DOE/NASA CONTRACTOR REPORT

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OCMULGEE NATIONAL MONUMENT VISITOR CENTER SOLAR HEATING AND COOLING SYSTEM DESIGN REVIEW DATA

Prepared by

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16. ABSTRACT

This document has been prepared as a part of the detailed design of the solar heating and cooling system to be installed at the Ocmulgee National Monument Visitor Center. It describes the 50 percent design review data for this site, and discusses the design approaches, system trade studies, subsystem design and development approach, solar collectors, preliminary specifications and other related information.

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FOREWARD

Honeywell was awarded Contract NAS8-32093 by the George C. Marshall Space Flight Center (MSFC) effective 9 July 1976.

The program calls for the development and delivery of eight (was 12) prototype solar heating and cooling systems for installation and operational test. Two (was 6) heating and six heating and cooling units will be delivered for sinlge-family residences (SFR), multiple-family residences (MFR) and commercial applications.

Lennox Industries, Marshalltown, Iowa, and Barber-Nichols Engineering Company, Arvada, Colorado, are supporting Honeywell in subcontractor roles.

This document has been prepared as a part of the detailed design of the heating and cooling system to be installed at the Ocmulgee National Monument Visitor Center. This document describes the 50 percent design review data for the above site.

CONTENTS

SECTION 1
INTRODUCTION

The Ocmulgee National Monument Visitor Center has been selected as an Operational Test Site for the Solar Heating and Cooling Systems Design and Development Program administered by the NASA George C. Marshall Space Flight Center.

The following data has been taken from several documents previously published for this program, including the Heating/Cooling Systems Preliminary Design Review. This document will serve to acquaint National Park Service officials with this Solar Heating and Cooling Program as well as present the 50 percent design review data as required by the NPS.

SECTION 2

SOLAR HEATING AND COOLING PROGRAM DESCRIPTION

2.1 DESIGN APPROACHES

Honeywell's approach to the selection of solar heating and cooling systems is illustrated in Figure 2-1. Primarily, the approach consists of two parallel efforts: identification of all candidate solar heating and cooling subsystem components, and identification of subsystem constraints or evaluation criteria. The next step, preliminary subsystem selection, is designed to narrow the list of candidate subsystem components, using the defined constraints. The major components for system selection were collector type, storage medium, cooling subsystem, and auxiliary cooling method.

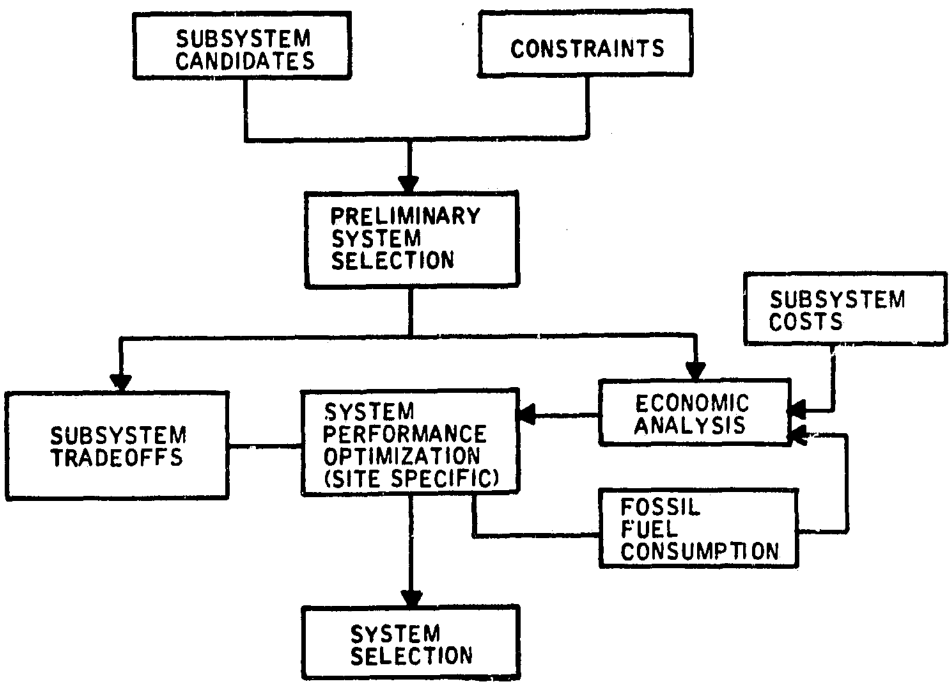


Figure 2-1. System Selection Flow Chart

The next step in system selection incorporates subsystem tradeoffs and economic tradeoffs to further reduce the number of workable and economically desirable systems. The subsystems or subsystem components upon which tradeoffs are examined are the following:

- Collector
- Storage
- Refrigeration section
- Rankine power section
- Auxiliary energy
- Working fluids
- Supplementary elements such as controls, piping, pumps, and heat exchangers

The economic analysis is made using methods which try to establish the most economical solar system.

The solar system performance is determined using Honeywell's Solar Systems Simulation Program including a Rankine Model. The economic analysis technique is used in conjunction with the simulation program to optimize the selected systems for the designated area and application.

Constraints and Design Criteria

Constraints or evaluation criteria have been selected for purposes of performing preliminary and detailed tradeoffs of subsystem components. These include the following:

- Modularity -- Subsystem components that are of standard design and size that can be put together to achieve the desired capability. An example that meets this constraint is the flat-plate collector panel, a component of standard size that can be combined to create any desired collector area and the 25-ton Rankine engine, a standard subsystem size that can be combined for larger cooling loads.

- Scalability -- A subsystem component of standard design that can provide a progressive increase in capability by changing some of the components of that subsystem. An example of this type of subsystem component is the standard home furnace, the output capability of which can be increased by scaling burners and blower motor.

- Architectural Aspects -- Includes interface of solar heating systems on a building (especially collectors), impact on construction, and aesthetic qualities.

- Fuel Type Availability -- Assurance that local utilities will provide the type and amounts of fuel required.

- Economic Aspects -- Costs of procurement, installation, maintenance, and operation.

- Development Risks -- Availability of components within required time-frame, including subsystem design maturity.

- Maintainability -- Skill, knowledge, and training required to maintain system.

- Reliability -- Confidence in assuring continued system operation life cycle.

- Safety -- Safety of operation and use of system.

- Control Philosophy -- Control of solar heating system to use needed energy directly from collector or storage. Store excess energy and use auxiliary energy when required.

Preliminary Subsystem Component Selection

The preliminary subsystem selection is designed to narrow the list of subsystem candidates for final consideration. By using the constraints identified, advantages and disadvantages of each subsystem component are examined with respect to these constraints. Relative strengths and weaknesses are identified, and components can be ranked with respect to each other.

Subsystem candidates include all those solar heating and cooling system components that could be used to design heating systems. Baseline candidate subsystem components identified at the heating PDR are listed in Table 2-1. The table includes the cooling baseline subsystem components. Subsystem candidates are categorized by collectors, storage, auxiliary heating subsystems, working fluid, supplementary elements, solar power, air conditioning and auxiliary cooling subsystems.

It is evident that collectors, storage subsystems, and the cooling subsystem are the three most critical elements of heating system designs. Other subsystems, such as space heat, domestic hot water and controls, are easily defined after the selection of these primary subsystems.

Table 2-1. Subsystem Component Candidates

Subsystem	Component
Collector	• Liquid flat plate
Thermal storage media	• Water
Auxiliary heating subsystems	• Fossil-fueled forced-air furnace • Fossil-fueled hydronic boiler • Heating-only heat pumps (optional)
Working fluids	• Water/ethylene glycol • Water
Supplementary elements	• Fans • Ducts • Controls • Piping • Pumps
Solar power subsystem	• Rankine power cycle
Air conditioning subsystem	• Direct expansion • Water chillers
Auxiliary cooling subsystem	• Electric motor

2.2 SYSTEM TRADE STUDIES

A methodology for a comparison of solar-assisted heating and cooling system concepts has been established. The methodology or approach allows a complete examination of the solar system and subsystem candidates. Studies include variation in the key parameters that influence solar heating and cooling systems cost and performance. A systems simulation program was used to analyze the solar systems cost and/or performance as a result of variations in the key parameters.

The system tradeoff methodology is shown schematically in Figure 2-2.

