg/m² 60 psf live load.

2.7.5.13 Stairways and Ladders

Provide stairs, 60-degree ship ladders or straight-rung ladders of standard design, starting at [ground] [roof] level and extending as high as required to gain access to fan decks and water distribution systems. Stairways and ladders, shall be hot-dip, zinc-coated steel. Ladders higher than 3 1/2 meters 12 feet shall have a safety cage.

2.7.5.14 Handrailings

Steel handrailings shall be not less than 1067 mm 42 inches high around the exterior of each working surface that is 3 1/2 meters 12 feet or more above the ground, roof, or other supporting construction. Railings shall be not smaller than 32 mm 1.25 inch zinc-coated steel pipe with standard zinc-coated steel railing.

2.7.5.15 Access Doors

Provide casings and fan decks with access doors to reach interior tower parts without removal of fill. Provide access doors in each endwall of each cooling tower cell. Frame and brace access doors to prevent damage when opening and closing. Locate doors adjacent to float controls.

2.7.5.16 Louvers

Provide air inlet openings in casings with individually removable louvers arranged to prevent escape of water. Fabricate from wood or fiberglass-reinforced plastic. When different materials are provided for casings and louvers, they shall be compatible; and one material shall not produce stains upon the other.

2.7.5.17 Fill

NOTE: Fire Safety: Design cooling towers having wood fill with heat responsive devices and remote controls to flood entire normal water distribution system in case of fire in dry cells of cooling towers. Indicate heat responsive devices under fan decks, distribution basins, or in other locations where necessary for activation. Where heat responsive devices are inaccessible, provide controls to test the system. Operation of heat responsive devices shall activate building fire alarm system, stop cooling tower fans, and provide both audible and visual signals on the air conditioning central control panel. Remote controls to flood normal water distribution system shall be quick action type. The design shall conform to the requirements of NFPA 214 "Water-Cooling Towers."

Polyvinyl chloride (PVC) formed sheets or designed as individual fill batts, or zinc-coated steel [, or treated Douglas-fir; treated hemlock; or treated redwood]. Zinc-coated steel shall have a minimum of 0.76 kg of zinc per square meter 2.5 ounces of zinc per square foot of surface. PVC fill shall not be provided when inlet temperatures exceed 52 degrees C 125 degrees F. No plasticized wood cellulose shall be provided for fill material. Fill shall be removable or otherwise made accessible for cleaning. Fill supports shall be wood or glass-reinforced polyester. Supports shall have structural strength of not less than five times design loading. Provide space supports as required to prevent sagging and misalignment, and provide for an even mixing of air and water.

2.7.5.18 Water Distribution Systems

Design water distribution systems for each cell of each tower so that a water flow of 140 percent of specified water flow will not cause overflowing or splashing. Water distribution systems shall be accessible and permit flexibility of operation. Distribution shall be open basin, flume and troughs, or a pipe system with nozzles spaced for even distribution, arranged so that flow to each cell can be regulated and turned on or off independently. Provide separate regulation and stop valves for complete balancing and complete shutoff from each cell. Systems shall be self-draining and nonclogging. Spray nozzles, if used, shall be cleanable; stainless steel, bronze, or high-impact plastic, nonclogging, removable; and, spaced for even distribution. Provide removable covers of same material and thickness as casing for entire water distribution basin. Support covers by basin sides with top of cover flush with top of basin.

2.7.5.19 Piping

Provide inlet pipe to each cell with a bleed connection. Connections shall have a regrinding globe valve set to pass 1.05 mL/s one gallon per hour for each 760 mL/s 12 gallons per minute (gpm) of rated cell capacity. Piping shall be installed under direct supervision of the tower manufacturer.

2.7.5.20 Drift Eliminators

Provide in tower outlet to limit drift loss to not over 0.2 percent of

specified water flow. Eliminators shall be constructed of not less than 10 mm 3/8 inch wood or polyvinyl chloride (PVC).

2.7.5.21 Fans

Provide each tower cell with one or more fans driven by electric motors, dynamically balanced. Provide propeller fans with adjustable-pitch air foil blades with a maximum tip speed of 56 m/s 11,000 feet per minute. Fan blades shall be aluminum, stainless steel, or fiberglass.

