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DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 23 64 00.00 10

LIQUID CHILLERS

10/07

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

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

AIR-CONDITIONING 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 495	(2005) Performance Rating of Refrigerant Liquid Receivers
ARI 550/590	(2003) Standard for Water-Chilling Packages Using the Vapor Compression Cycle
ARI 560	(2000) Absorption Water Chilling and Water Heating Packages
ARI 575	(1994) Method of Measuring Machinery Sound Within an Equipment Space
ARI 700	(2004) Specifications for Fluorocarbon Refrigerants
ARI 740	(1998) Refrigerant Recovery/Recycling Equipment

AMERICAN BEARING MANUFACTURERS ASSOCIATION (ABMA)

ABMA 11	(1990; R 1999) Load Ratings and Fatigue Life for Roller Bearings
ABMA 9	(1990; R 2000) Load Ratings and Fatigue Life for Ball Bearings

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

ASHRAE 15	(2007) Safety Code for Refrigeration
ASHRAE 34	(2007; Addendas a,b,c,d,e,f,g and h 2007) Designation and Safety Classification of Refrigerants

ASHRAE 64	(2005) Methods of Testing Remote Mechanical-Draft Evaporative Refrigerant Condensers
AMERICAN WELDING SOCIETY (AWS)	
AWS Z49.1	(2005) Safety in Welding, Cutting and Allied Processes
ASME INTERNATIONAL (ASME)	
ASME BPVC SEC IX	(2007) Boiler and Pressure Vessel Code; Section IX, Welding and Brazing Qualifications
ASME BPVC SEC VIII D1	(2007) Boiler and Pressure Vessel Code; Section VIII, Pressure Vessels Division 1 - Basic Coverage
ASTM INTERNATIONAL (ASTM)	
ASTM A 307	(2007) Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
ASTM B 117	(2007) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM D 520	(2000; R 2005) Zinc Dust Pigment
ASTM E 84	(2007) Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM F 104	(2003) Standard Classification System for Nonmetallic Gasket Materials
NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)	
NEMA MG 1	(2006; Errata 2007) Standard for Motors and Generators
NEMA MG 2	(2001; Rev 1 2007) Safety Standard for Construction and Guide for Selection, Installation, and Use of Electric Motors and Generators
NEMA SM 23	(1991; R 2002) Steam Turbines for Mechanical Drive Service
NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)	
NFPA 37	(2006) Installation and Use of Stationary Combustion Engines and Gas Turbines
NFPA 54	(2006) National Fuel Gas Code

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE J537

(2000) Storage Batteries

UNDERWRITERS LABORATORIES (UL)

UL 1236

(2006) Standard for Safety Battery
Chargers for Charging Engine-Starter
Batteries

1.2 SUBMITTALS

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

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, Air Force, and NASA projects.

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

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

SD-02 Shop Drawings

Drawings

Drawings, at least [5 weeks] [_____] prior to beginning construction, provided in adequate detail to demonstrate

compliance with contract requirements, as specified.

SD-03 Product Data

Refrigeration System

Manufacturer's standard catalog data, at least [5 weeks] [_____] prior to the purchase or installation of a particular component, highlighted to show material, size, options, performance charts and curves, etc. in adequate detail to demonstrate compliance with contract requirements. Data shall include manufacturer's recommended installation instructions and procedures. Data shall be adequate to demonstrate compliance with contract requirements as specified within the paragraphs:

- a. Liquid Chiller
- b. Chiller Components
- c. Accessories

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

Spare Parts

Spare parts data for each different item of equipment specified.

Posted Instructions

Posted instructions, at least [2] [_____] weeks prior to construction completion, including equipment layout, wiring and control diagrams, piping, valves and control sequences, and typed condensed operation instructions. The condensed operation instructions shall include preventative maintenance procedures, methods of checking the system for normal and safe operation, and procedures for safely starting and stopping the system. The posted instructions shall be framed under glass or laminated plastic and be posted where indicated by the Contracting Officer.

Verification of Dimensions

A letter, at least [2] [_____] weeks prior to beginning construction, including the date the site was visited, confirmation of existing conditions, and any discrepancies found.

Coil Corrosion Protection

Product data on the type coating selected, the coating thickness, the application process used, the estimated heat transfer loss of the coil, and verification of conformance with the salt spray test requirement.

Manufacturer's Multi-Year Compressor Warranty

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

Factory Tests

Schedules, at least [2] [_____] weeks prior to the factory test, which identify the date, time, and location for each test. Schedules shall be submitted for both the Chiller Performance Test and the Chiller Sound Test. [The Chiller Performance Test schedule shall also allow the witnessing of the test by a Government Representative.]

System Performance Tests

A schedule, at least [2] [_____] weeks prior to the start of related testing, for the system performance tests. The schedules shall identify the proposed date, time, and location for each test.

Demonstrations

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

SD-06 Test Reports

Factory Tests

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

System Performance Tests

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

SD-07 Certificates

Refrigeration System

Where the system, components, or equipment are specified to comply with requirements of AGA, NFPA, ARI, ASHRAE, ASME, or UL, [1] [_____] copy of proof of such compliance shall be provided. The label or listing of the specified agency shall be acceptable evidence. In lieu of the label or listing, a written certificate from an approved, nationally recognized testing organization equipped to perform such services, stating that the items have been tested and conform to the requirements and testing methods of the specified agency may be submitted. When performance requirements of this project's drawings and specifications vary from standard ARI rating conditions, computer printouts, catalog,

or other application data certified by ARI or a nationally recognized laboratory as described above shall be included. If ARI does not have a current certification program that encompasses such application data, the manufacturer may self certify that his application data complies with project performance requirements in accordance with the specified test standards.

Service Organization

A certified list of qualified permanent service organizations for support of the equipment which includes their addresses and qualifications. The service organizations shall be reasonably convenient to the equipment installation and be able to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals

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

1.3 SAFETY REQUIREMENTS

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

1.4 DELIVERY, STORAGE, AND HANDLING

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

1.5 PROJECT REQUIREMENTS

1.5.1 Verification of Dimensions

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

discrepancy before performing any work.

1.5.2 Drawings

Because of the small scale of the drawings, it is not possible to indicate all offsets, fittings, and accessories that may be required. The Contractor shall carefully investigate the plumbing, fire protection, electrical, structural and finish conditions that would affect the work to be performed and shall arrange such work accordingly, furnishing required offsets, fittings, and accessories to meet such conditions. The Contractor shall submit detailed drawings consisting of:

- a. Equipment layouts which identify assembly and installation details.
- b. Plans and elevations which identify clearances required for maintenance and operation.
- c. Wiring diagrams which identify each component individually and all interconnected or interlocked relationships between components.
- d. Foundation drawings, bolt-setting information, and foundation bolts prior to concrete foundation construction for all equipment indicated or required to have concrete foundations.
- e. Details, if piping and equipment are to be supported other than as indicated, which include loadings and type of frames, brackets, stanchions, or other supports.

1.5.3 Spare Parts

Submit spare parts data for each different item of equipment specified, after approval of detail drawings and not later than [_____] months prior to the date of beneficial occupancy. The data shall include a complete list of parts and supplies, with current unit prices and source of supply, a recommended spare parts list for 1 year of operation, and a list of the parts recommended by the manufacturer to be replaced on a routine basis

1.6 MANUFACTURER'S MULTI-YEAR COMPRESSOR WARRANTY

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

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

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

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

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

1.6.1 Indexed Notebook

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

Furnish to the Contracting Officer a bound and indexed notebook containing a complete listing of all air-cooled liquid chillers covered by a manufacturer's multi-year warranty. The chiller list shall state the duration of the warranty thereof, start date of the warranty, ending date of the warranty, location of the warranted equipment, and the point of contact for fulfillment of the warranty. Point of contact shall include the name of the service representative along with the day, night, weekend, and holiday phone numbers for a service call. The completed bound and indexed notebook shall be delivered to the Contracting Office prior to final acceptance of the facility.

