**************************************************************************
**USACE / NAVFAC / AFCEC / NASA** **UFGS-22 33 30.00 10 (April 2008)**
**--------------------------------**
**Preparing Activity: USACE** **Superseding**
**UFGS-22 33 30.00 10 (January 2008)**

**UNIFIED FACILITIES GUIDE SPECIFICATIONS**

**References are in agreement with UMRL dated October 2013**
**************************************************************************

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SOLAR WATER HEATING EQUIPMENT

**04/08**

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**USACE / NAVFAC / AFCEC / NASA** **UFGS-22 33 30.00 10 (April 2008)**

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**UNIFIED FACILITIES GUIDE SPECIFICATIONS**

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**************************************************************************

SECTION 22 33 30.00 10

# SOLAR WATER HEATING EQUIPMENT
**04/08**

**************************************************************************
**NOTE: This guide specification covers the requirements for solar domestic and service water heating equipment.**

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

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

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

## PART 1 GENERAL

**************************************************************************
**NOTE: In accordance with the design guidance presented in UFC 3-440-01, the system is designed around the properties of a particular collector. The designer should indicate the design methodology used on the drawings. This ensures that equipment shown on detail drawings (if different from the equipment assumed by the designer) is properly sized. It is particularly important for the designer to indicate on the drawings the collector parameters used in the design. Detail drawings returned should also be so noted, particularly if the collector chosen has properties different from those used in the original design. UFC 3-440-01 provides the designer, project manager, and quality assurance personnel a checklist of required drawings**

**and information called out by this guide specification to appear on the drawings.**
**************************************************************************

1.1 REFERENCES

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

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

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

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

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

| | |
|---|---|
| ANSI Z21.22/CSA 4.4 | (1999; Addenda A 2000, Addenda B 2001; R 2004) Relief Valves for Hot Water Supply Systems |

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

| | |
|---|---|
| ASHRAE 93 | (2010) Methods of Testing to Determine the Thermal Performance of Solar Collectors |

AMERICAN WATER WORKS ASSOCIATION (AWWA)

| | |
|---|---|
| AWWA C606 | (2011) Grooved and Shouldered Joints |

AMERICAN WELDING SOCIETY (AWS)

| | |
|---|---|
| AWS B2.1/B2.1M | (2009) Specification for Welding Procedure and Performance Qualification |
| AWS D1.2/D1.2M | (2008) Structural Welding Code - Aluminum |

ASME INTERNATIONAL (ASME)

| | |
|---|---|
| ASME B1.20.1 | (1983; R 2006) Pipe Threads, General Purpose (Inch) |

| | |
|---|---|
| ASME B1.20.2M | (2006; R 2011) Pipe Threads, 60 Deg. General Purpose (Metric) |
| ASME B16.15 | (2011; INT thru June 2011) Cast Copper Alloy Threaded Fittings Classes 125 and 250 |
| ASME B16.18 | (2012) Cast Copper Alloy Solder Joint Pressure Fittings |
| ASME B16.22 | (2012) Standard for Wrought Copper and Copper Alloy Solder Joint Pressure Fittings |
| ASME B16.24 | (2011) Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 600, 900, 1500, and 2500 |
| ASME B16.26 | (2011) Standard for Cast Copper Alloy Fittings for Flared Copper Tubes |
| ASME B16.39 | (2009) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300 |
| ASME B31.1 | (2012; INT 2-6, 8-10, 13, 15, 17-25, 27-31 and 42-46) Power Piping |
| ASME B40.100 | (2005; R 2010) Pressure Gauges and Gauge Attachments |
| ASME BPVC SEC VIII D1 | (2010) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1 |
| ASME PTC 19.3 TW | (2010) Thermowells Performance Test Codes |

ASTM INTERNATIONAL (ASTM)

| | |
|---|---|
| ASTM A183 | (2003; R 2009) Standard Specification for Carbon Steel Track Bolts and Nuts |
| ASTM A536 | (1984; R 2009) Standard Specification for Ductile Iron Castings |
| ASTM B152/B152M | (2013) Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar |
| ASTM B209 | (2010) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate |
| ASTM B209M | (2010) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate (Metric) |
| ASTM B32 | (2008) Standard Specification for Solder Metal |
| ASTM B62 | (2009) Standard Specification for Composition Bronze or Ounce Metal Castings |
| ASTM B75/B75M | (2011) Standard Specification for Seamless Copper Tube |

| | |
|---|---|
| ASTM B828 | (2002; R 2010) Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings |
| ASTM B88 | (2009) Standard Specification for Seamless Copper Water Tube |
| ASTM B88M | (2005; R 2011) Standard Specification for Seamless Copper Water Tube (Metric) |
| ASTM C1048 | (2012; E 2012) Standard Specification for Heat-Treated Flat Glass - Kind HS, Kind FT Coated and Uncoated Glass |
| ASTM D2000 | (2012) Standard Classification System for Rubber Products in Automotive Applications |
| ASTM F1199 | (1988; R 2010) Cast (All Temperatures and Pressures) and Welded Pipe Line Strainers (150 psig and 150 degrees F Maximum) |

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

| | |
|---|---|
| MSS SP-110 | (2010) Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends |
| MSS SP-58 | (2009) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation |
| MSS SP-69 | (2003; Notice 2012) Pipe Hangers and Supports - Selection and Application (ANSI Approved American National Standard) |
| MSS SP-72 | (2010a) Ball Valves with Flanged or Butt-Welding Ends for General Service |
| MSS SP-80 | (2013) Bronze Gate, Globe, Angle and Check Valves |

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

| | |
|---|---|
| NEMA MG 1 | (2011; Errata 2012) Motors and Generators |

U.S. DEPARTMENT OF DEFENSE (DOD)

| | |
|---|---|
| UFC 3-310-04 | (2012) Seismic Design for Buildings |

## 1.2 SOLAR ENERGY SYSTEM

**************************************************************************

**NOTE: For systems located in an area subject to freezing, the closed-loop antifreeze system is to be used. This system requires the propylene-glycol based heat transfer fluid, two pumps, a heat exchanger, and an expansion tank. For systems at**

**locations in which freezing temperatures do not occur, the direct circulation system may be used. UFC 3-440-01 provides further information on these system types and their appropriate uses.**

**************************************************************************

a. Provide a solar energy system arranged for preheating of service (domestic and/or process) water using flat plate liquid solar collectors. Include in the system components a solar collector array, storage tank, pump[s], automatic controls, instrumentation, interconnecting piping and fittings, [uninhibited food-grade propylene-glycol and water heat transfer fluid in a closed loop], [potable water heat transfer fluid in an open loop], [heat exchanger], [expansion tank], and accessories required for the operation of the system.

b. Submit manufacturer's descriptive and technical literature; performance chart and curves; catalog cuts; and installation instructions. Proposed diagrams, instructions, and other sheets, prior to posting. A copy of the posted instructions proposed to be used, including a system schematic, wiring and control diagrams, and a complete layout of the entire system. Include with the instructions, in typed form, condensed operating instructions explaining preventive maintenance procedures, methods of checking the system for normal safe operation and procedures for safely starting and stopping the system, methods of balancing and testing flow in the system, and methods of testing for control failure and proper system operation.

c. Submit drawings containing a system schematic; a collector layout and roof plan noting reverse-return piping for the collector array; a system elevation; an equipment room layout; a schedule of operation and installation instructions; and a schedule of design information including collector height and width, recommended flow rate and pressure drop at that flow rate, and number of collectors to be grouped per bank.

d. Include on the drawings complete wiring and schematic diagrams and any other details required to demonstrate that the system has been coordinated and will properly function as a unit. Drawings shall show proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work, including clearances for maintenance and operation.