2.7.5.22 Fan Stacks

Provide propeller fans with stacks of wood or fiberglass-reinforced plastic. Minimum thicknesses of material shall be: Wood, 15 mm 1/2 inch laminations reinforced at top and bottom; fiberglass-reinforced plastic, 4 mm 1/6 inch. Stacks shall be provided with a zinc-coated steel screen of No. 12 gage wire and not over 13 mm 1/2 inch mesh secured to a frame of zinc-coated steel.

2.7.5.23 Fan Drives

Mount fan on output shaft of a gear box with cut steel spiral, hypoid, or other equally quiet and efficient gears. Bearings shall be ball or roller type with a continuous oiling system with oil reservoir. Oil-level indicators and oil filling and drain connections shall be provided outside fan cylinder in an accessible location. If drain connection is below level of fan deck, drain pipe shall be extended to outside of tower at an accessible location. Rate gearing in accordance with AGMA 2005 and AGMA 373.04 with a service factor of 2 for cooling tower service. Gear reducers shall be spiral-bevel type for single reduction and spiral-bevel and helical with parallel shaft for double reduction. Drive shafts shall be of stainless steel and full-floating type, fitted at each end with stainless-steel-plate type flexible couplings.

2.7.5.24 Fan Motors

NOTE: Voltage withstand levels can be obtained through the manufacturer. They shall be specified based on the drive dv/dt and the known cable distance.

[Single speed] [Two speed], totally enclosed, insulation Class B, NEMA Design B, 1.0 service factor, continuous-rated, and conforming to NEMA MG 1. Fan motors 3/4 kW 1 hp and larger shall meet NEMA Premium Efficiency requirements. Fan motors less than 3/4 kW 1 hp shall meet NEMA High Efficiency requirements. [Two-speed motors shall have a single winding with variable torque characteristics.] [The voltage withstand level shall be [_____] when motors are operated with variable speed drives.]

2.7.5.25 Variable Speed Drives

NOTE: Variable speed drives use less energy to run motors operating at less than full load. Include this paragraph unless equipment consistently runs at or near full load.

[Provide factory-assembled variable speed drive with motor starter, pulse width modulation controller, and inverter gate bipolar transistors for variable speed control on [each] [_____] fan motor.]

2.7.5.26 Motor Starters

Reduced voltage with low voltage protection and thermal-overload manual reset relays. Starters shall conform to NEMA ICS 1 and NEMA ICS 2 and shall have a NEMA Type [1] [3R] enclosure and a MAN-OFF-AUTO selector switch. [Two-speed motor starters shall be provided with a speed selecting switch as part of the starter.]

2.7.5.27 Vibration Cutout Switches

Provide for each fan and interlock with motor wiring to stop motor under excessive fan vibration.

2.7.6 Tile Filled Towers

NOTE: Where tile filled towers are to be used in base bid or as an alternate, drawings must be coordinated to assure that structural loading has been incorporated in the design and that all construction details have been reflected on drawings. Indicate whether fan deck is to be furnished by tower manufacturer or under general construction.

Provide counterflow, induced-draft type with capacity as indicated.

2.7.6.1 Basins

Construct concrete basins using a continuous pour containing a waterproof additive in conformance with Section 03 30 00 CAST-IN-PLACE CONCRETE. Provide each basin with one or more steel, cast-iron, or concrete outlet sumps sized to prevent cavitation and air entrainment under operating conditions. If a single outlet is indicated, and the Contractor elects to furnish two or more sumps, additional header piping of same size as outlet pipe shown shall be provided. Provide each outlet with a removable screen. Screens shall consist of 15 mm 1/2 inch mesh, zinc-coated steel wire fastened to 32 by 32 by 4.76 mm 1.25 by 1.25 by 3/16 inch zinc-coated steel angle frames conforming to [ASTM A 123/A 123M] [ASTM A 653/A 653M]. Total screen area below operating water line shall be not less than 0.0929 square meter one square foot for each 25.24 L/s 400 gpm of specified tower capacity. Individual section of screens shall not weigh over 45.40 kg 100 pounds. Provide each basin with an overflow and a valved drain connection. Pipe overflow and drain connections to nearest sewer drain. Provide each basin with a float-controlled makeup water valve, located to discharge not less than 50 mm 2 inches or two pipe diameters, whichever is greater, above top of basin. Install a hose bibb of 20 mm 3/4 inch nominal size near tower casing. Connect makeup and hose bibb to water supply as indicated.