1.6.2 Local Service Representative

Furnish with each manufacturer's multi-year warranty the name, address, and telephone number (day, night, weekend, and holiday) of the service representative nearest to the location where the equipment is installed. Upon a request for service under the multi-year warranty, the service representative shall honor the warranty during the warranty period, and shall provide the services prescribed by the terms of the warranty.

1.6.3 Equipment Warranty Tags

At the time of installation, each item of manufacturer's multi-year warranted equipment shall be tagged with a durable, oil- and water-resistant tag, suitable for interior and exterior locations, resistant to solvents, abrasion, and fading due to sunlight. The tag shall

be attached with copper wire or a permanent, pressure-sensitive, adhesive backing. The tag shall be installed in an easily noticed location attached to the warranted equipment. The tag for this equipment shall be similar to the following in format, and shall contain all of the listed information:

MANUFACTURER'S MULTI-YEAR WARRANTY EQUIPMENT TAG

Equipment/Product Covered: _____

Manufacturer: _____ Model No.: _____ Serial No.: _____

Warranty Period: From _____ to _____

Contract No.: _____

Warranty Contact: _____

Name: _____

Address: _____

Telephone: _____

STATION PERSONNEL SHALL PERFORM PREVENTIVE
MAINTENANCE AND OPERATIONAL MAINTENANCE

PART 2 PRODUCTS

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

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

The following is a list of terms which are commonly used in regard to efficiency ratings of equipment defined within this specification.

COP - Coefficient of Performance (dimensionless)
EER - Energy Efficiency Ratio (Btuh/Watt)
IPLV - Integrated Part Load Value
(dimensionless or kW/ton)
NPLV - Non-Standard Part Load Value
(dimensionless or kW/ton)

Note that the IPLV ratings presented by manufacturers are based upon standard rating conditions established by ARI. NPLV ratings on the other hand are based upon site specific rating conditions. NPLV ratings should be specified in most applications. NPLV ratings will be coordinated with ARI and with the chiller manufacturers.

The following is a list of minimum full load and part load efficiency ratings to be used to specify electrically driven, air-cooled and water-cooled liquid chillers. Minimum efficiency ratings for absorption chillers are defined under paragraph ABSORPTION LIQUID CHILLER.

Minimum Efficiencies for Air-Cooled Chillers

	Full Load COP (EER)	IPLV COP (kW/ton)
Air-Cooled (with Condenser):		
527 kW (150 tons) or less =	2.8 (9.5)	3.1 (1.12)
greater than 527 kW (150 tons) =	2.7 (9.2)	2.9 (1.22)
Air-Cooled (Condenserless):		
All Capacities =	3.1 (10.6)	3.2 (1.10)

Minimum Efficiencies for Water-Cooled Chillers

Capacity	Full Load COP (EER)	IPLV COP (kW/ton)
281 kW (80 tons) or less =	3.9 (13.3)	4.7 (0.75)
greater than 281 kW (80 tons) or less than or equal to 351 kW (100 tons) =	3.9 (13.3)	5.1 (0.70)
greater than 351 kW (100 tons) or less than or equal to 702 kW (200 tons) =	4.7 (16.0)	5.4 (0.65)
greater than 702 kW (200 tons) or less than or equal to 1757 kW (500 tons) =	5.7 (19.4)	6.1 (0.58)
greater than 1757 kW (500 tons) =	5.9 (20.0)	6.3 (0.56)

Because of typical manufacturing practices, air-cooled and small water-cooled chillers (typically less than 527 kW (150 tons)) are not available in multiple efficiencies for each available capacity. Only one model, and therefore, only one efficiency is available from a manufacturer for a given capacity. The minimum efficiencies stated above for air-cooled and small water-cooled chillers are low enough to allow all of the major chiller manufacturers to competitively bid. Specifying a higher efficiency for air-cooled and small water-cooled chillers will limit competition and may require a sole source justification.

Larger water-cooled chillers (greater than 527 kW (150 tons)) are available in multiple efficiencies for each available capacity. The minimum efficiencies stated above are only guidelines in specifying efficiencies. The designer will be responsible for developing a life cycle cost comparison between available efficiencies to determine the optimum alternative. The decision to specify a more efficiency liquid chiller than the minimums defined above will typically be driven by the kW-hour costs, the electrical demand costs, and

the chiller's annual energy usage. A designer should develop a sole source justification (if applicable) to procure the most life cycle cost effective chiller applicable. Coordinate chiller efficiencies with chiller manufacturers prior finalizing the specification.

The driving force in the procurement of higher efficient equipment is Executive Order 12902. Executive Order 12902 specifies that energy consuming products be selected which are in the top 25 percent of their class for energy efficiency or, at a minimum, at least 10 percent better than current federal minimum standards, to the extent practical and cost effective.

Full and part load efficiencies for gas-engine driven liquid chillers will have a COP of between 1.0 and 2.0 based upon operating conditions (i.e., with heat recovery, without heat recovery, etc.). A designer will coordinate with chiller manufacturers prior to specifying a minimum full or part load efficiency for a gas-engine driven chiller. Gas-engine driven chiller can be provided with compressors of the centrifugal type (typically larger than 2460 kW (700 tons)), the rotary screw type (intermediate sizes), the reciprocating type (typically up to 703 kW (200 tons)), and the scroll type (small system).

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

Step 1. Identify the safety group classification of the refrigerant anticipated to be used in the new liquid chilling equipment. Refrigerants R-22 and R-134a are considered Group A1 refrigerants. Refrigerant R-123 is considered a Group B1 refrigerant.

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

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

Step 4. Estimate the quantity of refrigerant (grams or pounds) in the largest single liquid chiller or largest refrigerant circuit of the new equipment. The designer will research catalog data from a minimum of 2 different liquid chiller manufacturers in order to get an approximation.

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

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

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

2.1 STANDARD COMMERCIAL PRODUCTS

Materials and equipment shall be standard products of a manufacturer regularly engaged in the manufacturing of such products, which are of a similar material, design and workmanship. The standard products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2 year use shall include applications of equipment and materials under similar circumstances and of similar size. The 2 years experience shall be satisfactorily completed by a product which has been sold or is offered for sale on the commercial market through advertisements, manufacturer's catalogs, or brochures. Products having less than a 2 year field service record shall be acceptable if a certified record of satisfactory field operation, for not less than 6000 hours exclusive of the manufacturer's factory tests, can be shown. Products shall be supported by a [service organization](#), as specified in the Submittals paragraph. System components shall be environmentally suitable for the indicated locations.

2.2 NAMEPLATES

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

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

2.3 ELECTRICAL WORK

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

Electrical equipment, motors, motor efficiencies, and wiring shall be in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Electrical motor driven equipment specified shall be provided complete with motors, motor starters, and controls. Electrical characteristics shall be as shown, and unless otherwise indicated, all motors of 746 kW 1 horsepower and above with open, dripproof, totally enclosed, or explosion proof fan cooled enclosures, shall be high efficiency type. Field wiring shall be in accordance with manufacturer's instructions. Each motor shall conform to NEMA MG 1 and NEMA MG 2 and be of sufficient size to drive the equipment at the specified capacity without exceeding the nameplate rating of the motor. Motors shall be continuous duty with the enclosure specified. Motor starters shall be provided complete with thermal overload protection and other appurtenances necessary for the motor control indicated. Motors shall be furnished with a magnetic across-the-line or reduced voltage type starter as required by the manufacturer. Motor duty requirements shall allow for maximum frequency start-stop operation and minimum encountered interval between start and stop. Motors shall be sized for the applicable loads. Motor torque shall be capable of accelerating the connected load within 20 seconds with 80 percent of the rated voltage maintained at motor terminals during one starting period. Motor bearings shall be fitted with grease supply fittings and grease relief to outside of enclosure. Manual or automatic control and protective or signal devices required for the operation specified and any control wiring required for controls and devices specified, but not shown, shall be provided.