The criteria for selection of a solar heating and cooling system configuration will be the following:

- Minimum annual cost for conventional energy consumption.
- Reasonable mix of solar energy contribution to the building's cooling, heating, and hot water loads.
- Reasonable system payback
- Acceptable system safety
- System development risks
- Architectural considerations

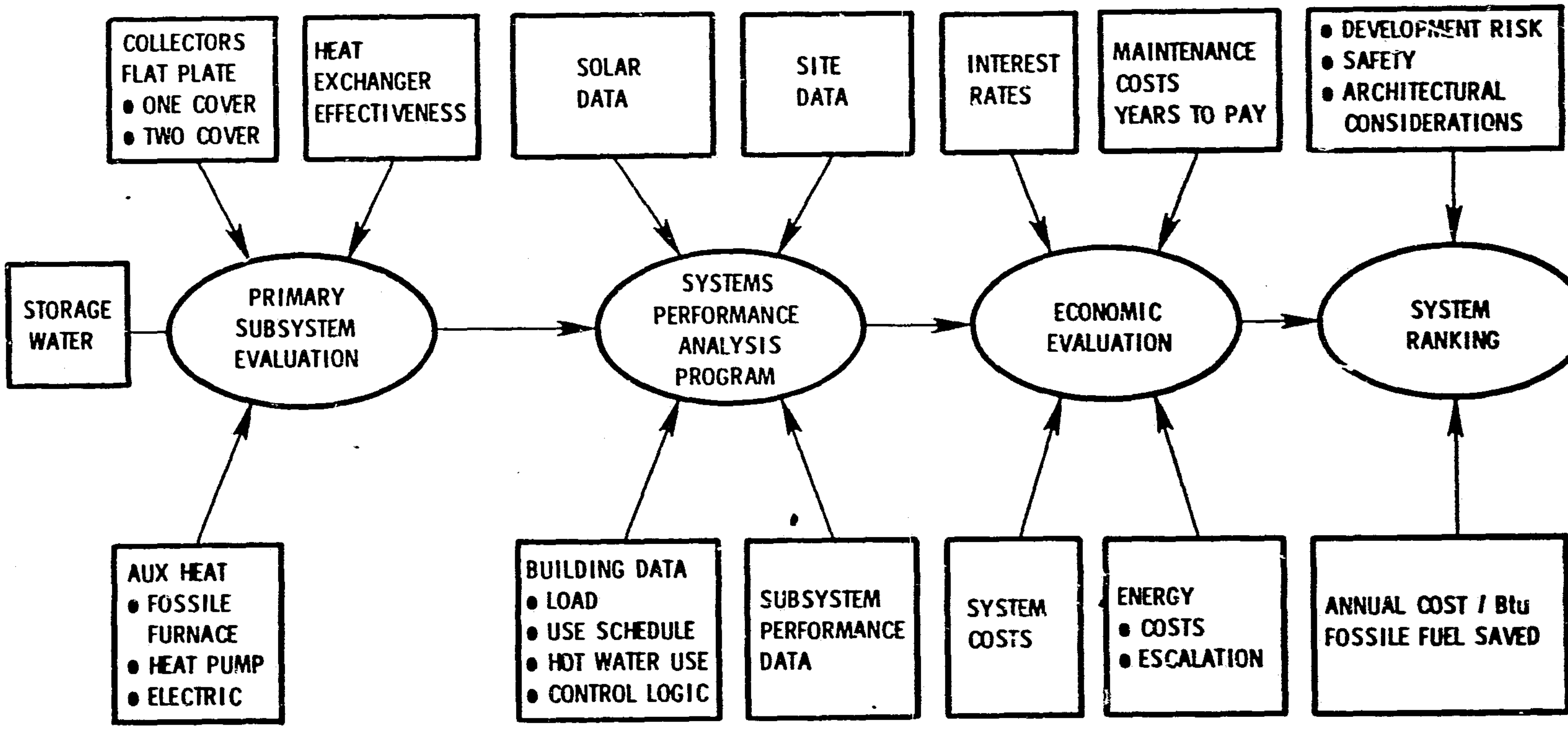


Figure 2-2. System Tradeoff Flow Chart

The prediction of the performance and economics of a solar heating and cooling system is based on a simulation analysis using recorded weather data and calculated incident solar energy as modified by cloud cover data. The system is simulated by a digital computer code on an hour-by-hour basis. The weather data is read from U.S. Weather Service magnetic tapes purchased from the National Weather Service in Asheville, N.C. The information includes ambient wet and dry bulb temperatures, wind speed, dew point, cloud cover, day, and time of day data.

The incident solar flux is calculated by an ASHRAE subroutine called SUN and modified by hourly local cloud cover data read from the weather tape. The heating and cooling system design conditions are based on the requirements outlined in Interim Performance Criteria for Solar Heating and Combined Heating and Cooling Systems and Dwellings (IPC).

A simulation analysis is performed for each specific site building and system. Building characteristic data is as follows:

- Building envelope areas and "U" values
- Building orientation
- Building use schedule
- Internal heat gain
- Characteristics of solar heating and cooling system

2.3 SUBSYSTEM DESIGN AND DEVELOPMENT APPROACH

The solar heating and cooling system will consist of the following subsystems:

- Collectors
- Energy Storage
- Space Heating
- Auxiliary Heating
- Energy Transport
- Controls
- Cooling
- Site Data Acquisition
- Collector Support Structure

The design of each subsystem is based on requirements imposed by each of the other subsystems with the final goal being the optimum system for the specific site involved.

A brief review of each subsystem is as follows.

2.3.1 Collectors

The collector subsystem is a product which is presently being manufactured by Lennox Industries. The collectors are modular, suitable for retrofit or new construction, and can be combined to provide any subsystem size. It was also recognized that a study of possible flow configurations for various collector arrays should be made. Of concern is the possibility of nonuniform flow in the collector arrays which can lead to serious degradation of performance. A simulation program was developed from which guidelines will be established to determine the number, size, and arrangement of the collector modules and supply and return headers in the collector arrays. The results of this study will be used to design the collector arrays.

2.3.2 Energy Storage Subsystem

The collected solar energy which cannot be used for space heating or domestic hot-water heating at the time of its availability will be stored in the solar storage water tank. The stored energy would be available for future use (e.g., at night or on cloudy days).

2.3.3 Space Heating Subsystem

See Section 3.

2.3.4 Auxiliary Heating Subsystem

See Section 3.

2.3.5 Energy Transport Subsystem

The energy subsystem consists of components necessary to ensure that subsystem components interface with one another and that necessary components are supplied for safe and efficient operation of the system. The following components are included in the transport subsystem:

- Piping sized for the system and site
- Expansion tank with fittings, ASME-rated
- Air separator and pressure-relief valves, ASME-rated
- Flow control devices with flowmeters
- Circulating pumps, centrifugal with machinable impellers
- Tube-and-shell heat exchanger
- Purge coil for dissipating excessive solar energy

The collector loop will be a pressurized loop containing an anti-freeze solution of ethylene glycol and water, having the following properties:

- Stability over wide temperature range
- Low coefficient of thermal expansion. If the aqueous-glycol solution undergoes complete freeze-up, upon thawing it will not crack the container.
- Noncorrosivity with inhibitor additives
- Completely nonflammable when above 20 percent aqueous solution
- Extremely low toxicity
- Annual check of the solution inhibitor level is normally required.

2.3.6 Controls Subsystem

The control subsystem design is based on the overall system definition that includes related subsystems such as collectors, solar storage, energy transport, and auxiliary heating/cooling. Control logic is determined so that solar energy is collected and used to minimize the consumption of conventional energy while maintaining conditions in the space consistent with the type and duration of occupancy. Through engineering analysis, operating modes that could be hazardous or lead to discomfort are eliminated. The heating or cooling system demand for energy is satisfied by using solar energy before adding conventional energy required to satisfy the load. Interrelated subsystems that affect the operating efficiency of other subsystems are also analyzed. This analysis determines a control logic that leads to a higher overall system efficiency. For example, if stored energy is higher than collected energy, the control subsystem prevents dissipation of the stored energy into the collector subsystem.

The control logic is used to design a control schematic of the subsystem and to determine the operating temperatures, pressure, flow, and differential-temperature requirements of the system. This information is then used to determine component requirements. The component requirements are then used to establish availability of off-the-shelf deliverables and items requiring complete component development. Off-the-shelf deliverable controls would include standard thermostats, control valves, motor operators and linkages, switching and time-delay relays, time clocks, etc. These are all standard components as used in the HVAC industry.

The differential-temperature controller is also a standard production item. This controller, when used with the proper resistor sensors, is designed as a module capable of providing a variety of automatic control functions in the switching of circulating pumps, valves, dampers, motors, and other accessories used in solar control systems. It has a solid-state differential amplifier with a two-pole switching relay. Control functions can be modified by changing the connections of the differential resistors, setpoint resistors, and resistor sensors. This module can be used as a:

- Differential-temperature control (relay makes on temperature differential rise)
- Setpoint temperature control (relay makes on temperature rise)
- Setpoint temperature control (relay makes on temperature drop)

The differential-temperature controller has the following design features:

- Modular construction (one basic module provides a variety of solar control functions)
- Solid-state differential amplifier
- Two-pole switching relay (one N.O. and one N.C. isolated contacts)
- Integral transformer for powering the low voltage control circuit
- Internal terminal stripe for line-voltage connections
- Internal terminal strip with screw terminals for low-voltage connections
- Plug-in differential resistors
- Mounts in any position on a standard 4 x 4-inch junction box
- Interchangeable resistor sensors

A central control panel for overall system control will be provided.