2.7.6.2 Walls

Construct with mortar having a waterproof additive in conformance with

Section 03 30 00 CAST-IN-PLACE CONCRETE. Cover built-up masonry interior walls of each cell completely with a membrane of fiberglass sheets of commercial, first-quality, polyester-resin reinforced with fiberglass mat, and secure to walls from top to bottom. Secure fiberglass sheets to walls with cadmium-plated nails spaced not less than 610 mm 24 inches on center in any direction. Seal nail heads and joints with polyester-resin-reinforced fiberglass stripping rolled into place. Apply finish coat of polyester resin, not less than 2 mm 1/32 inch, over entire membrane after completion of hanging and stripping.

2.7.6.3 Fan Decks and Stacks

Construct fan decks of precast, reinforced lightweight concrete, in multiple sections, forming a complete, vibration-free base for mounting fan, speed reducer, drive shaft, motor, and fan stacks. Construct fan stacks of precast, reinforced lightweight concrete in multiple sections, constrained with bands of zinc-coated steel conforming to [ASTM A 123/A 123M] [ASTM A 653/A 653M], not less than 3 by 76 mm 1/8 by 3 inches, and bolted to form a compressive load on stack perimeter. Secure stack in place on fan deck with Class A mortar.

2.7.6.4 Fill

Tile fill shall be multicellular design, set without mortar in a pattern of sufficient height to meet indicated performance. Tile shall be dense and vitreous, with a water absorption not to exceed 2 percent in a one-hour boil test. Tile shall have minimum crushing strength of 2758 kPa 400 psi over gross area of tile, when load is applied parallel to cells. Testing shall be in accordance with ASTM C 67. Support tile fill by cast-iron tee section lintels conforming to ASTM A 48/A 48M, Class 25, for gray iron castings designed with a safety factor of three, plus 3 mm 1/8 inch additional thickness for corrosion.

2.7.6.5 Water Distribution Systems

Provide each tower cell with a water distribution system and separate regulation and stop valves for complete balancing and shut-off of each cell. Distribution system for each cell shall consist of a centrally located header complete with junction boxes and side laterals, fittings, and nozzles. Piping 80 mm 3 inches and larger on the tower side of the shut-off valve, junction boxes, and fittings shall be cast iron. Nozzles shall be brass conforming to ASTM B 62. Piping smaller than 80 mm 3 inches shall be [standard weight galvanized-steel pipe with threads epoxy coated] [fiberglass-reinforced plastic pipe]. Cast-iron pipe shall be centrifugally cast and shall conform to specifications of the American Water Works Association (AWWA) or American National Standards Institute (ANSI) for the required class. Cast-iron flanged and screwed fittings shall conform to ASME B16.1 and ASME B16.4, respectively.

2.7.6.6 Inlet Pipe

Provide to each cell with a bleed connection having a regrinding type globe valve set to bypass 1.05 mL/s one gallon per hour for each 760 mL/s 12 gpm of rated cell capacity.

2.7.6.7 Drift Eliminators

Fabricate from fiberglass-reinforced polyester resin, mold-formed and power pressed in multipass zigzag form. Support eliminator sections on

fiberglass tee sections supported by stainless steel clips embedded in fan deck by 6.35 mm 1/4 inch brass rods. Free water carryover shall not exceed 0.05 percent of tower capacity.

2.7.6.8 Fans

Design fan assembly (fan and mounting) to give maximum fan efficiency and long life when handling saturated air at high velocities. Provide fans balanced by fan manufacturer either by individual blades or matched sets and of multiblade design with a minimum of six aluminum, stainless steel, or fiberglass blades. Fan hub shall be made of aluminum, ductile iron, stainless steel, or fabricated steel (hot-dip galvanized after fabrication), with adequate surface protection against corrosion. Tip speed of blades shall not exceed 56 m/s 11,000 fpm to ensure maximum quietness of operation. Where required by manufacturer or where needed for critical applications to avoid structural transmission of machine noise, provide hot-dipped, galvanized plates bolted and grouted to concrete deck after alignment of fan motor and gear box, with galvanized or stainless steel hold down bolts; or provide a unitized motor and gear support base of structural steel with vibration isolation units. Speed reducer gears shall be rated in accordance with AGMA using service factor of 2 for cooling tower services. Gear reducers shall be spiral-bevel type for single reduction and spiral-bevel and helical with parallel shaft for double reduction. Drive shafts shall be stainless steel and shall be full-floating type, fitted at each end with stainless-steel-plate type flexible couplings.