2.4 SELF-CONTAINED LIQUID CHILLER

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

then assembled, charged, and run-tested in the field.

Unless necessary for delivery purposes, units shall be assembled, leak-tested, charged (refrigerant and oil), and adjusted at the factory. In lieu of delivery constraints, a chiller may be assembled, leak-tested, charged (refrigerant and oil), and adjusted at the job site by a factory representative. Unit components delivered separately shall be sealed and charged with a nitrogen holding charge. Unit assembly shall be completed in strict accordance with manufacturer's recommendations. Chiller shall operate within capacity range and speed recommended by the manufacturer. Parts weighing 23 kg 50 pounds or more which must be removed for inspection, cleaning, or repair, such as motors, gear boxes, cylinder heads, casing tops, condenser, and cooler heads, shall have lifting eyes or lugs. Chiller shall include all customary auxiliaries deemed necessary by the manufacturer for safe, controlled, automatic operation of the equipment. Chiller shall be provided with a single point wiring connection for incoming power supply. Chiller's condenser and liquid cooler shall be provided with [standard] [marine] water boxes with [grooved mechanical] [flanged] [welded] connections.

2.4.1 Scroll, Reciprocating, or Rotary Screw Type

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

Chiller shall be constructed and rated in accordance with ARI 550/590. Chiller shall be conform to ASHRAE 15. [Chiller shall have a minimum full load COP EER rating of [_____] and a part load COP kW/ton rating of [_____] in accordance with ARI 550/590.] As a minimum, chiller shall include the following components as defined in paragraph CHILLER COMPONENTS.

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

2.4.2 Centrifugal or Rotary Screw Type

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

Chiller shall be constructed and rated in accordance with ARI 550/590.
[Chiller shall have a minimum full load COP EER rating of [_____] and a
part load COP kW/ton rating of [_____] in accordance with ARI 550/590.]
Chiller shall conform to ASHRAE 15. As a minimum, chiller shall include
the following components as defined in paragraph CHILLER COMPONENTS.

- a. Refrigerant and oil
- b. Structural base
- c. Chiller refrigerant circuit
- d. Controls package
- e. Centrifugal or rotary screw compressor
- f. Compressor driver, [electric motor] [gas-engine] [steam turbine]
- g. Compressor driver connection
- h. Liquid cooler (evaporator)
- i. [Air] [Water]-cooled condenser coil
- j. [Heat recovery condenser coil]
- k. [Receiver]
- l. Purge system for chillers which operate below atmospheric pressure
- m. Tools

2.5 SPLIT-SYSTEM LIQUID CHILLER

Total chiller system shall be constructed and rated in accordance with ARI 550/590. Individual chiller components shall be constructed and rated in accordance with the applicable ARI standards. Chiller system shall be conform to ASHRAE 15. [Chiller shall have a minimum full load COP EER rating of [_____] and a part load COP kW/ton rating of [_____] in accordance with ARI 550/590.] Chiller shall be assembled, leak-tested, charged (refrigerant and oil), and adjusted at the job site in strict accordance with manufacturer's recommendations. Unit components delivered separately shall be sealed and charged with a nitrogen holding charge. Unit assembly shall be completed in strict accordance with manufacturer's recommendations. Chiller shall operate within capacity range and speed recommended by the manufacturer. Parts weighing 23 kg 50 pounds or more which must be removed for inspection, cleaning, or repair, shall have lifting eyes or lugs. Chiller shall include all customary auxiliaries deemed necessary by the manufacturer for safe, controlled, automatic operation of the equipment. Chiller's condenser and liquid cooler shall be provided with [standard] [marine] water boxes with [grooved mechanical] [flanged] [welded] connections. As a minimum, chiller shall include the

following components as defined in paragraph CHILLER COMPONENTS.

- a. Refrigerant and oil
- b. Structural base
- c. Chiller refrigerant circuit
- d. Controls package
- e. [Receiver]
- f. Tools

2.5.1 Compressor-Chiller Unit

NOTE: A compressor-chiller unit contains both the compressor and liquid cooler as a single package from the factory. For a complete chilled water system, a compressor-chiller must be specified along with a remote condenser.

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

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

2.5.2 Compressor Unit

NOTE: A compressor unit contains only the compressor as a single package from the factory. For a complete system, a compressor unit must be specified along with a remote liquid cooler and a remote condenser.

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

- a. Scroll, reciprocating, or rotary screw compressor
- b. Compressor driver, electric motor
- c. Compressor driver connection

2.5.3 Remote Liquid Cooler (Evaporator)

NOTE: Delete this paragraph if a compressor unit is not specified.

Cooler shall be constructed and rated in accordance with **ARI 480**. Cooler shall be of the shell-and-coil or shell-and-tube type design. Cooler's refrigerant side shall be designed and factory pressure tested to comply with **ASHRAE 15**. Cooler's water side shall be designed and factory pressure tested for not less than [1,000] [1,700] kPa [150] [250] psi. Cooler shell shall be constructed of seamless or welded steel. Coil bundles shall be totally removable and arranged to drain completely. Tubes shall be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube shall be individually replaceable. Tubes shall be installed into carbon mild steel tube sheets by rolling. Tube baffles shall be properly spaced to provide adequate tube support and cross flow. Cooler shall be skid-mounted. Refrigerant circuit shall be complete with liquid solenoid valve and expansion device capable of modulating to the minimum step of capacity unloading.

2.5.4 Remote Air-Cooled Condenser

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

2.5.4.1 Condenser Casing

Condenser casing shall be aluminum not less than 2 mm 0.080 inch or hot-dip galvanized steel not lighter than 1.2 mm 18 gauge. Condensers having horizontal air discharge shall be provided with discharge baffle to direct air upward, constructed of the same material and thickness as the casing.

2.5.4.2 Coil

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

Condenser coil shall be of the extended-surface fin-and-tube type and shall be constructed of seamless [copper] [or] [aluminum] tubes with compatible [copper] [or] [aluminum] fins. Fins shall be soldered or mechanically bonded to the tubes and installed in a metal casing. Coils shall be circuited and sized for a minimum of 3 degrees C 5 degrees F subcooling and full pumpdown capacity. Coil shall be factory leak and pressure tested after assembly in accordance with **ASHRAE 15**. [Coil shall be protected in accordance with paragraph COIL CORROSION PROTECTION.]

2.5.4.3 Fans

NOTE: When the density of the ambient air to be handled by the fans differs substantially from the density of the standard air value of 1.2 kg per cubic m (0.075 pound per cubic foot) at 21 degrees C (70 degrees F) and 101 kPa (29.92 inches mercury), the density of the air and/or the elevation above mean sea level will be stated.

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

2.5.5 Remote Water-Cooled Condenser

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

2.5.6 Remote Evaporatively-Cooled Condenser

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

2.5.6.1 Condenser Casing

Enclosure shall be constructed of not lighter than [1.3 mm 18 gauge hot-dip galvanized steel] [2.0 mm 0.080 inch aluminum], reinforced and braced. Access doors or panels suitably sized and located shall be provided for access to water nozzles or distribution pan, coils, and valves for cleaning, repair, or removal of the item. Access doors or panels shall be gasketed with synthetic rubber, or equivalent gasket material, and locked in place with thumb screws or catches. One-half inch mesh hot-dip galvanized steel or copper air-inlet screens shall be provided on each air inlet.