2.3.7 Cooling Subsystem

The cooling subsystem consists of the Rankine Cycle Chiller providing chilled water to the conventional HVAC system. The Rankine Cycle Chiller consists of a Rankine engine, powered by solar heated fluid, driving an open-type water chiller.

2.3.7.1 Operation -- The cooling subsystem consists of two distinct thermodynamic portions, the Rankine-cycle (R/C) power loop and the air-conditioning (A/C) loop. The combined RC/AC subsystem is shown schematically in Figure 2-3.

In the Rankine cycle, working fluid is pumped from a water-cooled condenser through a regenerator to the boiler, which extracts heat from solar collector water. The regenerator is a liquid-to-vapor performance improvement heat exchanger operating within the R/C loop. Vapor leaving the boiler is admitted to nozzles which feed a turbine rotor. Turbine exhaust vapor passes through the vapor side of the regenerator and returns to the condenser, completing the Rankine cycle.

Turbine rotational speed is reduced by a gearbox whose low-speed shaft is connected by an overrunning clutch to a motor-generator and air-conditioning compressor. This configuration permits total input power to the A/C loop from the solar-powered R/C. If the R/C system cannot keep up with the cooling demand (i.e., if it is a partially cloudy day), rated cooling can be maintained with the help of the motor. During periods of high solar radiation and low cooling load, the motor-generator will generate electricity to be fed back into the electric system thus reducing yearly consumption of auxiliary electric energy.

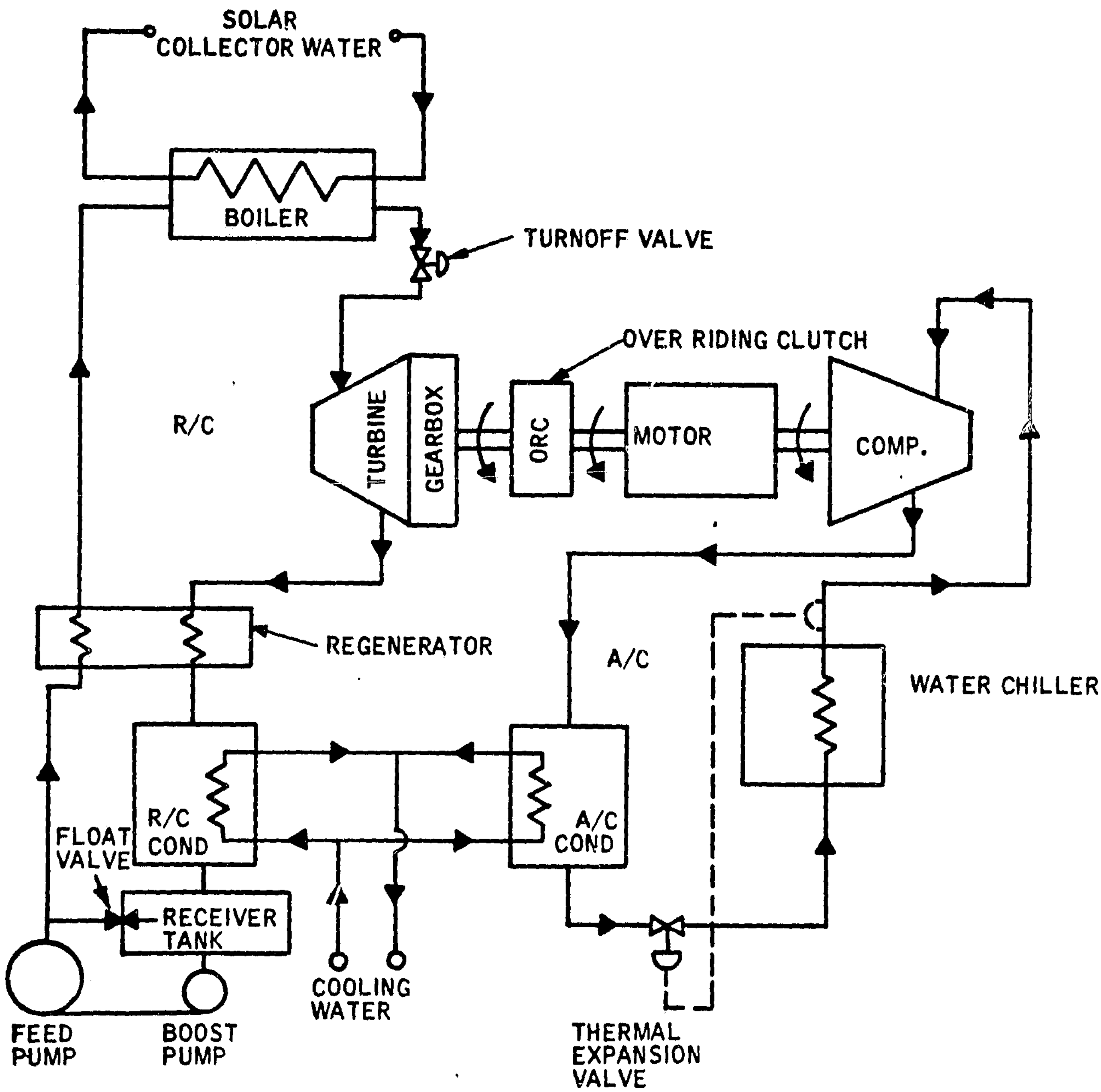


Figure 2-3. General System Schematic for Rankine-Cycle Air-Conditioning System

In the air-conditioning cycle, a compressor receives low-pressure refrigerant vapor from the evaporator (or chiller) and pressurizes it. The high-pressure vapor then enters a water-cooled condenser where the latent heat of vaporization is removed, leaving high-pressure liquid refrigerant. This liquid is allowed to pass through a thermal expansion valve to the low-pressure portion of the loop (i.e., evaporator). The expansion of this high-pressure liquid produces a mixture of refrigerant liquid droplets and vapor at a low temperature (about 45°F). This low temperature provides sufficient temperature difference to extract heat from air or water, as desired, and thus supply cooling. The energy taken from the air or water in the cooling process supplies heat of vaporization to the droplets of refrigerant liquid, producing refrigerant vapor. This low-temperature, low-pressure vapor then flows to the compressor, completing the A/C cycle.

2.3.7.2 Refrigeration Design Approach -- The Lennox approach to the NASA-404 Program is to develop a product which will economically bind together energy efficient hardware, consumer safety, producibility, and marketability in a common package. An economical design will be achieved by striving to select those components which are in common use in today's industry. The method by which these components are applied will differ from current designs, however.

The skin for the cabinetry of both the residential unit and the multiple-family commercial unit will be an adaptation of cabinetry currently used to contain Lennox CHA9 and DSS1 product lines. The present cabinets will be dimensionally modified to meet the package requirements.

The units will be painted with Lennox industrial-grade acrylic enamel finish. This finish meets the Lennox specifications, which have been developed in accordance with American Society for Testing Material (ASTM) Standard D-1654 (Evaluation of painted or coated specimens subject to corrosive environments) and Standard D-714 (Evaluating degree of blistering of paints). Testing consists of a 500-hour salt spray test, which is conducted in accordance with ASTM Standard B-117.

Marketable aesthetics will be maintained by using current Lennox silhouette and color schemes.

2.3.8 Site Data Acquisition Subsystem

In order to meet the data collection, performance evaluation, and data dissemination goals of the National Program for Solar Heating and Cooling, selected demonstration site contractor's must participate in the installation of a comprehensive instrumentation system on his project.

2.3.8.1 Data Collection -- The goal of ERDA's data collection activity is to provide the information necessary for evaluation of the performance and operation of solar systems and subsystems under different climatic conditions. The information generated as a result of this data collection activity will be utilized to stimulate industrial and commercial capability, including that of small business, to produce and distribute solar heating and cooling systems and through widespread applications, to reduce the demand on conventional fuel supplies. This information will also be used to improve the general knowledge and understanding of solar energy systems, to develop definitive solar energy system performance criteria, to provide the basis for component system improvements and to estimate the economics of solar energy systems in reducing the consumption of conventional fuels. Results will be available for use by property owners, the building industry and related sections of the economy to compare costs and benefits of solar heating and cooling systems. This information will also provide the data base for design of new applications in the private sector. ERDA's Technical Information Center at Oak Ridge, Tennessee, will be the National Solar Heating and Cooling Data Bank and will be the focal point for distribution of this information.

2.3.8.2 Data System Overview -- The Data System depicted in Figure 2-4 provides for the automatic gathering, conversion, transfer, reduction, and analysis of demonstration site data. This system is made up of three basic elements: installed sensors, a Site Data Acquisition Subsystem (SDAS), and a Central Data Processing System (CDPS).

The data will be gathered at each operational site at predetermined intervals of time and stored for transfer to the Central Processor. The collected data will be transferred via telephone communications upon request from the Central Data Processing Facility. At the Central Data Processing Facility, the collected data will be processed, analyzed, evaluated, and documented as Performance Evaluation Reports.