2.8 COOLING TOWER WATER TREATMENT SYSTEMS

NOTE: If the activity has a cooling water treatment contract in effect, ensure that the system specified is compatible with it.

Ozone water treatment for cooling towers is an effective way to reduce water and energy consumption and the release of hazardous chemicals to the environment. Specify ozone treatment if economically feasible, and if water hardness does not exceed 500 ppm as calcium carbonate or 100 ppm as sulfates. Water may be softened to operate with an ozone treatment system. Additional information on ozone treatment systems is available through DOE's New Technology Demonstration Program. The Federal Technology Alert is available at http://www.eere.energy.gov/femp/pdfs/FTA_OTCT.pdf.

Use the first paragraph for ozone treatment; use the second paragraph for chemical treatment. Include the Feed Pumps, Tanks, Valve Injection Assemblies, and Chemicals paragraphs if using chemical treatment.

[Capable of automatically feeding ozone and bleeding system water when needed to prevent scale, corrosion, and biological growths. Systems shall include an air dryer, air compressor, water and oil coalescing filters, particle filter, ozone injectors, an ozone generator and a monitoring/control system. Systems larger than 37,900 liters 10,000 gallons shall include multiple injection points.]

[Capable of automatically feeding chemicals, and bleeding system water to prevent scale, corrosion, and biological growths. Systems shall include chemical feed pump, tank, bleed-off solenoid valve, electric impulse water meter, electric timer, and conductivity controller. Provide a polyethylene tank and injection valve assembly for each feed pump.]

[2.8.1 Feed Pumps

Positive displacement type with an adjustable capacity and discharge pressure not less than 1.5 times the line pressure at the point of connection. Provide with pressure relief valve, and check valve mounted in the pump discharge.

2.8.2 Tanks

Construct of high density polyethylene, cylindrical in shape, and with a hinged cover. Tanks shall have sufficient capacity to require recharging only once per 7 days during normal operation. Provide tanks with a valved cold water line and, if necessary, a valved hot water fill line with suitable air gap. Provide tanks with device to indicate quantity of solution in the tank. Provide electric mixing device with tank.

2.8.3 Valve Injection Assemblies

Provide for each feed pump. Construct of bronze or material suitable for chemicals being used and install in condenser water line common to all pumps. Injection fittings shall have male pipe threads. Assemblies shall include shut-off valve and check valve provided close to condenser water line.

]2.8.4 Bleed-Off Solenoid Valves

Provide in bleed-off line. Valves shall normally be in closed position and be opened by a 120-volt waterproof solenoid coil. Connect bleed-off line to condenser water line and include a gate valve ahead of solenoid valve. Extend a discharge line from solenoid valves to sewer drain.

2.8.5 Water Meters

Provide with electric contacting register, and remote accumulative counter and installed in make-up water line near cooling tower. Meters shall be standard product used in water treatment.

2.8.6 Timers

Automatic reset, adjustable type, and electrically operated. House in metal NEMA type cabinet with a hinged front. Timers shall be suitable for 120 volt current.

2.8.7 Conductivity Controllers

Controllers shall measure total dissolved solids in system water by conductivity. Conductivity sensors shall consist of epoxy insulated carbon electrodes and shall not require platinizing. Controllers shall have a meter with a visual readout, set point adjustment with a range between 200 micromhos/cm and 4000 micromhos/cm and a red pilot light indicating water conductivity above set point. Units shall operate from a 120-volt power source.

2.8.8 Control Panels

Provide a factory-wired, NEMA 12, control panel for each system. Construct of steel with hinged door and lock, and suitable for surface mounting. Pre-wire controls to numbered terminal strips. Provide laminated plastic nameplates identifying the switch function. Include the following with the panel:

- a. Main power switch and indicating lamp;
- b. MAN-OFF-AUTO selector switch;
- c. Indicating lamp for bleed-off valve;
- d. 120 Volt, heavy-duty, grounded duplex receptacle;
- e. Conductivity controller;
- f. Electric timer; and
- g. Accumulative counter.