2.5.6.2 Refrigerant Section

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

2.5.6.3 Fans

NOTE: When the density of the ambient air to be handled by the fans differs substantially from the density of the standard air value of 1.2 kg per cubic m (0.075 pound per cubic foot) at 21 degrees C (70 degrees F) and 101 kPa (29.92 inches mercury), the density of the air and/or the elevation above mean sea level will be stated.

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

2.5.6.4 Water Section

Water eliminators shall be constructed of nonferrous metal, of an approved nonmetallic material, or of not lighter than 0.6 mm 24 gauge steel, hot-dip galvanized after fabrication. Spray nozzles shall be brass nonclogging type designed to permit easy disassembly, and shall be arranged for easy access. Water pump shall be bronze-fitted centrifugal or turbine type, and may be mounted as an integral part of the evaporative condenser or remotely on a separate mounting pad. Pump suction shall be fully submerged and provided with screened inlet. Water pan or sump shall be constructed of not lighter than 1.8 mm 14 gauge steel, hot-dip galvanized after fabrication, or molded acid-resistant glass-fiber-reinforced polyester. Water distribution pan shall be constructed of not lighter than 1.6 mm 16 gauge steel, hot-dip galvanized after fabrication. Joints shall be watertight. Water pan or sump shall be provided with drain, overflow, and

make-up water connection with stop valve and float valve. A bleed line with a flow valve of the needle type sized for the flow required or fixed orifice shall be provided in the pump discharge line and shall be extended to the nearest drain for continuous discharge.

2.6 CHILLER COMPONENTS

NOTE: Coordinate the type of chiller components required with the type of chiller specified in the previous paragraphs. Components define under this paragraph do not apply to absorption type chillers. Delete this paragraph if only absorption type chillers are specified.

2.6.1 Refrigerant and Oil

NOTE: Non-absorption type chillers shall operate on a refrigerant with an ozone depletion potential (ODP) less than or equal to 0.05. R-22, R-123, R-134a, R-407C, and R-410A all meet this requirement.

Refrigerants shall be one of the fluorocarbon gases. Refrigerants shall have number designations and safety classifications in accordance with ASHRAE 34. Refrigerants shall meet the requirements of ARI 700 as a minimum. Refrigerants shall have an Ozone Depletion Potential (ODP) of less than or equal to 0.05.

2.6.2 Structural Base

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

2.6.3 Chiller Refrigerant Circuit

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

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

2.6.4 Controls Package

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

Chiller shall be provided with a complete [factory-mounted] [remote-mounted where indicated], prewired electric or microprocessor based control system.

Controls package shall contain as a minimum a digital display or acceptable gauges, an on-auto-off switch, [motor starters,] [disconnect switches,] power wiring, and control wiring. Controls package shall provide operating controls, monitoring capabilities, programmable setpoints, safety controls, and EMCS interfaces as defined below.

2.6.4.1 Operating Controls

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

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

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

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

2.6.4.2 Monitoring Capabilities

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

- a. Entering and leaving chilled water temperatures
- b. Self diagnostic
- c. Operation status
- d. Operating hours
- e. Number of starts
- f. Compressor status (on or off)
- g. Refrigerant discharge and suction pressures
- h. Oil pressure
- i. [Condenser water entering and leaving temperatures]
- j. [Number of purge cycles over the last 7 days]

2.6.4.3 Programmable Setpoints

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

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

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

2.6.4.4 Safety Controls with Manual Reset

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

- a. Low chilled water temperature protection
- b. High condenser refrigerant discharge pressure protection
- c. Low evaporator pressure protection
- d. Chilled water flow detection
- e. High motor winding temperature protection
- f. Low oil flow protection if applicable
- g. [Motor current overload and phase loss protection]

2.6.4.5 Safety Controls with Automatic Reset

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

- a. Over/under voltage protection
- b. Chilled water flow interlock
- c. [Phase reversal protection]

2.6.4.6 Remote Alarm

During the initiation of a safety shutdown, a chiller's control system shall be capable of activating a remote alarm bell. In coordination with the chiller, the Contractor shall provide an alarm circuit (including transformer if applicable) and a minimum 100 mm 4 inch diameter alarm bell.

Alarm circuit shall activate bell in the event of machine shutdown due to the chiller's monitoring of safety controls. The alarm bell shall not sound for a chiller that uses low-pressure cutout as an operating control.

2.6.4.7 Energy Management Control System (EMCS) Interface

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

- a. Remote Unit Start/Stop
- b. [Remote Chilled Water Reset]
- c. [Remote Condenser Water Reset]

2.6.5 Compressor(s)

2.6.5.1 Reciprocating Compressor(s)

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

- a. Vertical, V, W, or radial cylinder design
- b. Oil lubrication
- c. Integrally cast block of close-grained iron or cast aluminum block with hardened steel cylinder sleeves
- d. Oil-level bull's eye

- e. Cast cylinder heads
- f. Cast-aluminum or forged-steel connecting rods
- g. Cast iron or forged-steel crankshaft
- h. Main bearings of the sleeve-insert type
- i. Crankcase oil heaters controlled as recommended by the manufacturer
- j. Suction and discharge refrigerant service valves that are flange connected, wrench operated, with cap
- k. A strainer on the suction side of the compressor
- l. [A hot-gas muffler to reduce vibration and noise from pulsations]

2.6.5.2 Scroll Compressor(s)

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

2.6.5.3 Rotary Screw Compressor(s)

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

- a. An open or hermetic, positive displacement, oil-injected design directly driven by the compressor driver. Compressor shall allow access to internal compressor components for repairs, inspection, and replacement of parts.
- b. Rotors which are solid steel forging with sufficient rigidity for proper operation.
- c. A maximum rotor operating speed no greater than 3600 RPM.
- d. Casings of cast iron, precision machined for minimal clearance about periphery of rotors.
- e. A lubrication system of the forced-feed type that provides oil at the proper pressure to all parts requiring lubrication.
- f. Shaft main bearings of the sleeve type with heavy duty bushings or rolling element type in accordance with [ABMA 9](#) or [ABMA 11](#). Bearings shall be conservatively loaded and rated for an L(10) life of not less than 200,000 hours.
- g. A differential oil pressure or flow cutout to allow the compressor to operate only when the required oil pressure or flow is provided to the bearings.

- h. A temperature- or pressure-initiated, hydraulically actuated, single-slide-valve, capacity-control system to provide minimum automatic capacity modulation from 100 percent to 15 percent.
- i. An oil separator and oil return system to remove oil entrained in the refrigerant gas and automatically return the oil to the compressor.
- j. Crankcase oil heaters controlled as recommended by the manufacturer.

2.6.5.4 Centrifugal Compressor(s)

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

Centrifugal compressors shall be single or multistage, having dynamically balanced impellers, either direct or gear driven by the compressor driver. Impellers shall be over-speed tested at 1.2 times the impeller-shaft speed. Impeller shaft shall be heat-treated alloy steel with sufficient rigidity for proper operation at any required operating speed. Centrifugal compressors shall include:

- a. Shaft main bearings that are the rolling element type in accordance with [ABMA 9](#) or [ABMA 11](#), journal type with bronze or babbitt liners, or of the aluminum-alloy one-piece insert type. Bearings shall be rated for an L(10) life of not less than 200,000 hours.
- b. Casing of cast iron, aluminum, or steel plate with split sections gasketed and bolted or clamped together.
- c. Lubrication system of the forced-feed type that provides oil at the proper pressure to all parts requiring lubrication.

d. Provisions to ensure proper lubrication of bearings and shaft seals prior to starting and upon stopping with or without electric power supply. On units providing forced-feed lubrication prior to starting, a differential oil pressure cutout interlocked with the compressor starting equipment shall allow the compressor to operate only when the required oil pressure is provided to the bearings.

e. Oil sump heaters controlled as recommended by the manufacturer.

f. Temperature-or pressure-actuated prerotation vane or suction damper to provide automatic capacity modulation from 100 percent capacity to 10 percent capacity. If operation to 10 percent capacity cannot be achieved without providing hot-gas bypass, then the Contractor shall indicate in the equipment submittal the load percent at which hot gas bypass is required.