## 1.3 SUBMITTALS

**************************************************************************

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

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

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

**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

Solar Energy System
As-Built Drawings

SD-03 Product Data

Spare Parts
Solar Energy System
Welder Qualifications

SD-06 Test Reports

Inspection and Testing

SD-10 Operation and Maintenance Data

Operation and Maintenance Procedures[; G][; G[, [_____]]]

## 1.4 WELDER QUALIFICATIONS

Qualify procedures and welders in accordance with the code under which the welding is specified to be accomplished. Submit, prior to welding operations, [_____] copies of qualified procedures and lists of names and identification symbols of qualified welders and welding operators.

## 1.5 DELIVERY, STORAGE, AND HANDLING

Protect all equipment delivered and placed in storage from the weather, excessive humidity and excessive temperature variation, and dirt and dust or other contaminants.

## 1.6 WARRANTY

**************************************************************************
**NOTE: Most flat plate collector manufacturers provide a 10-year warranty. In the past, the solar energy field attracted a large number of disreputable manufacturers, many of whom were out of business long before their warranty expired. Any manufacturer that meets this collector specification should provide a quality collector that is capable of surviving the warranty.**
**************************************************************************

Provide a minimum 10-year warranty against the following: failure of manifold or riser tubing, joints or fittings; degradation of absorber plate selective surface; rusting or discoloration of collector hardware; and embrittlement of header manifold seals. Include in the warranty full repair or replacement of defective materials or equipment.

## 1.7 SPARE PARTS

Submit data for each different item of material and equipment listed, including a complete list of parts and supplies, with current unit prices and source of supply; a list of parts and supplies that are either normally furnished at no extra cost with the purchase of equipment, or specified to be furnished as part of the contract; and a list of additional items recommended by the manufacturer to ensure efficient operation for a period of 120 days.

# PART 2 PRODUCTS

**************************************************************************
**NOTE: To comply with Public Law 109-58 (Energy Policy Act of 2005) design new federal buildings to achieve energy consumption levels that are at least 30 percent below the level required by ASHRAE 90.1-2004. As a minimum, all energy consuming products and systems shall meet or exceed the requirements of ASHRAE 90.1.**
**************************************************************************

## 2.1 GENERAL EQUIPMENT REQUIREMENTS

### 2.1.1 Standard Products

Provide materials and equipment which are the standard products of a manufacturer regularly engaged in the manufacture of such products and that essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Equipment shall be supported by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

### 2.1.2 Nameplates

Each major item of equipment 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.

2.1.3   Identical Items

Items of the same classification shall be identical, including equipment, assemblies, parts, and components.

2.1.4   Equipment Guards [and Access]

Fully enclose or guard belts, pulleys, chains, gears, couplings, projecting set-screws, keys, and other rotating parts so located that any person may come in close proximity. High-temperature equipment and piping so located as to endanger personnel or where it creates a potential fire hazard shall be properly guarded or covered with insulation of a type specified. [Provide catwalk, ladder, and guard rails where shown and in accordance with Section 05 50 13 MISCELLANEOUS METAL FABRICATIONS.]

2.1.5   Special Tools

Provide one set of special tools, calibration devices, and instruments required for operation, calibration, and maintenance of the equipment.

2.2   PIPING SYSTEM

Piping system shall be complete with pipe, pipe fittings, valves, strainers, expansion loops, hangers, inserts, supports, anchors, guides, sleeves, and accessories. System materials shall conform to the following:

2.2.1   Copper Tubing

ASTM B88M ASTM B88, Type K where buried, Type L otherwise. Collector risers Type L or M.

2.2.2   Solder

**************************************************************************

**NOTE: The solders referenced are necessary for compatibility with the fluids and metals contained in solar energy systems and also required for piping containing potable water.**

**************************************************************************

ASTM B32, Type Sb5, Sn94, Sn95, or Sn96.

2.2.3   Joints and Fittings for Copper Tubing

Wrought copper and bronze solder-joint pressure fittings shall conform to ASME B16.22 and ASTM B75/B75M. Cast copper alloy solder-joint pressure fittings shall conform to ASME B16.18 and ASTM B828. Cast copper alloy fittings for flared copper tube shall conform to ASME B16.26 and ASTM B62. Brass or bronze adapters for brazed tubing may be used for connecting tubing to flanges and to threaded ends of valves and equipment. Cast bronze threaded fittings shall conform to ASME B16.15. Extracted brazed tee joints produced with an acceptable tool and installed as recommended by the manufacturer may be used. Grooved mechanical joints and fittings shall be designed for not less than 862 kPa 125 psig service and shall be the product of the same manufacturer. Grooved fitting and mechanical coupling housing shall be ductile iron conforming to ASTM A536. Gaskets for use in grooved joints shall be molded synthetic polymer of pressure responsive design and shall conform to ASTM D2000 for circulating medium up to 110 degrees C 230 degrees F. Grooved joints shall conform to AWWA C606.

Coupling nuts and bolts for use in grooved joints shall be steel and shall conform to ASTM A183.

### 2.2.4 Flanges

Bronze, Class 125 or 150 as applicable, ASME B16.24.

### 2.2.5 Dielectric Waterways and Flanges

**************************************************************************
**NOTE: Since all wetted surfaces are required to be nonferrous, the only location for dielectric waterways to be considered is the penetrations to the storage tank.**
**************************************************************************

Waterways and flanges shall conform to the requirements of ASME B16.39. Dielectric waterways shall have metal connections at both ends suited to match connecting piping. Ends shall be threaded or soldered to match adjacent piping. Dielectric waterways shall be internally lined with an insulator specifically designed to prevent current flow between dissimilar metals. Dielectric waterways and flanges shall be suitable for the temperatures, pressures, and antifreeze encountered. Dielectric flanges shall meet the performance requirements described herein for dielectric waterways.

### 2.2.6 Bronze Gate, Globe, Angle, and Check Valves

**************************************************************************
**NOTE: MSS SP-80 shows standard practice for check valves. Of the check valves listed, only the metal to metal lift check valve (Type 1) may be used. However, spring loaded check valves (also called "nonslam" check valves) are available and are similar to the lift check valve referenced. These spring loaded check valves are preferred and should be used whenever practical.**
**************************************************************************

MSS SP-80, Type 1 (or nonslam, spring type), Class 125 or 150.

### 2.2.7 Ball Valves

[MSS SP-72] [or] [MSS SP-110], Class 125 or 150.