2.8.9 Sequence of Operation

2.8.9.1 Conductivity Controllers

Provide to open the bleed-off solenoid valve when conductivity of cooling water rises above set point of controller. When conductivity falls below set point, valve shall close.

2.8.9.2 Water Meters

Provide to start timer after a pre-set volume of make water has been measured.

2.8.9.3 Timers

Provide to turn [ozone injectors] [feed pumps] on for a pre-set amount of time.

2.8.10 Piping

Provide plastic piping and fittings conforming to [ASTM D 2996](#) for water treatment system. Piping for feed pump suction shall contain a foot valve and strainer.

2.8.11 [Water Analysis](#)

NOTE: If a water analysis is not available for
inclusion in the project specifications, choose the
second bracketed option and leave the description
table blank.

[Make-up water conditions are as follows:] [Provide make-up water analysis in accordance with the methods of tests of ASTM. Analysis shall include test results for the following:]

Description

Silica (SiO ₂)	[_____]
Insoluble	[_____]
Iron and Aluminum Oxides	[_____]
Calcium (Ca)	[_____]
Magnesium (Mg)	[_____]
Sodium and Potassium (Na and K)	[_____]
Carbonate (CO ₃)	[_____]
Bicarbonate (HCO ₃)	[_____]
Sulfate (SO ₄)	[_____]
Chloride (Cl)	[_____]
Nitrate (NO ₃)	[_____]
Turbidity	[_____]
pH	[_____]
Residual Chlorine	[_____]
Total Alkalinity	[_____]
Noncarbonate Hardness	[_____]
Total Hardness	[_____]
Dissolve Solids	[_____]
Fluorine	[_____]
Conductivity	[_____]

[2.8.12 **Chemicals**

NOTE: Choose one of the following options.

[Provide same chemicals used for treatment at station's other towers.]

[Provide chemicals in accordance with requirements of United States Environment Protection Agency, and the equipment manufacturer's recommendations. Chemicals shall have no detrimental effects on the materials in the systems. No chromium, zinc, or other heavy metal will be permitted. Chemicals shall be designated by chemical composition and also described by brand name.]

]2.9 **COATINGS FOR FINNED TUBE COILS**

NOTE: Research project location conditions to determine the environmental effects on finned tube coils. The research should include a survey of existing similar equipment. Prepare project specifications based on the conclusions of the research. Consideration should be given to the following combinations based on past experience of these materials in dealing with the local conditions.

1. Copper tube and aluminum fins, coated
2. Copper tube and copper fins, coated
3. Aluminum tube and aluminum fins, coated
4. Aluminum tube and aluminum fins, uncoated

5. Copper tube and copper fins, uncoated

6. Copper tube and aluminum fins, uncoated.

Include this article when coating of finned tube coils is required by the equipment specification paragraphs.

Where expressly stipulated in equipment specification paragraphs in this section, finned tube coils of the affected equipment items shall be coated as specified below.

2.9.1 Phenolic Coating

Coating shall be applied at the premises of a company specializing in such work. Coils shall be degreased and prepared for coating in accordance with coating applicator's standard procedures for the type metals involved. Coating material shall be a resin base thermosetting type phenolic. Phenolic coating shall be applied by immersion dipping of the entire coil. Minimum of two coats shall be applied by immersion dipping. Coils shall be baked or heat dried following each immersion. After final immersion and prior to final baking, entire coil shall be given a spray coating of phenolic with particular emphasis given to building up coating on sheared edges. Completed coating shall show no evidence of softening, blistering, cracking, crazing, flaking, or loss of adhesion. There shall be no evidence of phenolic "bridging" between the fins. Minimum dry film thickness of coating shall be 0.038 mm 1.5 mils.

2.9.2 Vinyl Coating

NOTE: Include the paragraphs below only in
PACNAVFACENGCOM projects or when specifically
directed.