2.6.6 Compressor Driver, Electric Motor

Motors, starters, [variable speed drives], wiring, etc. shall be in accordance with paragraph ELECTRICAL WORK. Motor starter shall be [unit mounted] [remote mounted] as indicated with starter type, wiring, and accessories coordinated with the chiller manufacturer. Starter shall be able to operate in temperatures up to 120 degrees F.

2.6.7 Compressor Driver, Gas-Engine

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

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

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

Gas-engine compressor driver shall operate on natural gas and be in accordance with NFPA 37 and NFPA 54. Engine shall be designed for stationary applications and include all ancillaries necessary for operation. Engine shall be a manufacturer's standard production model and

be specifically designed for chiller operation. Engine shall include as a minimum a [heavy duty industrial] [standard automotive] grade block, starting system, lubrication system, coolant system, engine heat exchanger, [engine cooling radiator,] fuel supply system, and controls package. Engine shall be naturally aspirated, supercharged, or turbocharged and include appropriate air filters. Engine shall be 2- or 4-stroke-cycle and compression-ignition type. Engine shall be vertical in-line, V- or opposed-piston type, with a solid cast block or individually cast cylinders. Engine shall have a minimum of 2 cylinders. Opposed-piston type engines shall have not less than 4 cylinders. Engine block shall have a coolant drain port.

2.6.7.1 Starting System

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

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

2.6.7.2 Lubrication System

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

2.6.7.3 Coolant System

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

2.6.7.4 Engine Heat Exchanger

Engine heat exchanger shall be of the shell-and-tube type construction and be in accordance with ASME BPVC SEC VIII D1. Shell material shall be

carbon steel. Tubes shall be seamless copper or copper-nickel. Tubes shall be individually replaceable. Unit's waterside working pressure shall be rated for not less than 1,000 kPa 150 psig and factory tested at 150 percent of design working pressure. Water connections larger than 75 mm 3 inches shall be ASME Class 1500 flanged. Unit shall be provided with gasketed removable covers, drains, and vents.

2.6.7.5 Engine Cooling Radiator

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

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

2.6.7.6 Fuel Supply System

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

2.6.7.7 Controls Package

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

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

2.6.7.8 Exhaust Piping

Exhaust piping installation shall be per the engine manufacturer's recommendations, except as modified herein. Horizontal sections of exhaust

piping shall be sloped downward away from the engine to a drip leg for collection of condensate with drain valve and cap. Changes in direction shall be long radius. Exhaust piping and mufflers shall be insulated in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS.

Vertical exhaust piping shall be provided with a hinged, gravity-operated, self-closing, rain cover.

2.6.7.9 Exhaust Muffler

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

2.6.7.10 Exhaust System Connections

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

2.6.8 Compressor Driver, Steam Turbine

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

2.6.9 Compressor Driver Connections

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

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

2.6.10 Liquid Cooler (Evaporator)

NOTE: The standard performance fouling factor per ARI is 0.0001 h(ft²)(degrees F)/Btu.

Cooler shall be of the shell-and-coil or shell-and-tube type design. Condenser's refrigerant side shall be designed and factory pressure tested to comply with [ASHRAE 15](#). Condenser's water side shall be designed and factory pressure tested for not less than [1,000] [1,700] kPa [150] [250] psi. Cooler shell shall be constructed of seamless or welded steel. Coil bundles shall be totally removable and arranged to drain completely. Tubes shall be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube shall be individually replaceable. Tubes shall be installed into carbon mild steel tube sheets by rolling. Tube baffles shall be properly spaced to provide adequate tube support and cross flow. Performance shall be based on a water velocity not less than 0.91 m/s 3 fps nor more than 3.7 m/s 12 fps and a fouling factor of [0.000018 m²(degrees C)/W (0.0001 h(ft²)(degrees F)/Btu)] [0.000044 m²(degrees C)/W (0.00025 h(ft²)(degrees F)/Btu)] [0.000088 m²(degrees C)/W (0.0005 h(ft²)(degrees F)/Btu)] [0.0001 h(ft²)(degrees F)/Btu] [0.00025 h(ft²)(degrees F)/Btu] [0.0005 h(ft²)(degrees F)/Btu].

2.6.11 Air-Cooled Condenser Coil

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

Condenser coil shall be of the extended-surface fin-and-tube type and shall be constructed of seamless [copper] [or] [aluminum] tubes with compatible [copper] [or] [aluminum] fins. Fins shall be soldered or mechanically

bonded to the tubes and installed in a metal casing. Coils shall be circuited and sized for a minimum of 3 degrees C 5 degrees F subcooling and full pumpdown capacity. Coil shall be factory leak and pressure tested after assembly in accordance with ASHRAE 15. [Coil shall be protected in accordance with paragraph COIL CORROSION PROTECTION.]

2.6.12 Water-Cooled Condenser Coil

NOTE: The standard performance fouling factor per
ARI is 0.00025 h(ft2)(degrees F)/Btu for condenser.

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

2.6.13 Heat Recovery Condenser Coil

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

Condenser shall be of the shell-and-coil or shell-and-tube type design and shall not be a part of the standard condenser. Condenser shall be provided and installed by the chiller manufacturer. Condenser's refrigerant side shall be designed and factory pressure tested to comply with ASHRAE 15. Condenser's water side shall be designed and factory pressure tested for not less than [1,000] [1,700] kPa [150] [250] psi. Condenser shall have performance characteristics as indicated on the drawings. Condenser shell

shall be constructed of seamless or welded steel. Coil bundles shall be totally removable and arranged to drain completely. Tubes shall be seamless copper, plain, integrally finned with smooth bore or integrally finned with enhanced bore. Each tube shall be individually replaceable, except for the coaxial tubes. Tube baffles shall be properly spaced to provide adequate tube support and cross flow. Performance shall be based on water velocities not less than 0.91 m/s 3 fps nor more than 3.7 m/s 12 fps and a fouling factor of [0.00025] [0.0005].

2.6.14 Receivers

Liquid receivers not already specified herein as an integral factory-mounted part of a package, shall be designed, fitted, and rated in accordance with the recommendations of ARI 495, except as modified herein. Receiver shall bear a stamp certifying compliance with ASME BPVC SEC VIII D1 and shall meet the requirements of ASHRAE 15. Inner surfaces shall be thoroughly cleaned by sandblasting or other approved means. Each receiver shall have a storage capacity not less than 20 percent in excess of that required for the fully-charged system. Each receiver shall be equipped with inlet, outlet drop pipe, drain plug, purging valve, relief valves of capacity and setting required by ASHRAE 15, and two bull's eye liquid-level sight glasses. Sight glasses shall be in the same vertical plane, 90 degrees apart, perpendicular to the axis of the receiver, and not over 75 mm 3 inches horizontally from the drop pipe measured along the axis of the receiver. In lieu of bull's eye sight glass, external gauge glass with metal glass guard and automatic closing stop valves may be provided.

2.6.15 Chiller Purge System

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

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

2.6.16 Tools

One complete set of special tools, as recommended by the manufacturer for field maintenance of the system, shall be provided. Tools shall be mounted

on a tool board in the equipment room or contained in a toolbox as directed by the Contracting Officer.