### 2.2.8 Relief Valves, Pressure and Temperature

**************************************************************************
**NOTE: The system should be used with 862 kPa (125 psig) pressure relief and 99 degrees C (210 degree F) temperature relief whenever possible. In the event of overpressure, the pressure relief valves located at the low points in the system (usually on the expansion tank in the equipment room) should open first due to the elevation head of the system. This prevents fluid release at the collector level and serves to alert maintenance personnel of a problem.**
**************************************************************************

ANSI Z21.22/CSA 4.4. Pressure relief valves located on the solar collector array upper manifold and on the expansion tank shall open and discharge the collector fluid [into drain indicated] [into drain tank] when fluid pressure rises above 862 kPa 125 psig. Pressure and temperature relief valves located on the solar storage tank shall open and discharge water [into drain indicated] [into drain tank] when fluid pressure rises above [862] [_____] kPa [125] [_____] psig or when fluid temperature rises above [99] [_____] degrees C [210] [_____] degrees F.

2.2.9 Calibrating Balancing Valves

Calibrated balancing valves shall be suitable for 862 kPa 125 psig and 121 degrees C 250 degrees F service. Calibrated balancing valves shall be of bronze body/brass ball construction with seat rings compatible with system fluid and shall have differential readout ports across valve seat area. Readout ports shall be fitted with internal insert of compatible material and check valve. Calibrated balancing valves shall have memory stop feature to allow valve to be closed for service and reopened to set point without disturbing balance position, and shall have calibrated nameplate to assure specific valve settings.

2.2.10 Air Vents

Brass or bronze valves or cocks suitable for 862 kPa 125 psig service. Air vents shall be provided with threaded plugs or caps.

2.2.11 Strainers

ASTM F1199, removable basket and screen, Y pattern, cast iron strainer with pressures to 862 kPa 125 psig, simplex type; or a combination elbow-strainer with straightening vanes and strainer arranged for horizontal flow.

2.2.12 Pressure Gauges

ASME B40.100. Pressure gauges shall be provided with throttling type needle valve or a pulsation dampener and shutoff valve. Minimum dial size shall be 90 mm 3-1/2 inch.

2.2.13 Thermometers

ASME PTC 19.3 TW, Type I, Class 3. Thermometers shall be supplied with wells and separable bronze sockets.

2.2.14 Pipe Threads

ASME B1.20.2MASME B1.20.1.

2.2.15 Pipe Supports

MSS SP-58 and MSS SP-69. Metal insulation shield shall be stainless steel.

2.2.16 Aluminum Sheets

ASTM B209M ASTM B209, Alloy 3003.

2.2.17 Copper Sheets Copper Alloy 110

ASTM B152/B152M.

## 2.3 ELECTRICAL WORK

Electric motor-driven equipment specified shall be provided complete with motor, motor starters, and controls. Electrical equipment and wiring shall be in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Electrical characteristics shall be as specified or indicated. Motor starters shall be provided complete with thermal overload protection and other appurtenances necessary for the motor control specified. Each motor shall be of sufficient size to drive the equipment at the specified capacity without exceeding the nameplate rating of the motor. Manual or automatic control and protective or signal devices required for the operation specified, and any control wiring required for controls and devices, but not shown, shall be provided. Integral size motors shall be the premium efficiency type in accordance with NEMA MG 1.

## 2.4 COLLECTOR SUBSYSTEM

### 2.4.1 Solar Collector Construction

**************************************************************************

**NOTE: As discussed in UFC 3-440-01, the design of a solar energy system is heavily dependent on the choice of a collector. The minimum area per collector is 2.6 square meters (28 square feet) and it is important that the collector around which the system is designed be described as thoroughly as possible on the designer's drawings. Of particular interest are the length and width of the collector (for spacing and roof layout reasons), the recommended flow rate of the collector, and the rated pressure drop at that flow rate. The designer should verify that the values of the following parameters are indicated in schedules on the drawings:**

**a. Number of collectors**
**b. Gross area and net aperture area**
**c. Collector height and width**
**d. Collector fluid volume**
**e. Collector filled weight**
**f. Collector manufacturer's warranty period**
**g. Recommended collector flow rate**
**h. Pressure drop across the collector at recommended flow rate.**

**************************************************************************

Collectors shall be of the flat plate, liquid, internally manifolded type. Each collector shall be provided with cover glazing, an absorber plate, heat transfer liquid flow tubes, internal headers, weep holes, insulation, and a casing. Collectors shall be of weather-tight construction. Solar collectors shall withstand a stagnation temperature of 177 degrees C 350 degrees F and a working pressure of 862 kPa 125 psig without degrading, out-gassing, or warping. Collector net aperture area shall be as shown and shall be a minimum of 2.6 square meters 28 square feet. Collector length, width, and volume shall be as shown.

### 2.4.2 Absorber Plate and Flow Tubes

Absorber sheet or plate shall be copper. Top of absorber plate shall be coated with selective surface of black chrome and shall have an emissivity less than 0.2 and absorptivity greater than 0.9. Flow tubes shall be Type L or Type M copper, and shall be soldered, brazed, or mechanically bonded to the absorber plate. Tubes shall be installed on the absorber plate so that they drain by gravity.

### 2.4.3 Cover Glazing

Each collector shall have a single layer of cover glazing made of clear float, water white or low iron type tempered glass. Glass shall meet ASTM C1048. Cover glazing shall be completely replaceable from the front of the collector without disturbing the piping or adjacent collectors. Cover glazing shall be separated from the collector by a continuous gasket made of EPDM rubber.

### 2.4.4 Insulation

Back and sides of the absorber plate shall be insulated. Insulation shall fill space between absorber plate and casing and shall have an R value of 4 minimum. Insulation shall conform to EPA requirements in accordance with Section 01 62 35 RECYCLED/RECOVERED/BIOBASED MATERIALS and shall be fibrous glass, polyisocyanurate, urethane foam, or other material suitable for the intended purpose, and shall withstand the moisture, sun exposure, and stagnation temperature limitations of the solar collector. Polyisocyanurate insulation shall not come in contact with the absorber plate.

### 2.4.5 Casing

Casing shall be aluminum. Finish shall be mill finish or factory applied baked enamel, embossed or bronze anodized aluminum. Cover glazing shall be separated from the casing by an EPDM rubber gasket or equivalent material. Allowance shall be made for thermal expansion between the cover and absorber plates and the casing, and for drainage of moisture through weep holes.

### 2.4.6 Mounting and Assembly Hardware

Mounting brackets and hinges shall be aluminum or stainless steel. Assembly hardware including all bolts, washers, and nuts shall be stainless steel.

### 2.4.7 Solar Collector Performance

**************************************************************************

**NOTE: The maximum number of collectors per bank allowed by the manufacturer should be investigated. This number is dependent on the header and riser diameters, flow rates, and thermal expansion characteristics of the collector. It is expected that most 1.2 m (4 foot) wide collectors can be grouped into banks of at least seven, and this is the largest bank size allowed.**

**************************************************************************

Thermal performance shall be plotted on the thermal efficiency curve in accordance with ASHRAE 93. The y-intercept shall be equal to or greater than 0.68, and the numerical value of the slope of the curve (FRUL) shall be between 0 and minus 5.7 watts per square meter per degree K (0 and minus 1.0 Btu per hour per square foot per degree F) 0 and minus 1.0 Btu per hour per square foot per degree F. Manufacturer's recommended volumetric flow rate and the design pressure drop at the recommended flow rate shall be as shown. Manufacturer's recommendations shall allow at least seven collectors to be joined per bank while providing for balanced flow and for thermal expansion considerations.