Equipment shall be disassembled to extent necessary to provide access to spray a special finish on the coil and fins. Exterior bare metal surfaces of equipment shall also be provided with this special finish. Application shall be by experienced applicators, at the premises of a company specializing in such work, using an airless fog nozzle. At least two passes shall be made with the nozzle over the surfaces to be painted for each coat. Materials to be applied are as follows:

2.9.2.1 Mild Steel Surfaces

Self-curing, zinc filled, inorganic coating with 80, plus or minus 2 percent solids content by weight minimum: 1 coat, 0.076 mm

Lower temperature curing Epoxy-Polyamide, high build coating with 58, plus or minus 2 percent solids content by volume of mixture components: 2 coats, 0.127 mm per coat

Self-curing, zinc filled, inorganic coating with 80, plus or minus 2 percent solids content by weight minimum: 1 coat, 3 mils

Lower temperature curing Epoxy-Polyamide, high build coating with 58, plus or minus 2 percent solids content by volume of mixture components: 2

coats, 5 mils per coat

2.9.2.2 Non-Ferrous and Heat Exchanger Finned Surfaces

Total dry film thickness, 0.165 mm maximum

Vinyl primer 24, plus or minus 2 percent solids content by volume: 1 coat, approx. 0.051 mm

Vinyl copolymer 30, plus or minus 2 percent solids content by volume: 1 coat, approx. 0.102 mm

Total dry film thickness, 6.5 mils maximum

Vinyl primer 24, plus or minus 2 percent solids content by volume: 1 coat, approx. 2 mils

Vinyl copolymer 30, plus or minus 2 percent solids content by volume: 1 coat, approx. 4 mils

2.9.2.3 Galvanized Surfaces

Modified vinyl primer, rust inhibiting with 24, plus or minus 2 percent solids content by volume: 2 coats, 0.051

Vinyl copolymer 30, plus or minus 2 percent solids content by volume: 2 coats, 0.102 mm

Modified vinyl primer, rust inhibiting with 24, plus or minus 2 percent solids content by volume: 2 coats, 2 mils

Vinyl copolymer 30, plus or minus 2 percent solids content by volume: 2 coats, 4 mils

2.10 FINISHES

Steel surfaces of equipment including reciprocating, helical rotary, scroll, air cooled water chillers, and air-cooled, remote-type condensers, that do not have a zinc coating conforming to [ASTM A 123/A 123M] [ASTM A 653/A 653M], or a duplex coating of zinc and paint, shall be provided with a factory applied coating or paint system. Thickness of coating or paint system on the actual equipment shall be identical to that on the salt-spray test specimens with respect to materials, conditions of application, and dry film thickness.

2.11 SOURCE QUALITY CONTROL

2.11.1 Salt-Spray Tests

Factory-applied coating or paint system on equipment located outdoors including reciprocating, helical rotary, scroll, air-cooled water chillers, and air-cooled remote-type condensers, shall be factory salt-spray tested in accordance with ASTM B 117. Period of test shall be 500 hours. Test specimens shall have a standard scribe mark as defined in ASTM D 1654. Upon completion of exposure, coating or paint system shall be evaluated and rated in accordance with procedures A and B of ASTM D 1654. Rating of failure at the scribe mark shall be not less than six (average creepage not greater than 3 mm 1/8 inch). Rating of the unscribed area shall not be less than 10 (no failure).

PART 3 EXECUTION

3.1 INSTALLATION

Installation procedures shall conform to **ASHRAE 15**, and manufacturer's recommendations. Refrigerant safety relief devices shall have discharge piped to building exterior. Interlock compressor operation with the chilled [and condenser] water pump starters, so that compressors cannot operate unless the pumps are operating. Make piping connections to equipment after piping systems have been tested and cleaned.

3.2 FOUNDATIONS

Foundations for mounting of equipment, accessories, appurtenances, piping, and controls shall be provided, including supports, vibration isolators, stands, guides, anchors, clamps, and brackets. Anchor bolts and sleeves shall be set using templates. Anchor bolts shall be provided with welded-on plates on the head end embedded in the concrete. Equipment bases shall be leveled, using jacks or steel wedges, and grouted in using a nonshrinking type of grouting mortar. Foundations shall conform to manufacturer's recommendations.

3.3 LOCATIONS AND CLEARANCES

Equipment shall be located so that working space is available for necessary servicing such as shaft removal, disassembling compressor cylinders and pistons, replacing or adjusting drives, motors, or shaft seals, access to water heads and valves of shell and tube equipment, tube cleaning or replacement, access to automatic controls, refrigerant charging, lubrication, oil draining and working clearance under overhead lines. Provide manufacturer's recommended clearances for installation, operation, and maintenance, for cooling towers and chillers located within enclosures.