2.7 ABSORPTION LIQUID CHILLER

NOTE: Perform a life cycle cost analysis to determine the most economical type (single- or two-stage) of absorption unit to specify. The initial cost of a two-stage chiller is typically much higher than a single-stage machine, however a two-stage chiller will provide a substantial amount of energy savings over the life of the equipment.

Minimum efficiencies will either be presented in this paragraph or on the design drawings. Delete the efficiency ratings in this paragraph if equipment efficiencies are shown on the drawings. If the efficiencies are shown on the drawings, reference the applicable ARI standard. The following is a list of appropriate minimum full load and part load ratings for absorption chillers. These values or higher values will be entered into the specification where indicated. The designer should contact manufacturers to determine what is available before specifying full and part load values.

	Full Load (*COP)	IPLV (*COP)
Single Effect (Indirect Fired): All Capacities	0.65	0.65
Double Effect (Indirect Fired): All Capacities	1.20	1.25
Double Effect (Direct Fired): All Capacities	0.90	0.90

* - Units are dimensionless (output / input)

Indicate the type of water boxes (standard or marine) required for the evaporator, the absorber, and the condenser on the drawings. Note that some manufacturers do not offer marine water boxes for each connection.

2.7.1 General

Chiller shall be constructed and rated in accordance with [ARI 560](#) and shall bear the appropriate underwriter's laboratories (UL) label. [Chiller shall have a minimum cooling Coefficient of Performance (COP) of [_____] at full load conditions in accordance with [ARI 560](#). Chiller shall have a minimum cooling COP of [_____] at part load conditions in accordance with [ARI 560](#).]

Chiller shall be the [single-stage] [two-stage] hermetic, water-cooled type design. Chiller shall be [indirectly-fired with [steam] [hot water]] [directly-fired with a [single] [dual] fuel burner]. [For direct-fired

units, ratings for cooling capacity, fuel consumption, and COP shall be based on the higher heating value (HHV) or the specific type of fuel utilized.]

2.7.2 Assembly

Unless necessary for delivery purposes, chiller shall be assembled, leak-tested, charged, and adjusted at the factory. In lieu of delivery constraints, a chiller may be assembled, leak-tested, charged, and adjusted at the job site by a factory representative. Unit components delivered separately shall be sealed and charged with a nitrogen holding charge. Unit assembly shall be completed in strict accordance with manufacturer's recommendations.

2.7.3 Operation

Chiller shall operate within capacity range and speed recommended by the manufacturer. Parts weighing 23 EKG 50 pounds or more which must be removed for inspection, cleaning, or repair shall have lifting eyes or lugs. Chiller shall be provided with insulation on surfaces subject to sweating including the liquid cooler and water boxes. Chiller shall be provided from the factory with a single point wiring connection for incoming power supply. Magnetic across-the-line motor starters with overload protection shall be provided for each factory supplied pump. Chiller shall include all customary auxiliaries deemed necessary by the manufacturer for safe, controlled, automatic operation of the equipment.

2.7.4 Components

Chiller shall include the following as a minimum:

- a. Absorber, evaporator, and condenser
- b. [Generator] [First and second stage generators]
- c. Refrigerant, absorber, and inhibitor solutions
- d. [Low] [Low and high] temperature heat exchanger(s)
- e. Self-contained, hermetically sealed, self lubricating, liquid cooled, refrigerant and solution pumps. Pumps shall be direct coupled with the motor and shall include isolation valves.
- f. [Factory-installed combustion burner assembly and pre-piped fuel train]
- g. [Cooling/heating switch valve]
- h. [Exhaust gas economizer]
- i. [Automatic] [Manual] purge system
- j. Automatic decrystallization system
- k. Chiller controls package
- l. Interconnecting piping and wiring
- m. [Grooved mechanical] [Flanged] [Welded] connections for water boxes

- n. Refrigerant spray nozzles
- o. Factory-mounted structural steel base (welded or bolted) or support legs
- p. Thermometers and sight glasses to allow visual inspection of unit operation. Mercury shall not be used in thermometers.

2.7.5 Component Construction

NOTE: Delete the requirements for the first and second stage generators if a two-effort chiller is not specified.

Chiller exterior surfaces shall be factory painted, finished, and insulated as applicable. Chiller shell shall be of carbon steel construction with cast iron or welded steel heads. Evaporator, absorber, condenser, generator(s), and heat exchanger(s) shall be of the shell-and-tube type construction and be in accordance with **ASME BPVC SEC VIII D1**. Evaporator, absorber, condenser, and heat exchanger tubes shall be seamless copper or cupronickel (CuNi). [First stage generator tubes shall be seamless Type 409 stainless steel or cupronickel. Second stage generator] [Generator] tubes shall be seamless cupronickel. Tubes shall be individually replaceable. Water boxes shall be provided with lifting lugs, gasketed removable covers, drains, and vents. Unit's internal waterside components shall be rated for not less than **1,000 kPa 150 psig** and factory tested at 150 percent of design working pressure. Insulation shall be provided for the refrigerant pump, all exposed chilled water piping, the absorber shell, the steam or hot water inlet piping.

2.7.6 Combustion Burner Assembly

NOTE: Delete this paragraph if a direct-fired absorption chiller is not specified.

Chiller shall be provided with a forced draft, flame retention type burner and fuel train assembly. Burner shall be the [single] [dual] fuel type capable of burning [natural gas] [propane] [and] [number 1 fuel oil] [number 2 fuel oil] [diesel]. Burner and fuel train shall be listed by the underwriters laboratories (UL). Burner assembly shall be provided with all pressure regulators, switches, controls, ignition system, blower fans, and other devices required for proper and safe operation of the burner. Burner assembly shall be equipped with an external primary-secondary air ratio adjustment that allows adjustment without dismantling the burner. Burner controls shall allow either manual or automatic burner operation. Fuel changeover shall be accomplished [by a manual fuel changeover switch] [automatically as indicated].

2.7.7 Controls Package

Chiller shall be provided with a complete factory mounted and prewired electric or microprocessor based control system. Controls package shall be [unit-mounted] [floor-mounted where indicated] which contains as a minimum a digital display or acceptable gauges, an on-auto-off switch, motor

starters, power wiring, control wiring, and disconnect switches. Controls package shall provide operating controls, monitoring capabilities, programmable setpoints, safety controls, and EMCS interfaces as defined below.

2.7.7.1 Operating Controls

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

- a. Leaving chilled water temperature control
- b. System capacity control to adjust the unit capacity in accordance with the system load and the programmable setpoints. Controls shall automatically re-cycle the chiller on power interruption.

2.7.7.2 Monitoring Capabilities

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

- a. Entering and leaving chilled water temperatures
- b. Entering and leaving condenser water temperatures
- c. Refrigerant and solution temperatures
- d. Generator pressures and temperatures
- e. Self diagnostic
- f. Operation status
- g. Operating hours
- h. Number of starts
- i. Number of purge cycles over the last 7 days

2.7.7.3 Programmable Setpoints

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

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

2.7.7.4 Safety Controls with Manual Reset

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

- a. Refrigerant or solution pump thermal or current overload

- b. Low refrigerant temperature
- c. Loss of chilled water
- d. Loss of condenser water
- e. High or low condenser water temperatures
- f. Power failure
- g. Generator high temperature or pressure
- h. Low solution level
- i. [Burner or related combustion malfunction]

2.7.7.5 Remote Alarm

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

2.7.7.6 Energy Management Control System (EMCS) Interface

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

- a. Remote Unit Start/Stop
- b. Remote Chilled Water Reset
- c. Remote Condenser Water Reset

2.8 ACCESSORIES

2.8.1 Refrigerant Leak Detector

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

When a detector is required, the location will be indicated on the drawings. Detectors are best located between the refrigeration system and the room exhaust. Sampling points from a detector will be located a maximum of 457 mm (18 inches) above the finished floor since all commonly-used refrigerants are heavier than air.