## 2.5 Solar Collector Array

### 2.5.1 Net Absorber Area and Array Layout

**************************************************************************

**NOTE: The minimum array aperture area allowed for the project is that collector array area associated with the highest LCC savings by the SOLFEAS solar feasibility study computer program. The array layout should be completed according to the methods discussed in UFC 3-440-01. For flow balancing purposes, each bank must have the same number of collectors. Banks must contain between 4 and 7 collectors each. Generally, the array should follow building lines, but must keep within 20 degrees of due south. Care should be taken to distinguish between magnetic and due south for the project location. Row spacing is a function of the collector height and projection location; methodology for determining this spacing is given in UFC 3-440-01. It is imperative to proper construction of the system that the array layout be accurately shown on the drawings. Items to be shown on the drawings must include:**

**a. SOLFEAS result for minimum array size**
**b. Total array size to be installed**
**c. Bank size (4, 5, 6, or 7 collectors) and number of banks**
**d. Minimum row spacing in event of multiple rows of collection**
**e. Array orientation with respect to true south.**

**************************************************************************

Array shall consist of an assembly of solar collectors as shown with a minimum total array aperture area of [_____] square meters square feet. Solar collectors shall be assembled as shown in banks of equal number of collectors. Banks shall consist of no less than 4 and no more than 7 collectors each. Collector array shall be oriented so that all collectors face the same direction and are oriented within 20 degrees of true south and with respect to true south as indicated. Collectors arranged in multiple rows shall be spaced so that no shading from other collectors is evident between 1000 hours and 1400 hours solar time on December 21. Minimum spacing between rows shall be as shown.

### 2.5.2 Piping

**************************************************************************

**NOTE: The reverse-return strategy is important to proper array operation. Because this strategy results in what may be initially perceived by the Contractor as excess piping, it is important that the array piping be shown and indicated on the drawing as satisfying this requirement. Rules, methodology, and examples of the reverse-return strategy are given in UFC 3-440-01. Collector loop flow rate should be determined by multiplying the recommended flow rate per collector by the number of collectors to be installed. Collector headers must be located such that there is no possibility of air pockets. Items to be shown on the drawings must include:**

**a. Flow rate through collector loop based on recommended flow per collector**
**b. Reverse-return piping shown and noted**
**c. Valves, strainers, automatic controls, and all accessories**
**d. Pipe pitch for draining.**
**************************************************************************

The array piping shall include interconnecting piping between solar collectors, and shall be connected in a reverse-return configuration as indicated with approximately equal pipe length for any possible flow path. Flow rate through the collector array shall be as indicated. Automatic pressure relief valves shall be provided in the array piping system as indicated, and shall be adjusted to open when the pressure within the solar array rises above 862 kPa 125 psig. Each collector bank shall be capable of being isolated by valves, and each bank capable of being separated shall have a pressure relief valve installed and shall be capable of being drained. Manually operated air vents shall be located at system high points, and all array piping shall be pitched a minimum of 21 mm/meter 0.25 inch/foot as shown so that piping can be drained by gravity. Calibrated balancing valves shall be supplied at the outlet of each collector bank as indicated.

2.5.3 Supports for Solar Collector Array

**************************************************************************
**NOTE: The support structure for the solar array is to be constructed from aluminum to eliminate cost and maintenance of a painting system. For the majority of solar projects, this structure will be constructed as a support rack on a flat roof. Design loads for solar arrays include the filled weight of the collectors, weight of filled piping, wind, seismic and snow loads, and the weight of the support structure itself. Of these, the wind imposed on solar collector arrays may require the most attention. Provide seismic details, if a Government designer (either Corps office or A/E) is the Engineer of Record, and show on the drawings. Delete the bracketed phrase if seismic details are not provided. Pertinent portions of UFC 3-310-04 and Sections 13 48 00 and 13 48 00.00 10 must be included in the contract documents. Support structures provided by the collector manufacturer**

**may be used if they meet the stated specification.**
**************************************************************************

Support structure for collector array shall be aluminum and shall be in accordance with Section [05 50 13 MISCELLANEOUS METAL FABRICATIONS][05 50 14 STRUCTURAL METAL FABRICATIONS]. Support structure shall secure collector array at the tilt angle with respect to horizontal and orientation with respect to true south as shown. Support structure shall withstand static weight of filled collectors and piping, wind, snow, seismic, and other loads as indicated. Seismic details shall [conform to UFC 3-310-04 and Sections 13 48 00 SEISMIC PROTECTION FOR MISCELLANEOUS EQUIPMENT and 13 48 00.00 10 SEISMIC PROTECTION FOR MECHANICAL EQUIPMENT] [be as shown on the drawings]. Support structure shall allow access to all equipment for maintenance, repair, and replacement.

## 2.6 STORAGE TANK

**************************************************************************
**NOTE: Storage tank volume should be between 61 to 81 liters per square meter (1.5 to 2 gallons per square foot) of collector area. This range of acceptable values should be inserted in the blanks provided based on the array area inserted in paragraph Net Absorber Area and Array Layout. Storage volume outside of this range becomes undesirable from a system performance point of view. Items to be shown on the drawings must include:**

**a. Range of acceptable storage tank volumes**
**b. Number of liters (gallons) of storage provided per square meter (square foot) of collector area for given tank**
**c. Minimum R value of tank insulation**
**d. Type of lining in tank.**
**************************************************************************

Solar system hot water storage tank shall have a storage volume between [_____] and [_____] liters gallons and shall be as shown. Solar system storage tank shall conform to specifications for hot water storage tanks in Section 22 00 00 PLUMBING, GENERAL PURPOSE. Insulation shall be in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS, except that insulation shall have an R value of not less than 30. Tank penetrations shall be designed to allow for connections to copper piping without risk of corrosion due to dissimilar metals, and shall be factory installed as indicated.

## 2.7 TRANSPORT SUBSYSTEM

### 2.7.1 Heat Exchanger

**************************************************************************
**NOTE: Although solar energy system performance is not strongly dependent on the effectiveness of the particular heat exchanger used, it is very important to ensure that it is sized properly. Use of the approach and return temperatures stated in this paragraph ensures that the effectiveness of the heat exchanger is within acceptable limits. The hot side**

**return temperature can be less than 49 degrees C (120 degrees F) if the designer feels that the effectiveness should be greater than 0.5. When multiplate heat exchangers are used, the effectiveness can be significantly increased above 0.5 for a small increase in heat exchanger cost. Both shell-and-tube and multiplate or plate-and-frame heat exchangers are allowable for solar systems. Although the shell-and-tube exchangers are more common, multiplate heat exchangers are becoming readily available from a variety of manufacturers. The multiplate heat exchanger has the advantages over shell-and-tube of being more compact, more efficient, easier to clean, and it is commonly produced from superior materials. They can also be easily expanded to larger sizes if necessary, and many require little or no insulation. The designer should consider use of these exchangers whenever practical. Because of the wide variety of configurations used by these heat exchangers, they must often be sized by the individual manufacturers. In accordance with UFC 3-440-01, the flow rate on the storage side of the heat exchanger should be 1.25 times that on the collector side. Items to be shown on the drawings must include:**

**a. Type of heat exchanger and heat exchanger materials**
**b. Flow rates on both sides of heat exchanger**
**c. Plate or tube heat transfer area.**

**************************************************************************

The heat exchanger construction and testing shall be in accordance with ASME BPVC SEC VIII D1. Minimum design pressure rating shall be 862 kPa 125 psig. Heat exchanger shall be capable of returning a hot-side exit temperature of [49] [_____] degrees C [120] [_____] degrees F or less given a hot-side approach temperature of 60 degrees C 140 degrees F and a cold-side approach temperature of 38 degrees C 100 degrees F. Heat exchanger shall be capable of withstanding temperatures of at least 116 degrees C 240 degrees F. Heat exchanger shall be capable of operation at the flow rates as shown.