3.4 IDENTIFICATION TAGS AND PLATES

Provide equipment with tags numbered and stamped for their use. Plates and tags shall be brass or nonferrous material. Minimum letter and numeral sizes shall be **3 mm 1/8 inch** high.

3.5 FIELD QUALITY CONTROL

Verify equipment is properly installed, connected, and adjusted. Perform tests and provide labor, materials, and equipment required. Notify the Contracting Officer, in writing, 10 days before performing tests. Tests shall be performed in the presence of a manufacturer's representative. Tests shall conform to Section **23 08 00.00 20 HVAC TESTING/ADJUSTING/BALANCING**.

3.5.1 Start-Up and Initial Operational Tests

Provide chemicals and place water treatment systems in operation before initial start-up. Equipment shall be started and operated. Follow manufacturer's procedures and place systems under all modes of operation. Initial charges of refrigerant lubricating oil shall be supplemented to ensure maximum operating capacity. Safety and automatic control instruments shall be adjusted. Record manufacturer's recommended readings hourly. Operational tests shall cover a period of not less than [_____] days.

3.5.2 Laboratory Tests of Field-Assembled Cooling Towers

NOTE: If field-assembled cooling towers are not specified, delete these paragraphs.

Cooling towers shall be tested by a testing laboratory, in accordance with either **ASME PTC 23** or **CTI ATC-105**. Prior to commencing tests, testing laboratory shall have been approved by Contracting Officer. Reference in **CTI ATC-105** to "CTI Observer" shall be interpreted to mean testing laboratory observer, and no arrangements or agreements with CTI are implied or desired.

3.5.2.1 Air Temperatures

Take air temperatures by mechanically aspirated psychrometers, and in accordance with **ASME PTC 23**. Temperatures shall be used as ambient conditions. When using CTI procedure, temperature measurements shall be in accordance with **CTI ATC-105**.

3.5.2.2 Thermometers

Provide to read air and water temperatures simultaneously. Immediately prior to tests, calibrate thermometers by simultaneous immersion in hot well, or other mutually agreed upon method, and note correction factors and points of utilization for each thermometer together with its serial number.

3.5.2.3 Laboratory Test Results

Submit computations together with six complete sets of test results. Computations and test results shall be presented in full compliance with particular test procedure employed by testing agency.

3.5.3 Cooling Tower Water Treatment Tests

Conduct performance tests to determine required capacity and performance of chemical feed machinery. Determine and record the following:

- a. Raw water total hardness, ppm;
- b. Concentration cycles;
- c. Chemical solution used;
- d. Quantity of chemical solution injected into system per cycle;
- e. Make-up water required; and
- f. Waste to drain requirement.

3.5.4 Manufacturer's Field Services

Furnish manufacturer's representatives who are directly employed by the equipment manufacturers and trained to perform the services specified. The manufacturer's representatives shall furnish advice and services on the following matters:

- a. Erection, alignment, testing and dehydrating;
- b. Testing hermetic equipment under pressure for leaks, and evacuation and dehydration of machine to one degree C 35 degrees F wet bulb or an absolute pressure of not over 690 Pa 0.204 inch of mercury;
- c. Charging equipment with refrigerant and oil; and
- d. Starting equipment and training Government personnel on equipment care, operation, and maintenance.

3.6 WASTE MANAGEMENT

 NOTE: Diverting waste from the landfill contributes to the following LEED credit: MR2. Coordinate with Section 01572 CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT.

Separate waste in accordance with the Waste Management Plan, placing copper materials, ferrous materials, and galvanized sheet metal in designated areas for reuse. Close and seal tightly all partly used adhesives and solvents; store protected in a well-ventilated, fire-safe area at moderate temperature.

3.7 SCHEDULE

Some metric measurements in this section are based on mathematical conversion of inch-pound measurements, and not on metric measurements commonly agreed on by the manufacturers or other parties. The inch-pound and metric measurements shown are as follows:

<u>Products</u>	<u>Inch-Pound</u>	<u>Metric</u>
a. Alarm Bell Diameter	= 4 inches	= 100 mm
b. Condenser Water Side Design Pressure	= 150 psig	= 1034 kPa (gage)
-- End of Section --		