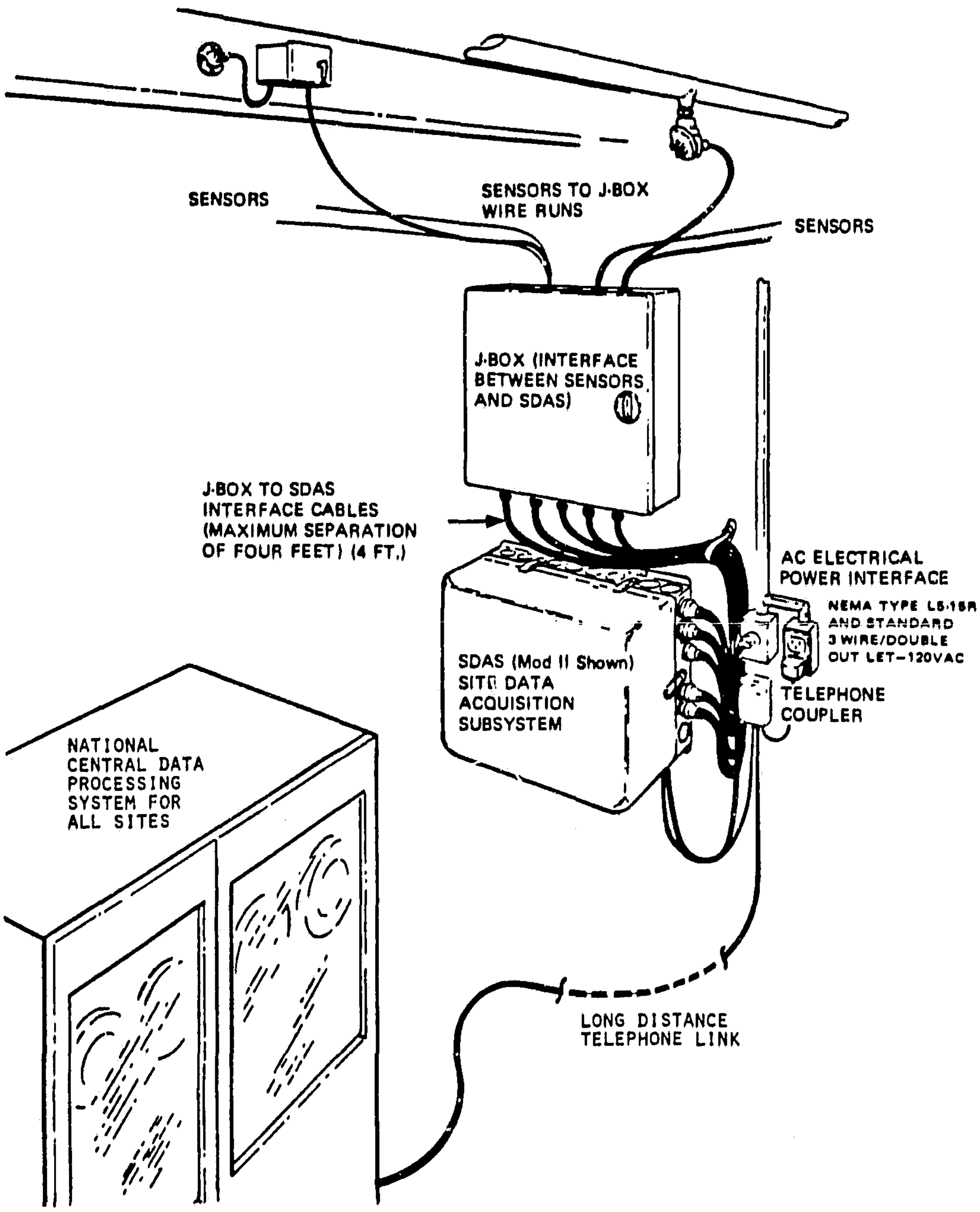


Figure 2-4. Site Instrumentation Interface Hardware

2.3.9 Collector Support Structure

2.3.9.1 Introduction -- Solar collector support structures, for both new construction and retrofit installations, represent a considerable portion of the installed costs of solar heating and cooling systems. This is true of the smaller single family residential systems as well as the larger multifamily and commercial systems.

To reduce the installation costs of solar heating and cooling systems the development of economical collector support systems is imperative.

2.3.9.2 Technical Approach -- Experience with several operating solar heating systems designed by Honeywell has provided data with which to evaluate each prospective design. This experience with costly conventional custom designed structures has led to the intention of using standard components as manufactured by several major manufacturers of metal framing systems.

The collector support structure will use standard mass-produced metal framing components as manufactured by several major manufacturers. The structure will have the following components and features:

- Lightweight, high-strength roll formed steel members of various shapes and load carrying capacities completely painted and ready for installation.
- Standard accessories for interfacing with conventional structural steel components and for mounting of solar collectors and header piping.
- Bolt together construction for rapid and simple field erection and/or pre-assembly.

The design analysis for the collector support structure was performed based on applicable requirements from the following codes and standards:

- HUD Intermediate Minimum Property Standards, Solar Supplement (MPS Solar)
- HUD Minimum Property Standards, Multifamily Housing (MPS Multi)
- American National Standards Institute A58.1 (ANSI)
- American Institute of Steel Construction (AISC)

Specific analysis has also been done in areas not appropriately covered in the codes. The support structure, designed for operation in 90 mph wind combined with 50 pounds/square foot snow load, meets code requirements for the majority of U. S. Cities. Beam size and post spacing are being analyzed based on site specific loading conditions. Stresses within the support structure are also being reviewed to determine possible material cost reduction modifications.

A typical complete collector and structure installation is shown in Figure 2-5. Collector piping headers and header covers are installed as shown in Figure 2-6.