As a rule of thumb, the distance between any

refrigeration system and a refrigerant sampling point shouldn't exceed 15 m (50 feet). In order to meet the recommended 15 m (50 foot) distance, a mechanical room can be provided with either multiple detectors each with single sampling points or with one detector that has the capability of monitoring at multiple sampling points. If multiple sampling points are required, enter the number in the appropriate blank below.

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

As an additional item, ASHRAE 15 states that open-flame devices (i.e., boilers, etc.) cannot be installed in the same area as a refrigeration system, unless either combustion air for the open-flame device is ducted straight from outside to the device; or the alarm relay from the detector is used to automatically shutdown the combustion process in the event of refrigerant leakage. Indicate all applicable alarm controls on the drawings.

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

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

any refrigerant alarm conditions.]

2.8.2 Refrigerant Relief Valve/Rupture Disc Assembly

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

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

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

2.8.3 Refrigerant Signs

Refrigerant signs shall be a medium-weight aluminum type with a baked enamel finish. Signs shall be suitable for indoor or outdoor service. Signs shall have a white background with red letters not less than 13 mm 0.5 inches in height.

2.8.3.1 Installation Identification

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

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

2.8.3.2 Controls and Piping Identification

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

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

2.8.4 Refrigerant Recovery/Recycle System

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

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

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

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

2.8.5 Automatic Tube Brush Cleaning System

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

2.8.5.1 Brush and Basket Sets

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

2.8.5.2 Flow-Diverter Valve

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

2.8.5.3 Control Panel

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

- a. Timer to initiate the on-load cleaning cycle.
- b. Manual override of preset cleaning cycle.
- c. Power-on indicator.
- d. Diverter-position indicator.
- e. Cleaning-cycle-time adjustment.
- f. Flow-switch bypass.

2.8.6 Gaskets

Gaskets shall conform to ASTM F 104 - classification for compressed sheet with nitrile binder and acrylic fibers for maximum 371 degrees C 700 degrees F service.

2.8.7 Bolts and Nuts

Bolts and nuts, except as required for piping applications, shall be in accordance with ASTM A 307. The bolt head shall be marked to identify the manufacturer and the standard with which the bolt complies in accordance with ASTM A 307.

2.9 FINISHES

2.9.1 Factory Coating

2.9.1.1 Coil Corrosion Protection

NOTE: Research local conditions to determine the corrosiveness of the environment. Where condenser or evaporator coils are to be installed in highly corrosive atmospheres, carefully consider the coil

and fin combinations specified. Standard coil construction is typically copper tubes with aluminum fins. For excessively corrosive atmospheres, either copper tubes with copper fins or aluminum tubes with aluminum fins should be considered.

For maximum coil protection, include the requirements of this paragraph. This paragraph addresses phenolic, vinyl, and epoxy type coatings. For coils with relatively close fin spacing the phenolic or epoxy coating are the preferred types as these have less tendency to bridge across the fins than vinyl. In addition, the phenolic and epoxy type coatings can typically provide better thermal conductivity than vinyl.

If coatings are specified, note that a coil's heat transfer capacity can be reduced anywhere between 1 to 5 percent; total unit capacity may have to be increased as a result.

Provide coil with a uniformly applied [epoxy electrodeposition] [phenolic] [vinyl] [epoxy electrodeposition, phenolic, or vinyl] type coating to all coil surface areas without material bridging between fins. Coating shall be applied at either the coil or coating manufacturer's factory. Coating process shall encure complete coil encapsulation. Coating shall be capable of withstanding a minimum 1,000 hours exposure to the salt spray test specified in [ASTM B 117](#) using a 5 percent sodium chloride solution.

2.9.1.2 Equipment and Components

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

Unless otherwise specified, equipment and component items, when fabricated from ferrous metal, shall be factory finished with the manufacturer's standard finish, except that items located outside of buildings shall have weather resistant finishes that will withstand [125] [500] hours exposure to the salt spray test specified in [ASTM B 117](#) using a 5 percent sodium chloride solution. Immediately after completion of the test, the specimen shall show no signs of blistering, wrinkling, cracking, or loss of adhesion and no sign of rust creepage beyond 3 mm 1/8 inch on either side of the scratch mark. Cut edges of galvanized surfaces where hot-dip galvanized sheet steel is used shall be coated with a zinc-rich coating conforming to [ASTM D 520](#), Type I.

2.9.2 Factory Applied Insulation

Chiller shall be provided with factory installed insulation on surfaces subject to sweating including the liquid cooler, suction line piping, economizer, and cooling lines. Insulation on heads of coolers may be field

applied, however it shall be installed to provide easy removal and replacement of heads without damage to the insulation. Where motors are the gas-cooled type, factory installed insulation shall be provided on the cold-gas inlet connection to the motor per manufacturer's standard practice. Factory insulated items installed outdoors are not required to be fire-rated. As a minimum, factory insulated items installed indoors shall have a flame spread index no higher than 75 and a smoke developed index no higher than 150. Factory insulated items (no jacket) installed indoors and which are located in air plenums, in ceiling spaces, and in attic spaces shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50. Flame spread and smoke developed indexes shall be determined by [ASTM E 84](#). Insulation shall be tested in the same density and installed thickness as the material to be used in the actual construction. Material supplied by a manufacturer with a jacket shall be tested as a composite material. Jackets, facings, and adhesives shall have a flame spread index no higher than 25 and a smoke developed index no higher than 50 when tested in accordance with [ASTM E 84](#).

2.10 [FACTORY TESTS](#)

2.10.1 Chiller Performance Test

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

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

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

The ARI testing of chillers allows a deviation to chiller capacity of up to 5% at full load. Load

calculations should consider this tolerance.

The Contractor and proposed chiller manufacturer shall be responsible for performing the chiller factory test to validate the specified full load capacity, full load EER, and [IPLV] [NPLV] in accordance with ARI 550/590 except as indicated. [The chiller factory test shall be performed in the presence of a Government representative.] The Contractor and chiller manufacturer shall provide to the Government a certified chiller factory test report in accordance with ARI 550/590 to confirm that the chiller performs as specified. Tests shall be conducted in an ARI certified test facility in conformance with ARI 550/590 procedures and tolerances, except as indicated. At a minimum, chiller capacity shall be validated to meet the scheduled requirements indicated on the drawings. Tolerance or deviation shall be in strict accordance with ARI 550/590. Stable operation at minimum load of 10 percent of total capacity shall be demonstrated during the factory test.

2.10.1.1 Temperature Adjustments

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

2.10.1.2 Test Instrumentation

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

2.10.1.3 Test Report

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

2.10.1.4 Equipment Adjustments

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

2.10.2 Chiller Sound Test

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

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

Chillers shall be sound tested at the factory prior to shipment to confirm the sound pressure level specified herein. Tests and data shall be conducted and measured in strict accordance with ARI 575 at the full load system operating conditions. The chiller sound pressure level, in decibels (dB), with a reference pressure of 20 micropascals, shall not exceed [85] [90] [_____] dB, A weighted. Ratings shall be in accordance with ARI 575. No reduction of entering condenser water temperature or raising of leaving chilled water temperature shall be allowed. A minimum of 75 percent of the sound data points shall be taken along the length of the machine, and established as the minimum percentage of total possible points used to determine sound levels. In the event that the chiller does not meet the dBA sound pressure level, the manufacturer shall, at his expense, provide sufficient attenuation to the machine to meet the specified value. This attenuation shall be applied in such a manner that it does not hinder the operation or routine maintenance procedures of the chiller. The attenuation material, adhesives, coatings, and other accessories shall have surface burning characteristics as determined by ASTM E 84.