2.7.1.1 Plate Heat Exchanger

Heat exchanger shall be constructed of multiple plates of 316 stainless steel, titanium, copper, copper-nickel, or brass. Plates shall be frame-mounted, mechanically bonded, welded, or brazed at edges. Plate-type heat exchanger shall be able to be cleaned. Gaskets shall be of EPDM rubber or Viton. All plate heat exchanger characteristics shall be as indicated.

2.7.1.2 Tube-in-Shell Heat Exchanger

Heat exchanger shall be [fixed] [removable] bundle, shell-and-tube type. Shell, tube sheets, and end plates shall be constructed of nonferrous, brass, copper-nickel, or 316 stainless steel. Shell insulation shall be in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS, except that insulation shall have a minimum R value of not less than 12.

Tubes shall be seamless copper or copper alloy and shall be mechanically bonded, welded, or brazed to the end tube plates. Tubes shall be straight and supported by tube sheets which maintain the tubes in alignment. [Straight tube heat exchanger shall be arranged for mechanical cleaning.] All tube-in-shell heat exchanger characteristics shall be as indicated.

2.7.2 Pumps

Circulating pumps shall be electrically-driven, single-stage, centrifugal type. The pumps shall be supported [on a concrete foundation] [or] [by the piping on which installed]. The pumps shall have a capacity not less than that indicated and shall be either integrally-mounted with the motor or direct-connected by a flexible-shaft coupling on a cast-iron or steel subbase. The pump shaft shall be constructed of corrosion resistant alloy steel, sleeve bearings and glands of bronze designed to accommodate a mechanical seal. Pumps shall have stainless steel impellers and casings of bronze. The motors shall have sufficient power for the service required, shall be of a type approved by the manufacturer of the pump, shall be suitable for the available electric service and for the heat transfer fluid used, and shall conform to the requirements specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. The motors shall be controlled by suitable switches that can be activated by either the differential temperature controller or by manual override (Hand-Off-Automatic). Each pump suction and discharge connection shall be provided with a pressure gauge as specified.

2.7.3 Pipe Insulation

Pipe insulation and coverings shall be applied in accordance with Section 23 07 00 THERMAL INSULATION FOR MECHANICAL SYSTEMS as called out for steam piping to 103 kPa 15 psig. Array piping insulation shall be capable of withstanding 121 degrees C 250 degrees F, except that piping within 450 mm 1.5 feet of collector connections shall be capable of withstanding 204 degrees C 400 degrees F.

2.7.4 Expansion Tank

**************************************************************************

**NOTE: Care should be taken by the designer to properly size the expansion tank according to the guidance in UFC 3 440-01. This expansion tank sizing criteria requires the expansion tank to be able to accept an amount of fluid equal to the fluid volume of the collectors plus piping at the same height or above the collectors. This is in contrast to the conventional method of sizing the expansion tank to account for thermal expansion of the heat transfer fluid. The method described above allows for the large volume increase corresponding to the vaporization of fluid in the collectors during stagnation. This "oversizing" provides a fail-safe means of system pressure control during stagnation conditions, and prevents heat transfer fluid discharge by keeping the system pressure below the maximum 862 kPa (125 psig) relief value. A bladder-type expansion tank is required to separate the heat transfer fluid from the metal tank material. Use of a precharged tank allows the overall tank size to be smaller. Care should be**

**taken to ensure that the expansion tank precharge pressure is less than the fill pressure at the expansion tank. Items to be shown on the drawings must include:**

**a. Expansion tank acceptance and total volume**
**b. Expansion tank and bladder materials**
**c. Maximum relief, system cold fill, and precharge pressures.**

**************************************************************************

Expansion tank shall be constructed and tested in accordance with ASME BPVC SEC VIII D1 and as applicable for a working pressure of 862 kPa 125 psig. Tank shall be provided with an elastomeric EPDM bladder which separates the system fluid from the tank walls and is suitable for a maximum operating temperature of 116 degrees C 240 degrees F. Expansion tank acceptance volume shall be a minimum of [_____] liters gallons as shown. Total tank size and arrangement shall be as shown. Tank shall be provided with 862 kPa 125 psi pressure relief valve. Tank shall be provided with precharge pressure of [_____] kPa psi as shown.

2.7.5 Heat Transfer Fluid

**************************************************************************

**NOTE: In most instances, freezing temperatures at the project location dictate the use of an uninhibited propylene-glycol/water solution. USP/food-grade uninhibited propylene-glycol is a nontoxic, noncorrosive fluid used by the food industry, and has been approved for use with single isolation heat exchangers in closed-loop military solar energy systems by the Office of the Surgeon General (DASG) in coordination with the Toxicology Division of the Army Environmental Hygiene Agency. The concentration to be used is a function of the climate where the system is to be located. The concentration should be either 30 or 50 percent, with climates that commonly attain freezing temperatures (those above approximately 2,222 heating Kelvin days (4000 heating degree F days)) receiving the 50 percent solution. Although inhibited propylene-glycol is often used in mechanical systems, uninhibited propylene-glycol is specified for solar systems to eliminate fluid maintenance requirements. Indicate in equipment schedules on drawings the heat transfer fluid used, the concentration, and the maximum operating temperature to assure proper equipment and materials compatibility. Water should only be used as a heat transfer fluid when the direct circulation system is specified. Items to be shown on the drawings regarding the heat transfer fluid must include, if applicable:**

**a. Use of uninhibited, food-grade propylene- glycol and distilled water solution**
**b. 30 or 50 percent concentration**
**c. Note of tamper resistant seal requirement.**

**************************************************************************

[Solar collector loop fluid shall be uninhibited USP/food-grade propylene-glycol and shall be mixed with distilled or demineralized water to form a [30] [50] percent by volume propylene-glycol solution as shown]. [Solar collector loop fluid shall be potable water.]

## 2.8 CONTROL AND INSTRUMENTATION SUBSYSTEM

### 2.8.1 Differential Temperature Control Equipment

**************************************************************************

**NOTE: At the time of preparation of this specification, few manufacturers were producing controllers specifically for solar energy systems. The guidance contained in UFC 3-440-01 discusses desired diagnostic capabilities of controllers that are presently not available. As these controllers again become more widespread, it is anticipated that manufacturers will include such diagnostic capabilities. Until that time, paragraph Differential Temperature Control Equipment may be considered sufficient. The designer should check updates to this guide specification for additions or refinements to this and other equipment covered under this guidance.**

**************************************************************************

Differential temperature control equipment shall be supplied as a system by a single manufacturer. Controller shall be solid-state electronic type complete with an integral transformer to supply low voltage, shall allow a minimum adjustable temperature differential (on) of 4 to 11 degrees C 8 to 20 degrees F, a minimum adjustable temperature differential (off) of 2 to 3 degrees C 3 to 5 degrees F, and shall include a switching relay or solid state output device for pump control. Thermostat shall operate in the on-off mode. Controller accuracy shall be plus or minus 0.5 degree C 1 degree F. Controller shall be compatible with 10-kOhm thermistor temperature sensors. Differential control shall provide direct digital temperature readings of all temperatures sensed. Control shall indicate visually when pumps are energized. Control ambient operating range shall be a minimum of 0 to 49 degrees C 32 to 120 degrees F.