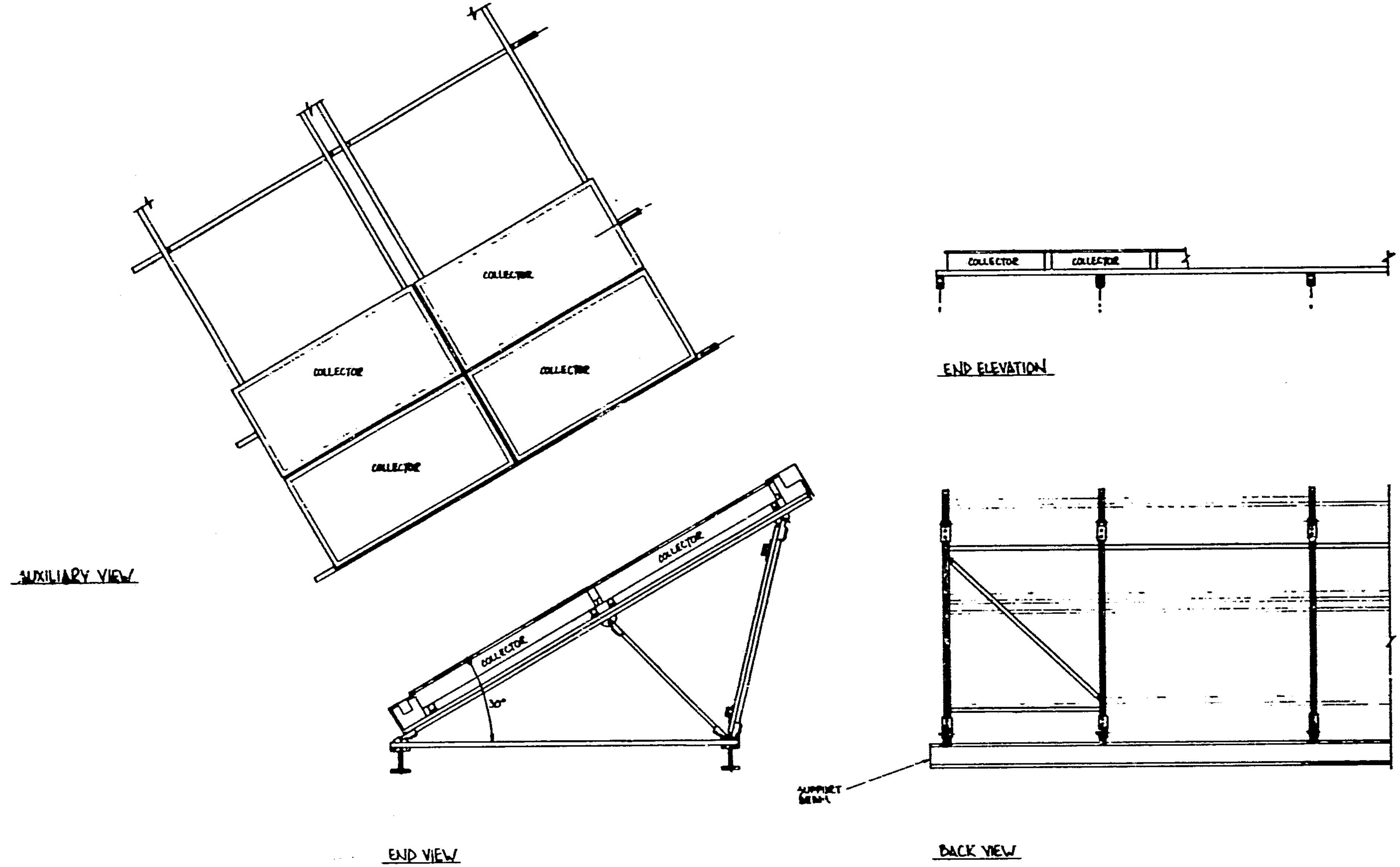


Figure 2-5. Collector Structure

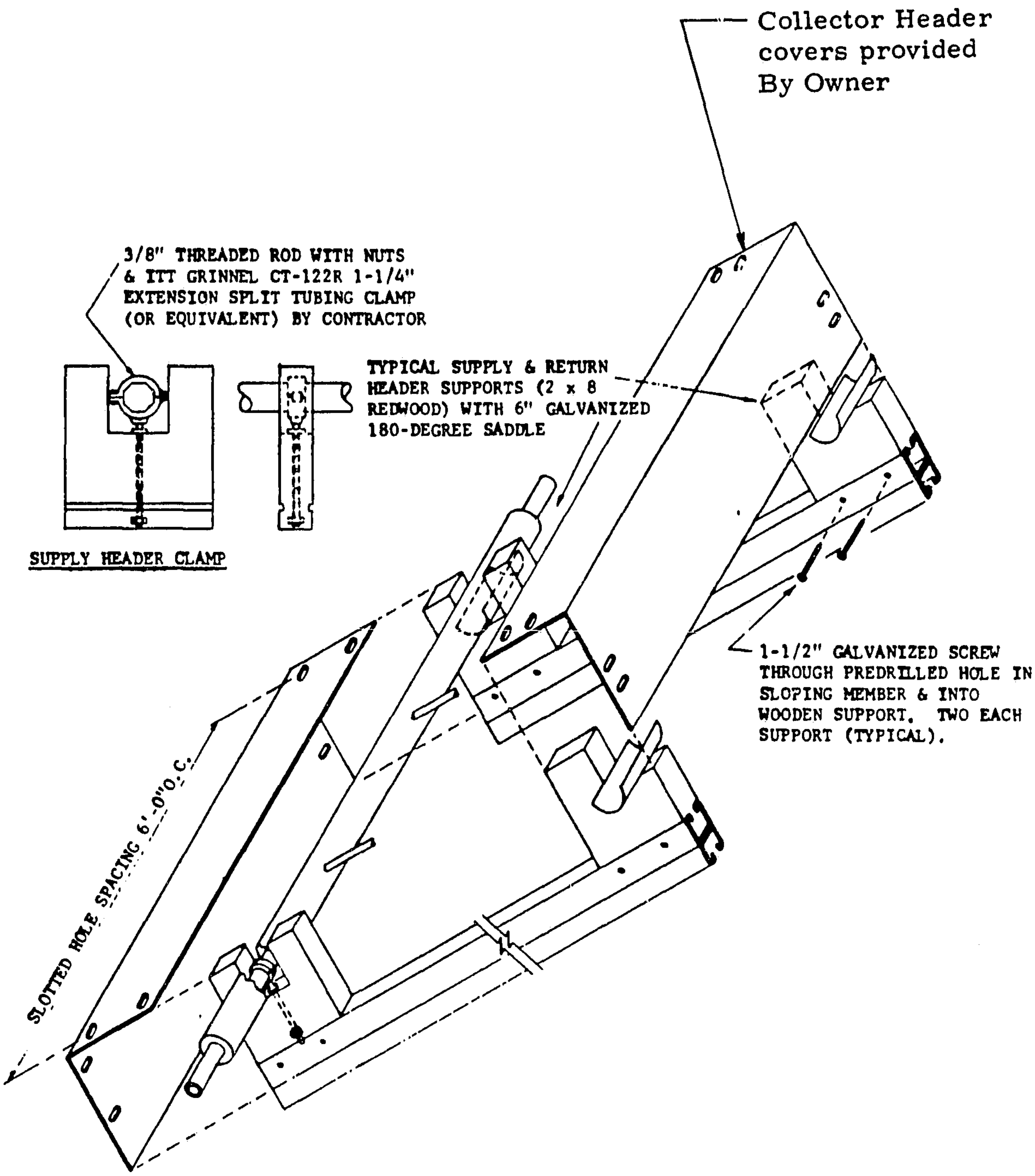


Figure 2-6. Header Support

SECTION 3

OCMULGEE NATIONAL MONUMENT VISITOR CENTER 50 PERCENT DESIGN REVIEW

3.1 GENERAL OVERVIEW

The selection of the Ocmulgee National Monument Visitor Center as an Operational Test Site provided the following advantages:

- High visibility to the public
- A very cooperative and willing site owner
- Excellent access to site/system for performance monitoring
- Opportune timing to coincide with a general rehabilitation of the building
- Excellent match of building/HVAC system to the solar heating and cooling system
- Excellent physical space, orientation and location for solar collectors and for all mechanical equipment

3.2 BASELINE SYSTEM DESIGN CRITERIA

As a part of the solar heating and cooling program, baseline systems have been developed for the single family, multi-family and commercial applications. These designs were developed based on the following criteria:

- Objectives of the program
- Satisfactory operation of each component in the system

- System simplicity
- System control
- Pumping energy in relation to solar energy contribution
- Tradeoff between yearly pumping energy cost and installed first cost
- System and component reliability

The baseline systems are then modified slightly so as to conform with the specific site requirements of each site.

3.3 SITE SPECIFIC DESIGN

The selection of this site presented the following site specific requirements for physical location of equipment:

- Due to the lack of sufficient roof area, the collectors must be installed on a ground-mounted support structure immediately north-east of the Visitor Center building in an existing open area.
- The existing mechanical room is of sufficient size to accommodate all of the mechanical equipment for the solar heating and cooling system including the Rankine Cycle chiller.
- Space is available on the roof of the mechanical room for location of the cooling tower and purge unit.

These requirements were determined to be very compatible with objectives of this program and the baseline designs previously developed.

The building itself also presented several site specific criteria based upon its function as the Visitor Center for the Ocmulgee National Monument. An appropriate solar heating and cooling system for this site must have the following characteristics:

- Ability to provide solar heating to building during the heating season, and solar cooling to building during cooling season.
- Ability to provide, during periods of spring and fall, cooling to some zones of the building and heating to other zones simultaneously, as required to provide optimum comfort to all building occupants.
- Optimum integration with auxiliary energy sources
- Ability to preheat domestic hot water for the Visitor Center building
- Central control system to provide the above qualifications as well as provide system operation characteristics which will maximize utilization of solar energy and minimize consumption of conventional auxiliary energy.

The above criteria were easily incorporated into the design process and resulted in the development of a solar heating and cooling system schematic as shown in Figure 3-1.