2.11 SUPPLEMENTAL COMPONENTS/SERVICES

2.11.1 Chilled and Condenser Water Piping and Accessories

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

2.11.2 Refrigerant Piping

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

2.11.3 Cooling Tower

Cooling towers shall be provided and installed in accordance with Section 23 65 00.00 10 COOLING TOWER.

2.11.4 Temperature Controls

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

A sequence of control, a schematic of controls, and a ladder diagram should be included on the drawings for each cooling tower fan, chilled water pump,

condenser water pump, etc. in order to define the overall system operation.

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

PART 3 EXECUTION

3.1 INSTALLATION

Work shall be performed in accordance with the manufacturer's published diagrams, recommendations, and equipment warranty requirements. Where equipment is specified to conform to the requirements of ASME BPVC SEC VIII D1 and ASME BPVC SEC IX, the design, fabrication, and installation of the system shall conform to ASME BPVC SEC VIII D1 and ASME BPVC SEC IX.

3.1.1 Refrigeration System

3.1.1.1 Equipment

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

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

Refrigeration equipment and the installation thereof shall conform to ASHRAE 15. Necessary supports shall be provided for all equipment, appurtenances, and pipe as required, including frames or supports for compressors, pumps, cooling towers, condensers, liquid coolers, and similar items. Compressors shall be isolated from the building structure. If

mechanical vibration isolators are not provided, vibration absorbing foundations shall be provided. Each foundation shall include isolation units consisting of machine and floor or foundation fastenings, together with intermediate isolation material. Other floor-mounted equipment shall be set on not less than a 150 mm 6 inch concrete pad doweled in place. Concrete foundations for floor mounted pumps shall have a mass equivalent to three times the weight of the components, pump, base plate, and motor to be supported. In lieu of concrete pad foundation, concrete pedestal block with isolators placed between the pedestal block and the floor may be provided. Concrete pedestal block shall be of mass not less than three times the combined pump, motor, and base weights. Isolators shall be selected and sized based on load-bearing requirements and the lowest frequency of vibration to be isolated. Isolators shall limit vibration to [_____] percent at lowest equipment rpm. Lines connected to pumps mounted on pedestal blocks shall be provided with flexible connectors. Foundation drawings, bolt-setting information, and foundation bolts shall be furnished prior to concrete foundation construction for all equipment indicated or required to have concrete foundations. Concrete for foundations shall be as specified in Section 03 31 00.00 10 CAST-IN-PLACE STRUCTURAL CONCRETE. Equipment shall be properly leveled, aligned, and secured in place in accordance with manufacturer's instructions.

3.1.1.2 Field Refrigerant Charging

- a. Initial Charge: Upon completion of all the refrigerant pipe tests, the vacuum on the system shall be broken by adding the required charge of dry refrigerant for which the system is designed, in accordance with the manufacturer's recommendations. Contractor shall provide the complete charge of refrigerant in accordance with manufacturer's recommendations. Upon satisfactory completion of the system performance tests, any refrigerant that has been lost from the system shall be replaced. After the system is fully operational, service valve seal caps and blanks over gauge points shall be installed and tightened.
- b. Refrigerant Leakage: If a refrigerant leak is discovered after the system has been charged, the leaking portion of the system shall immediately be isolated from the remainder of the system and the refrigerant shall be pumped into the system receiver or other suitable container. The refrigerant shall not be discharged into the atmosphere.
- c. Contractor's Responsibility: The Contractor shall, at all times during the installation and testing of the refrigeration system, take steps to prevent the release of refrigerants into the atmosphere. The steps shall include, but not be limited to, procedures which will minimize the release of refrigerants to the atmosphere and the use of refrigerant recovery devices to remove refrigerant from the system and store the refrigerant for reuse or reclaim. At no time shall more than 85 g 3 ounces of refrigerant be released to the atmosphere in any one occurrence. Any system leaks within the first year shall be repaired in accordance with the specified requirements including material, labor, and refrigerant if the leak is the result of defective equipment, material, or installation.

3.1.1.3 Oil Charging

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

of the tests, the oil shall be drained and replaced with the second charge.

3.1.2 Mechanical Room Ventilation

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

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

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

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

b. For a mechanical ventilation system, ASHRAE 15 requires both normal and alarm ventilation. Normal ventilation will be sized to cover personnel ventilation requirements 2.5 l/s/m² or (0.5 cfm/ft²) and heat buildup requirements if applicable. Alarm ventilation will be sized based upon the equations in ASHRAE 15. Both the normal and alarm ventilation rates can be achieved using the same ventilation system (e.g., multi-speed exhaust fans), however, individual systems are preferred. For the alarm ventilation, exhaust intakes will be located near the equipment and close to the finished floor. Most commonly used refrigerants are heavier-than-air and subsequently sink to the floor. Also per ASHRAE 15, air supply and exhaust ducts to the mechanical room will serve no other area within a facility. Discharge air from a mechanical ventilation system will be to the outdoors.

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

3.1.3 Field Applied Insulation

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

3.1.4 Field Painting

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

3.2 MANUFACTURER'S FIELD SERVICE

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

a. Hermetic machines:

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

b. Open Machines:

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

c. Absorption Units:

- (1) Testing and evacuation.
- (2) Charging the machine with refrigerant.
- (3) Starting the machine.

3.3 CLEANING AND ADJUSTING

Equipment shall be wiped clean, with all traces of oil, dust, dirt, or paint spots removed. Temporary filters shall be provided for all fans that are operated during construction, and new filters shall be installed after all construction dirt has been removed from the building. System shall be maintained in this clean condition until final acceptance. Bearings shall be properly lubricated with oil or grease as recommended by the manufacturer. Belts shall be tightened to proper tension. Control valves and other miscellaneous equipment requiring adjustment shall be adjusted to setting indicated or directed. Fans shall be adjusted to the speed indicated by the manufacturer to meet specified conditions. Testing, adjusting, and balancing shall be as specified in Section 23 05 93.00 10 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS.

3.4 SYSTEM PERFORMANCE TESTS

3.4.1 General Requirements

Before each refrigeration system is accepted, tests to demonstrate the general operating characteristics of all equipment shall be conducted by a registered professional engineer or an approved manufacturer's start-up representative experienced in system start-up and testing, at such times as directed. Tests shall cover a period of not less than [48] [_____] hours for each system and shall demonstrate that the entire system is functioning in accordance with the drawings and specifications. Corrections and adjustments shall be made as necessary and tests shall be re-conducted to demonstrate that the entire system is functioning as specified. Prior to acceptance, service valve seal caps and blanks over gauge points shall be installed and tightened. Any refrigerant lost during the system startup shall be replaced. If tests do not demonstrate satisfactory system performance, deficiencies shall be corrected and the system shall be retested. Tests shall be conducted in the presence of the Contracting Officer. Water and electricity required for the tests will be furnished by the Government. Any material, equipment, instruments, and personnel required for the test shall be provided by the Contractor. Field tests shall be coordinated with Section 23 05 93.00 10 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS.

3.4.2 Test Report

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

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

3.5 DEMONSTRATIONS

Contractor shall conduct a training course for the operating staff as designated by the Contracting Officer. The training period shall consist of a total [_____] hours of normal working time and start after the system

is functionally completed but prior to final acceptance tests. The field posted instructions shall cover all of the items contained in the approved operation and maintenance manuals as well as demonstrations of routine maintenance operations.

-- End of Section --