### 2.8.2 Thermistor Temperature Sensors

Temperature sensors shall be 10-kOhm thermistors supplied by the differential temperature controller manufacturer, with an accuracy of plus or minus 1 percent at 25 degrees C 77 degrees F. Model supplied must have passed an accelerated life test conducted by subjecting thermistor assemblies to a constant temperature of 204 degrees C 400 degrees F or greater for a period of 1000 hours minimum. Accuracy shall have remained within plus or minus 1 percent as stated above. Thermistors shall be hermetically sealed glass type. Operating range shall be minus 22 to plus 204 degrees C minus 40 to plus 400 degrees F. Immersion wells or watertight threaded fittings shall be provided for temperature sensors.

### 2.8.3 Sensor and Control Wiring

18 AWG minimum twisted and shielded 2, 3, or 4 conductor to match analog function hardware. Control wiring shall have 600 volt insulation. Multiconductor wire shall have an outer jacket of PVC.

2.8.4 Flowmeters

**************************************************************************
**NOTE: Venturi pressure differential is dependent on the flow rates to be measured. System flow rates are dependent on recommended collector flow rates. UFC 3 440-01 and paragraphs Piping and Heat Exchanger should be used to determine both the collector side and storage side flow rates.**
**************************************************************************

Flowmeters shall consist of a venturi, 150 mm 6 inch dial differential pressure meter, valved pressure taps, and bar stock needle valves. Venturi flow nozzle shall have threaded bronze ends for pipe sizes up to 50 mm 2 inches and flanged ends for pipe sizes 65 mm 2-1/2 inches and above. Venturi length shall not be less than 1.6 times the pipe size. Venturi shall be selected to read differential pressure corresponding to 0.5 to 1.5 times the system flow rate. Venturi shall have an accuracy of plus or minus 1 percent of the range. Meter shall have an accuracy of plus or minus 2 percent of the full scale range.

2.8.5 Sight Flow Indicators

Sight flow indicators shall consist of a clear glass window or cylinder and a nonferrous or 316 stainless steel body and impeller. Indicator shall have threaded ends for pipe sizes up to 50 mm 2 inches and flanged ends for pipe sizes 65 mm 2-1/2 inches and above. Maximum operating pressure shall be no less than 862 kPa 125 psi. Maximum operating temperature shall be no less than 121 degrees C 250 degrees F.

2.9 PAINTING AND FINISHING

Equipment and component items, when fabricated from ferrous metal and located inside the building, shall be factory finished with the manufacturer's standard finish.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming thoroughly 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.

3.2 INSTALLATION

3.2.1 Collector Subsystem

3.2.1.1 Collector Array

**************************************************************************
**NOTE: UFC 3-440-01 discusses installation design guidelines for solar collector arrays. The tilt angle of the collectors off horizontal should be near the site latitude within plus or minus 10 degrees. Items to be shown on the drawings with regard to the installation of the array must include:**

**a. Tilt angle of collectors from horizontal**
**b. Elevation of bottom or back of collectors off of flat or pitched roof**
**c. Location and elevation of piping with regard to array supply and return.**
**************************************************************************

Solar collector array shall be installed at the tilt angle, orientation, and elevation above roof as indicated. [For installation on flat roofs with rack type collector mounting or for ground mounted collectors, bottom of collector shall be a minimum of 450 mm 18 inches from roof or ground surface.] [For mounting on pitched roofs, back of collectors shall be installed a minimum of 50 mm 2 inches above roof surface.] Each solar collector shall be removable for maintenance, repair, or replacement. Solar collector array shall not impose additional loads on the structure beyond the loads scheduled on the structural drawings.

3.2.1.2 Array Piping

Collector array piping shall be installed in a reverse-return configuration so that path lengths of collector supply and return are of approximately equal length. All piping must be coded with fluid type and flow direction labels in accordance with Section 09 90 00 PAINTS AND COATINGS.

3.2.1.3 Array Support

Array support shall be installed in accordance with the recommendations of the collector manufacturer. Structural members requiring welding shall be welded in accordance with AWS D1.2/D1.2M for aluminum and welders should be qualified according to AWS B2.1/B2.1M.

3.2.2 Storage Subsystem

Solar storage tank penetrations shall be installed as shown so that cold water inlet to storage tank and outlet from storage tank to collector array are located near the bottom of the tank, and inlet from collector array and outlet to load are located near the top of the tank.

3.2.3 Transport Subsystem

3.2.3.1 Flow Rates

**************************************************************************
**NOTE: The reverse-return strategy is important to proper array operation. Because this strategy results in what may be initially perceived by the Contractor as excess piping, it is important that the array piping be shown and indicated on the drawing as satisfying this requirement. Rules, methodology, and examples of the reverse-return strategy are given in UFC 3 440-01. Collector loop flow rate should be determined by multiplying the recommended flow rate per collector by the number of collectors to be installed. Collector headers must be located such that there is no possibility of air pockets. Items to be shown on the drawings must include:**

**a. Flow rate through collector loop based on**

recommended flow per collector
b. Reverse-return piping shown and noted
c. Valves, strainers, automatic controls, and all accessories
d. Pipe pitch for draining.

**Although solar energy system performance is not strongly dependent on the effectiveness of the particular heat exchanger used, it is very important to ensure that it is sized properly. Use of the approach and return temperatures stated in this paragraph ensures that the effectiveness of the heat exchanger is within acceptable limits. The hot side return temperature can be less than 49 degrees C (120 degrees F) if the designer feels that the effectiveness should be greater than 0.5. When multiplate heat exchangers are used, the effectiveness can be significantly increased above 0.5 for a small increase in heat exchanger cost. Both shell-and-tube and multiplate or plate-and-frame heat exchangers are allowable for solar systems. Although the shell-and-tube exchangers are more common, multiplate heat exchangers are becoming readily available from a variety of manufacturers. The multiplate heat exchanger has the advantages over shell-and-tube of being more compact, more efficient, easier to clean, and it is commonly produced from superior materials. They can also be easily expanded to larger sizes if necessary, and many require little or no insulation. The designer should consider use of these exchangers whenever practical. Because of the wide variety of configurations used by these heat exchangers, they must often be sized by the individual manufacturers. In accordance with UFC 3-440-01, the flow rate on the storage side of the heat exchanger should be 1.25 times that on the collector side. Items to be shown on the drawings must include:**

**a. Type of heat exchanger and heat exchanger materials**
**b. Flow rates on both sides of heat exchanger**
**c. Plate or tube heat transfer area.**
**************************************************************************

[Flow rate in the collector loop shall be based on recommended collector flow rate, and shall be as shown. Storage loop flow rate shall be 1.25 times the collector loop flow rate.] [System flow rate shall be based on recommended collector flow rate, and shall be as indicated.] All flow rates shall be below 1.5 meters/second 5 feet/second.