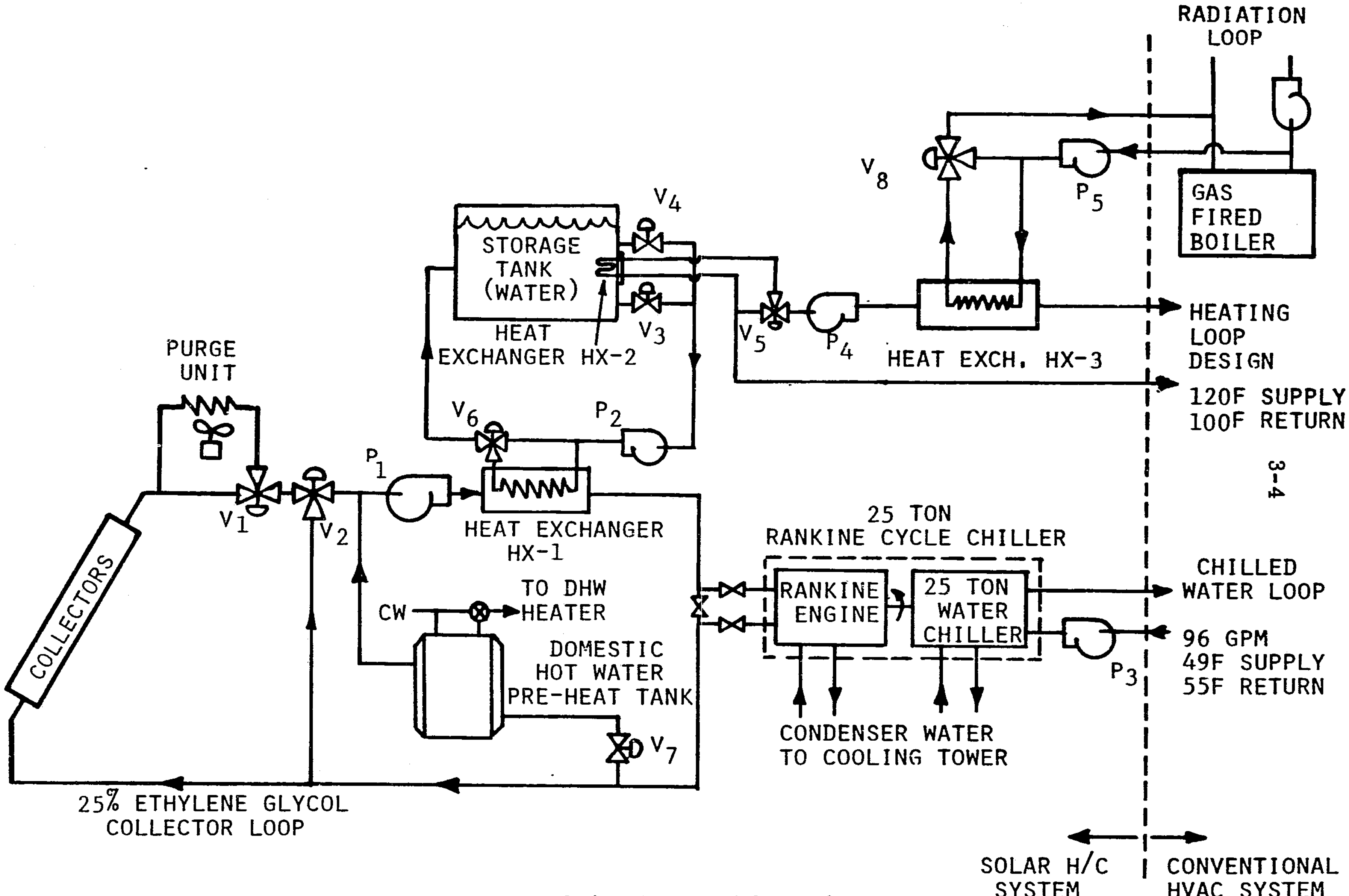


Figure 3-1. System Schematic

The solar heating and cooling system consists of a pressurized collector loop which contains a 25% ethylene glycol-water anti-freeze solution and connects the solar collectors with the purge unit, the storage heat exchanger HX-1 and the Rankine Cycle chiller thru circulation from pump P_1. The storage loop connects the storage tank with the storage heat exchanger HX-1 thru circulation from pump P_2 for storage of collected solar energy. The pressurized chilled water loop connects the Rankine Cycle chiller with the HVAC fan-coil units throughout the building as supplied by pump P_3. The remainder of the chilled water loop will be of conventional design. The HVAC fan-coil units are provided with heat by a pressurized heating loop thru circulation from pump P_4. Solar heat is supplied from the storage tank thru a tube bundle heat exchanger HX-2, and auxiliary heat is added at heat exchanger HX-3, thru circulation pump P_5 from the boiler, if necessary, to maintain a design heating loop supply temperature of $120^{\circ}F$. This arrangement and low design loop temperature ($120^{\circ}F$) allows the auxiliary heat to be supplied as a back up source to solar heating in a convenient manner while still enabling the solar H/C system to satisfy as much of the yearly heating load as possible. Higher temperature ($200^{\circ}F$ range) water is available from the boiler for the radiation loop of the conventional HVAC system.

Domestic hot water pre-heating is provided by a DHW preheat tank. Solar heated fluid is diverted thru a jacket-type heat exchanger around the tank, as controlled by control valve V_7. This design provides the necessary "double-wall" isolation between the toxic ethylene glycol solution and the potable domestic hot water. The preheated water is piped to the conventional hot water heater where additional heat is added if required.

This solar heating and cooling system design enables the conventional HVAC system to be formulated in what is known as a "4-pipe design". This type of design enables the system to provide cooling to some zones of the building while providing heating to other zones. The design of the solar heating and cooling system and the interface with conventional HVAC system allows either system to be shut down for maintenance while the other continues to operate. This provides a simple, flexible and reliable system for the Visitor Center building.

This system provides 9 modes of operation as follows:

- Direct cooling from collectors
- Direct cooling and simultaneous storage charging
- Cooling from storage
- Electric motor auxiliary cooling
- Storage charging
- Heating from storage
- Auxiliary heating from boiler
- Rankine engine generate mode
- Purge excess energy

3.4 50 PERCENT DESIGN REVIEW DATA

3.4.1 Computer Simulation of System Performance

Computer simulation work is proceeding based on preliminary design conditions. Final simulation results will not be available until all design parameters are fixed (e.g. roof insulation factor, ventilation load, lighting load, etc.). Current simulation results indicate the following system performance targets based on a collector area of 5184 gross square feet:

- Heating Load Solar Contribution: 60% to 70%
- Cooling Load Solar Contribution: 55% to 65%
- Domestic Hot Water Load Solar Contribution: 60% to 70%

3.4.2 Collector Subsystem

As previously mentioned, due to the lack of sufficient roof area, the collectors must be installed on a ground-mounted support structure immediately north-east of the Visitor Center building in an existing open area. Based on preliminary computer simulations, a collector area of 5000 gross square feet was found to be an appropriate compromise between solar energy contribution and cost.

Three potential collector layouts were considered each being two collectors high. Configurations having 3, 4 and 5 rows are shown in Figure 3-2. Each of the layouts is oriented parallel and perpendicular to the Visitor Center building so as to blend well with the building. This results in the collector field facing approximately 39^{o} west of south, which according to preliminary computer simulations will provide satisfactory performance.

The four row configuration having 72 collectors in each row (36 long x 2 high) was selected as best layout, based upon visual impact to the site and minor technical advantages.

As previously mentioned, the collector to be provided will be the Lennox solar collector. Data on the collector is shown in Appendix A. The collectors, when installed on the support structure will look similar to an array of collectors currently installed at the Honeywell Solar Lab and shown on page 3-14.

3.4.3 Mechanical Room Layout

Several potential mechanical room layouts were developed which resulted in a final layout as shown in Figure 3-3. This layout enables the Storage Tank and the Rankine Cycle chiller to be installed inside the building which is advantageous in terms of piping cost and visual impact to the site. Service space around the Rankine Cycle chiller is adequate with tube removal spaces shown.

Also shown are locations for Energy Transport Subsystem (pumps, heat exchangers, etc.), controls, electrical equipment and Site Data Acquisition Subsystem. The cooling tower and purge unit are located on the roof above.

A cutaway view of the Rankine Cycle Chiller is shown in Figure 3-4.

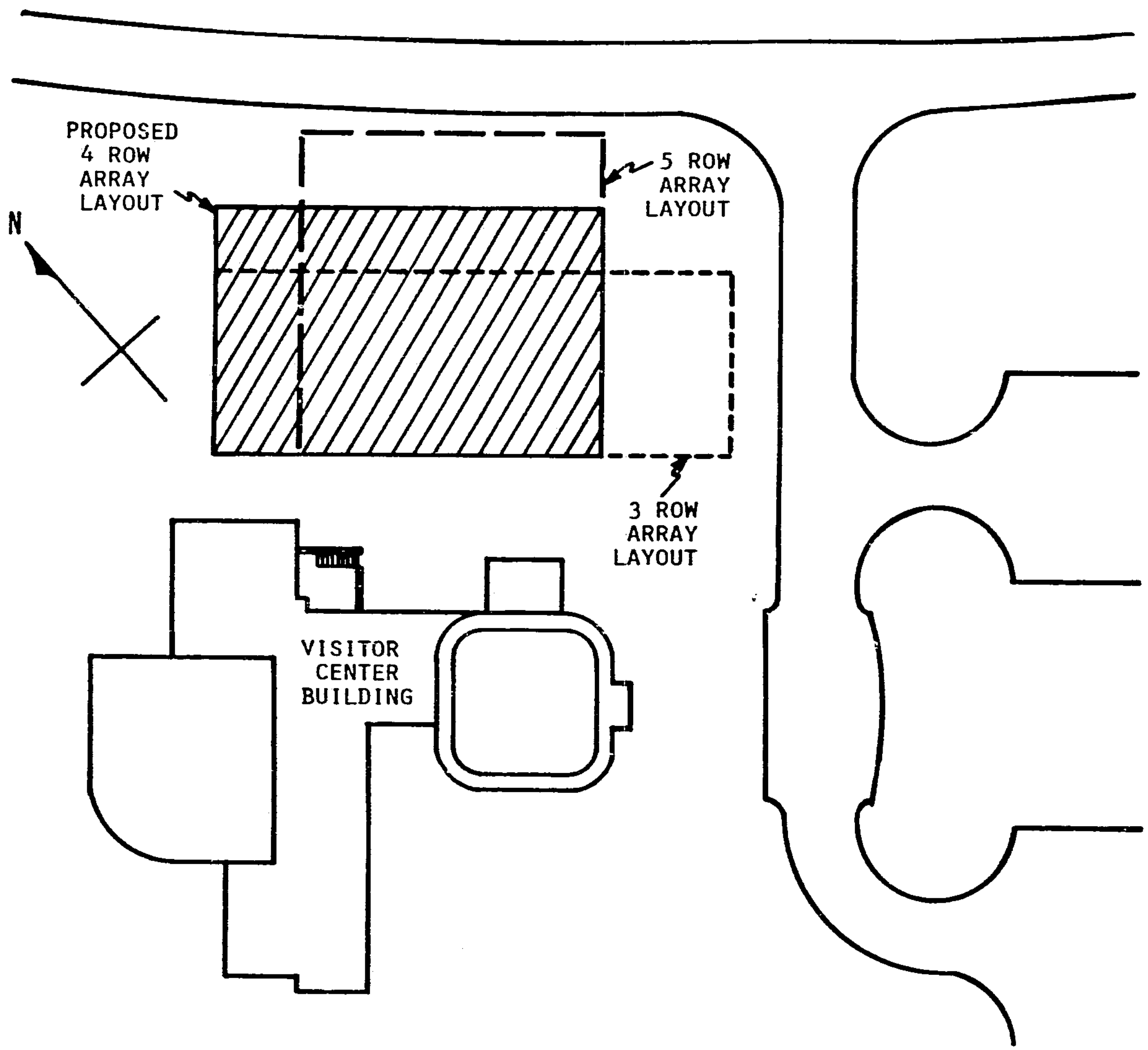


Figure 3-2. Collector Layout Arrangements

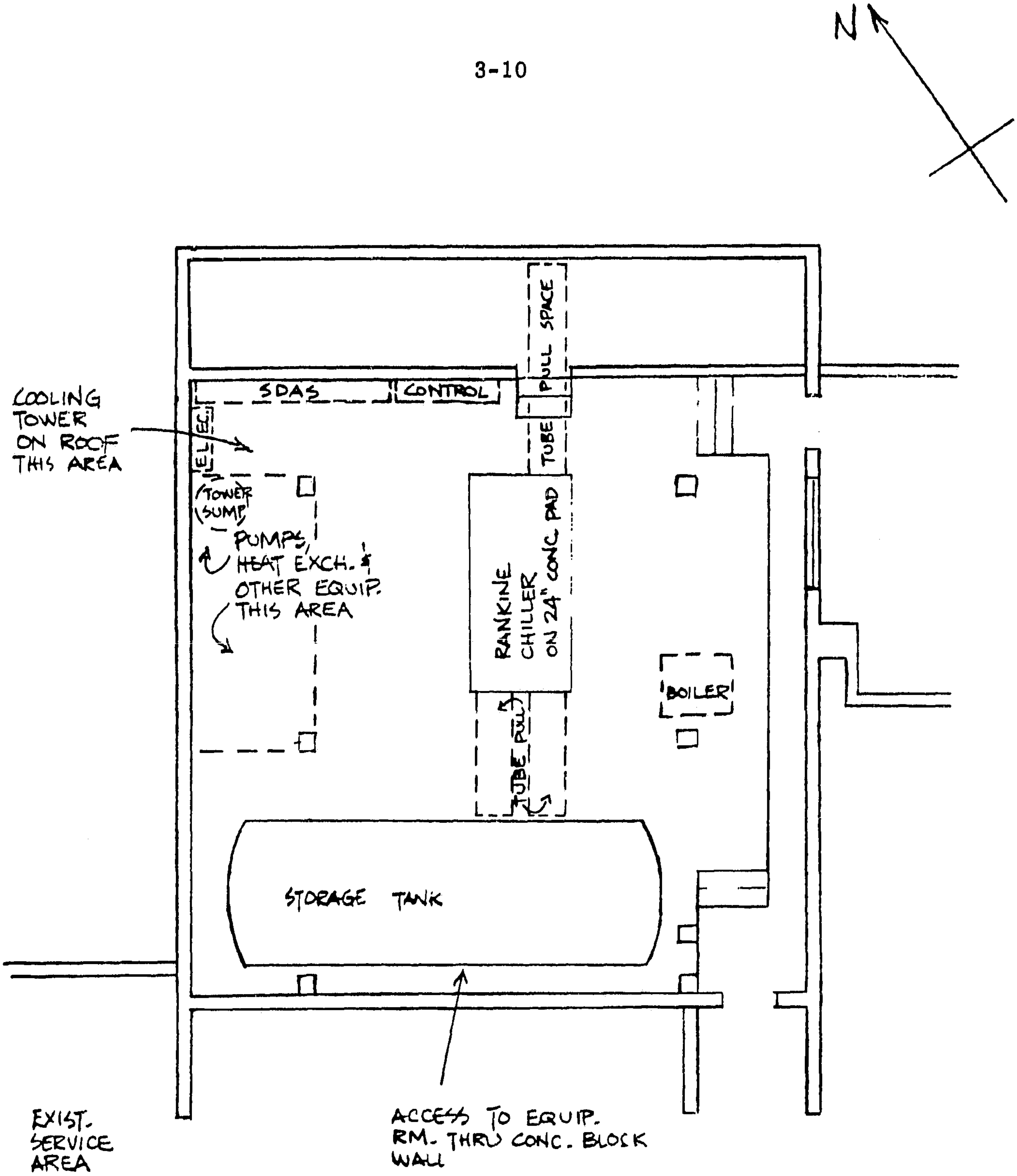


Figure 3-3. Mechanical Room Layout

3.4.4 Control Subsystem

As previously mentioned a central control panel will be provided for control of the solar heating and cooling system. Appropriate interfaces between the central control panel and the controls associated with the various components of the conventional HVAC system (e.g., boiler, fan-coil units time clock, etc.). It is important to note that the central control panel for the solar heating and cooling system and all associated aquastats, sensors, control valves, and motor operators will be provided by Honeywell as a part of the NASA contract. But, all control hardware associated with the conventional HVAC system will be provided by others. Close coordination between all parties in the design team should result in a simple and effective control system for the project.