3.2.3.2 Pumps

[Pumps shall be installed on foundations, leveled, grouted, and realigned before operation in accordance with manufacturers instructions.] [Additional pipe supports shall be provided for close-coupled in-line pumps.] [All base mounted pumps shall have a straight pipe between the suction side of the pump and the first elbow. The length of this pipe shall be a minimum of five times the diameter of the pipe on the suction side of the pump, or a suction diffuser of the proper size shall be attached to the suction side of the pump.] [All in-line pumps shall have straight pipe between the suction side of the pump and the first elbow. The length of this pipe shall be a minimum of five times the diameter of the pipe size on the suction side of the pump.] Drain line sizes from the pumps shall not be less than the drain trap or the pump dirt pocket, but in no case shall the drain line be less than 13 mm 1/2 inch iron pipe size. Drain lines shall terminate to spill over the nearest floor or open sight drain.

3.2.3.3 Expansion Tank

Expansion tank shall be installed on suction side of pump as shown.

3.2.3.4 Piping, Valves, and Accessories

**************************************************************************

**NOTE: In most instances, freezing temperatures at the project location dictate the use of an uninhibited propylene-glycol/water solution. USP/food-grade uninhibited propylene-glycol is a nontoxic, noncorrosive fluid used by the food industry, and has been approved for use with single isolation heat exchangers in closed-loop military solar energy systems by the Office of the Surgeon General (DASG) in coordination with the Toxicology Division of the Army Environmental Hygiene Agency. The concentration to be used is a function of the climate where the system is to be located. The concentration should be either 30 or 50 percent, with climates that commonly attain freezing temperatures (those above approximately 2,222 heating Kelvin days (4000 heating degree F days)) receiving the 50 percent solution. Although inhibited propylene-glycol is often used in mechanical systems, uninhibited propylene-glycol is specified for solar systems to eliminate fluid maintenance requirements. Indicate in equipment schedules on drawings the heat transfer fluid used, the concentration, and the maximum operating temperature to assure proper equipment and materials compatibility. Water should only be used as a heat transfer fluid when the direct circulation system is specified. Items to be shown on the drawings regarding the heat transfer fluid must include, if applicable:**

**a. Use of uninhibited, food-grade propylene- glycol and distilled water solution**
**b. 30 or 50 percent concentration**
**c. Note of tamper resistant seal requirement.**

**************************************************************************

Piping shall be installed in accordance with Section 22 00 00 PLUMBING, GENERAL PURPOSE, except where noted otherwise. Solders used on piping shall be as shown. Piping shall be coded with fluid type and flow direction labels in accordance with Section 09 90 00 PAINTS AND COATINGS. When a food-grade uninhibited propylene-glycol solution is used to heat potable service water, tamper resistant seals must be attached to all fill ports. All propylene-glycol circuits must be labeled "CONTAINS UNINHIBITED FOOD-GRADE PROPYLENE-GLYCOL: INTRODUCTION OF ANY NONAPPROVED FLUID MAY CONSTITUTE A HEALTH HAZARD." All tamper resistant seals must carry the name of the registered engineer or licensed plumber who certifies that only a [30] [50] percent food-grade uninhibited propylene-glycol and water solution has been installed in the system. Air vents shall be installed at the high points of the collector array and in the equipment room.

#### 3.2.3.5 Pipe Expansion

Expansion of supply and return pipes shall be provided for by changes in the direction of the run of pipe or by expansion loops as indicated. Expansion loops shall provide adequate expansion of the main straight runs of the system within the stress limits specified in ASME B31.1. Loops shall be cold-sprung and installed where indicated. Pipe guides shall be provided as indicated. Expansion joints shall not be used in system piping.

#### 3.2.3.6 Valves

**************************************************************************

**NOTE: Calibrated balancing valves are required at the outlet of each bank in addition to the ball valve required at this outlet. If the reverse-return piping strategy is properly adhered to, this valve may prove unnecessary. It is specified, however, to allow the array to be flow balanced in the event of improper construction or modification of the array at some later time. The ball valves are required to enable the array to be disconnected for maintenance or repair. Check valves at pump discharges are required to prevent back flow into pumps and are required on the collector loop to prevent fluid cooled in the collectors at night from migrating around the loop to the heat exchanger.**

**************************************************************************

Valves shall be installed at the locations indicated and where required for the proper functioning of the system. Valves shall be installed with their stems horizontal or above. Gate or ball valves shall be installed at the inlet and outlet of each bank of internally manifolded collectors. Calibrated balancing valves with integral pressure taps shall be installed at the outlet of each bank and at the pump discharge. Final setting for each valve shall be marked on each valve. Ball valves shall be installed with a union immediately adjacent. Gate valves shall be installed at the inlet and outlet of each pump and also at the inlet and outlet of each heat exchanger. A check valve shall be installed at pump discharges. Discharges of relief valves shall be piped to the nearest floor drain or as indicated on system drawings.

#### 3.2.3.7 Foundations

Concrete foundations or pads for storage tanks, heat exchangers, pumps, and other equipment covered by this specification shall be constructed in accordance with manufacturer's recommendations and be a minimum of 150 mm 6 inches high with chamfered edges.

3.2.3.8   Grooved Mechanical Joints

Grooves shall be prepared according to the coupling manufacturer's instructions. Grooved fittings, couplings, and grooving tools shall be the products of the same manufacturer. Pipe and groove dimensions shall comply with the tolerances specified by the coupling manufacturer. The diameter of grooves made in the field shall be measured using a "go/no-go" gauge, vernier or dial caliper, narrow-land micrometer, or other method specifically approved by the coupling manufacturer for the intended application. Grooved width and dimension of groove from end of pipe shall be measured and recorded for each change in grooving tool setup to verify compliance with the coupling manufacturer's tolerances. Grooved joints shall not be used in concealed locations.

3.2.4   Control Subsystem

3.2.4.1   Differential Temperature Controller

Automatic control equipment shall be installed at the location shown in accordance with the manufacturer's instructions. Control wiring and sensor wiring shall be installed in conduit. [Collector temperature sensor shall be mounted in a temperature sensor well in the fluid stream along the top manifold of a bank between two adjacent collector units.] [Collector temperature sensor shall be provided by differential temperature controller manufacturer and mounted directly on the absorber plate by the manufacturer.] Unless otherwise indicated, operators, controllers, sensors, indicators, and like devices when installed on equipment casings and pipe lines shall be provided with stand-off mounting brackets, bases, nipples, adapters, or extended tubes to provide clearance, not less than the thickness of the insulation, between the surface and the device. These stand-off mounting items shall be integral with the devices or standard accessories of the controls manufacturer unless otherwise approved. Clamp-on devices or instruments where direct contact with pipe surface is required shall be exempted from the use of the above mounting items. All control wiring shall be color coded and identified with permanent numeric or alphabetic codes.

3.2.4.2   Sequence of Operation

**************************************************************************

**NOTE: The following on/off set differentials are common for liquid systems:**

**Pump on = 7 to 11 degrees C (12 to 20 degrees F).**
**Pump off = 2 to 4 degrees C (3 to 8 degrees F).**

**************************************************************************

The differential temperature controller sensing temperature difference between the fluid in a solar collector and water in the storage tank shall start solar collector loop [and storage loop] pumps[s] when the temperature differential (Delta T - ON) rises above [8] [_____] degrees C [15] [_____] degrees F, and shall stop the pump when the differential (Delta T - OFF) falls below [3] [_____] degrees C [5] [_____] degrees F.

3.3   INSPECTION AND TESTING

Submit an independent testing agency's certified reports of inspections and laboratory tests, including analysis, position of flow-balancing equipment, and interpretation of test results. Each report shall be properly identified. Describe test methods used and compliance with recognized test standards.

### 3.3.1 Inspection

Make system available for inspection at all times.

### 3.3.2 Testing Prior to Concealment

#### 3.3.2.1 Hydrostatic Test

Demonstrate to Contracting Officer that all piping has been hydrostatically tested, at a pressure of 862 kPa 125 psi for a period of time sufficient for inspection of every joint in the system and in no case less than 2 hours, prior to installation of insulation. Expansion tank and relief valves shall be isolated from test pressure. No loss of pressure shall be allowed. Leaks found during tests shall be repaired by replacing pipe or fittings and the system retested. Caulking of joints shall not be permitted.

#### 3.3.2.2 Cleaning of Piping

System piping shall be flushed with clean, fresh water prior to concealment of any individual section and prior to final operating tests. Prior to flushing piping, relief valves shall be isolated or removed. Solar collectors shall be covered to prevent heating of cleaning fluid, unless cleaning is performed during hours of darkness. The solution shall be circulated through the section to be cleaned at the design flow rate for a minimum of 2 hours.

### 3.3.3 Posting Framed Instructions

Framed instructions under glass or in laminated plastic shall be posted where directed. These instructions shall include a system schematic, and wiring and control diagrams showing the complete layout of the entire system. Condensed operating instructions explaining preventative maintenance procedures, balanced flow rates, methods of checking the system for normal safe operation, and procedures for safely starting and stopping the system shall be prepared in typed form, framed as specified above, and posted beside the diagrams. Proposed diagrams, instructions, and other sheets shall be submitted for approval prior to posting. The framed instructions shall be posted before acceptance testing of the system.

### 3.3.4 Acceptance Testing and Final Inspection

Notify the Contracting Officer 7 calendar days before the performance and acceptance tests are to be conducted. Tests shall be performed in the presence of the Contracting Officer. Furnish all instruments and personnel required for the tests. Electricity and water will be furnished by the Government. A written record of the results of all acceptance tests shall be maintained, to be submitted in booklet form. The tests shall be as follows:

#### 3.3.4.1 As-Built Drawings

Submit, as a condition of final acceptance, a complete set of as-built system drawings. Drawings shall clearly indicate the actual condition of the installed solar energy system at the time of the final test.

3.3.4.2 Final Hydrostatic Test

Demonstrate to Contracting Officer that all piping has been hydrostatically tested at a pressure of 862 kPa 125 pounds per square inch for a period of time sufficient for inspection of every joint in the system and in no case less than 2 hours. Expansion tank and relief valves shall be isolated from test pressure. Gauges used in the test shall have been calibrated within the 6-month period preceding the test. Test shall be witnessed by Contracting Officer. No loss of pressure shall be allowed. Leaks found during tests shall be repaired by replacing pipe or fittings and the system retested. Caulking of joints shall not be permitted.

3.3.4.3 System Flushing

For the final inspection, the system shall be thoroughly flushed, in no case for less than 2 hours,of all foreign matter until a white linen bag installed in a strainer basket shows no evidence of contamination. The white linen bag shall be in the strainer basket during the entire flushing operation prior to its being presented to the Contracting Officer for approval. The Contracting Officer will inspect the linen bag prior to completion of flushing and approve the flushing operation. System shall be drained prior to final filling.

3.3.4.4 System Filling

System shall be filled through indicated connections with [propylene-glycol solution. Solution shall be mixed externally to the solar system and consist of [30] [50] percent propylene-glycol and [70] [50] percent distilled water by volume] [distilled water]. Air shall be vented from the system after filling. System pressure at the high point on the roof shall be 69 kPa 10 psig minimum.

3.3.4.5 Operational Test

Operational test shall occur over a period of 48 consecutive hours with sufficient solar insulation to cause activation of the solar energy system during daylight hours. With system fully charged so that pressure at the high point on the roof or the lowest system pressure is a minimum of 69 kPa 10 psig and with fluid and pump[s] energized, [sight flow indicator must indicate flow] [flowmeter must indicate flow as indicated]. Calibrated balancing valves with pressure taps shall indicate bank flow rate as shown.

3.3.4.6 Control Logic

**************************************************************************

**NOTE: The following on/off set differentials are common for liquid systems:**

**Pump on = 7 to 11 degrees C (12 to 20 degrees F).**
**Pump off = 2 to 4 degrees C (3 to 8 degrees F).**

**************************************************************************

By substituting variable resistors for collector and storage tank temperature sensors, demonstrate the differential temperature controller correctly energizes the system pump[s] when the collector sensor indicates a temperature of [8] [_____] degrees C [15] [_____] degrees F greater than the storage tank temperature, as indicated on the controller display panel. The differential temperature controller shall de-energize the system pump[s] when the displayed temperature of the solar collectors is

[3] [_____] degrees C [5] [_____] degrees F greater than the displayed temperature of the storage tank.

3.3.4.7 Temperature Sensor Diagnostics

Demonstrate that the controller will correctly identify open and short circuits on both the solar collector temperature sensor circuit and the storage tank sensor circuit.

3.3.4.8 Overall System Operations

Demonstrate that the solar energy system will operate properly while unattended for a period of at least 72 hours and that the controller will start pump[s] after being warmed by the sun, and that it will properly shut down during cloudy weather or in the evening over a minimum of three complete cycles. Contractor is permitted to manipulate the temperature of the storage tank by the introduction of cold water at local groundwater temperature.

## 3.4 FIELD TRAINING

Provide a field training course for designated operating and maintenance staff members. Training shall be provided for a minimum period of [_____] hours of normal working time and shall start after the system is functionally complete but prior to final acceptance tests. The training shall include discussion of the system design and layout and demonstrations of routine operation and maintenance procedures. This training shall include: normal system operation and control; flow balancing; detection of a nonfunctioning system due to sensor, controller, and/or mechanical failure; filling, draining, and venting of the collector array; replacement of sensors, collectors, and collector components; collector cleaning and inspection for leaks; and heat exchanger cleaning and expansion tank charging if applicable. Submit [6] [_____] copies of operation and [6] [_____] copies of maintenance manuals for the equipment furnished. One complete set prior to performance testing and the remainder upon acceptance. Manuals shall be approved prior to the field training course. Operating manuals shall detail the step-by-step procedures required for system filling, startup, operation, and shutdown. Operating manuals shall include the manufacturer's name, model number, service manual, parts list, and brief descriptions of all equipment and their basic operating features. Maintenance manuals shall list routine maintenance procedures, possible breakdowns and repairs, troubleshooting guides, piping and equipment layout, balanced fluid flow rates, and simplified wiring and control diagrams of the system as installed.

-- End of Section --