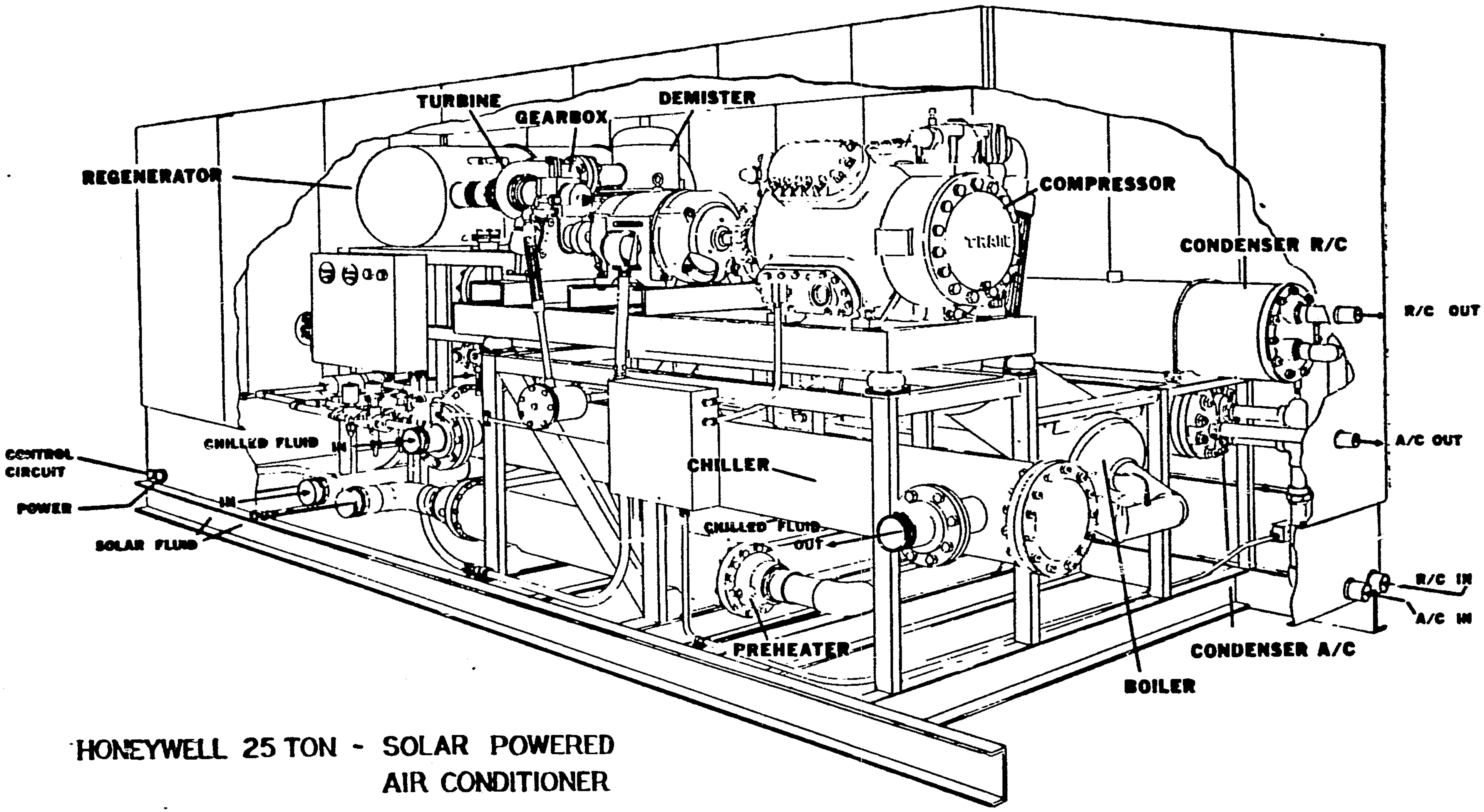


Figure 3-4. Rankine Cycle Chiller

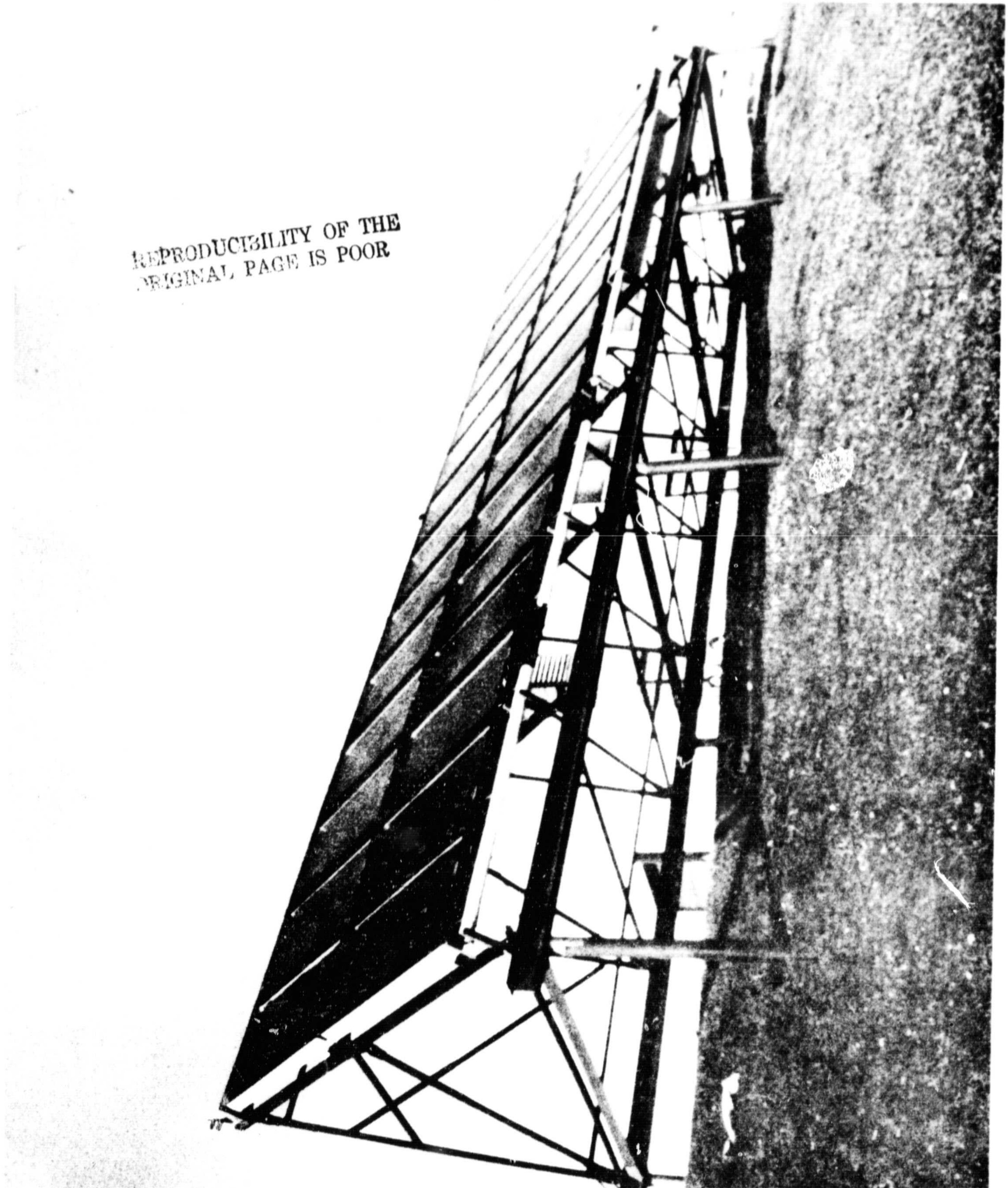
3.5 HONEYWELL FURNISHED EQUIPMENT

Equipment to be furnished by Honeywell under the NASA contract will pertain only to the solar heating and cooling system as shown in Figure 3-1. This would include:

- Solar collectors
- Collector support structure (excluding header covers)
- Collector pipe headers, hoses and clamps
- 25 Ton Rankine Cycle Chiller
- Storage Tank (excluding field insulation)
- Cooling tower
- Purge unit
- Pumps P_1 thru P_5
- Condenser water pumps
- Control valves V_1 thru V_8
- Heat exchangers HX-1, HX-2, HX-3
- Hydronic specialties
- Ethylene glycol
- Controls, as specified in section 3.4.4
- Domestic Hot Water Pre-Heat Tank

3.6 PRELIMINARY SPECIFICATIONS

Preliminary specifications for this project can be found in Appendix B. Portions of these specifications have been used in preparation of construction documents on several other solar heating and cooling projects.



APPENDIX A

SOLAR COLLECTOR

LENNOX SOLAR COLLECTORS LSC18-1S AND LSC18-1

- Easy Installation and Service
- Factory Assembled
- Durable Construction
- Single or Double Glass Cover
- Double Anti-Reflection Etched Glass
- Black-Chrome Coated Absorber Plate
- Corrosion Resistant Copper Tubing
- Electrostatically Dip Painted Enclosure
- Anodized Aluminum Cover Frame
- Insulated Enclosure
- Versatile Mounting Brackets
- External Piping Connections

Lennox Solar Energy Collectors Feature High Thermal Efficiency, Maximum Service Life And Ease Of Installation

The Lennox LSC18 solar collector is a development of the Lennox Research Laboratory Solar Design department, Lennox Manufacturing group and the Solar Research group of Honeywell Inc. The LSC18 is a glass cover, selective absorber, modular collector adaptable to any type and size solar system. Lennox collectors are available with single (LSC18-1S) or two-glass (LSC18-1) covers and utilized to accumulate solar energy which may be used in systems for heating residences, commercial areas, domestic hot water, swimming pool water, etc. The LSC18 collector is a high thermal efficiency, flat plate collector applicable to new or retrofit installations. Collectors are designed for easy installation in separate supports or frames constructed of wood or metal. The solar collector structural framing system may be installed on a roof or at ground level. Collectors can be installed individually or in multiple banks end to end and/or side by side and assembled in parallel, series or series parallel combination. When collectors are installed the thermal expansion of each absorber plate is approximately 0.125 inch for a temperature difference of 200°F. Since the inlet and outlet from each collector are on opposite sides of the modules, the inter connection forms an expansion loop relieving thermal expansion forces. Service access to each collector may be accomplished without removing the entire module or disturbing the adjacent modules. All piping connections are located external to the collector enclosure. The high output-to-insolation ratio of the collector is accomplished primarily in the design of the steel absorber plate which captures solar energy and transfers it to usable heat. The plate is formed around the copper flow tubes and sealed with a solder filler. The wrap-around contact of plate to tubes provides maximum heat transfer and the tubes, permanently sealed against oxide corrosion, have continuing high efficiency. In addition, the entire plate is given a special black-chrome coating for high absorptivity and low re-radiation loss. The absorber plate is completely isolated on rubber pads within the enclosure, eliminating metal-to-metal contact that would result in conductivity loss. Surfaces of the glass cover(s) have acid etched surface lines that increase light transmission by reducing reflection. Tempered, low iron glass is abrasion resistant and structurally strong. In case of breakage, the weather tight aluminum cover frame can be easily dismantled for glass replacement. The collector enclosure is constructed of galvalume steel with a electrostatically dip-painted finish. Enclosure is completely lined with high temperature fiberglass insulation both beneath and around the absorber plate. Two-position mounting brackets on each corner of the enclosure permits installation either vertically or on flat surfaces. Collectors are shipped individually and factory assembled. The installer has only to mount collector in type of framing structure desired and make connections to system supply and return lines.

NOTE - Specifications, Ratings and Dimensions subject to change without notice.

FEATURES

Transparent Cover — Composed of one or two sheets of 1/8 inch thick tempered low iron glass. Both surfaces of the glass sheet are anti-reflection surface etched to increase transmission. The glass sheet has a PVC (Poly Vinyl Chloride) weatherstrip seal around the edges and is enclosed in an extruded aluminum frame which may be disassembled for replacement of the glass. Vent holes are provided in the aluminum frame. The rugged glass cover is structurally strong enough to withstand heavy wind, rain and snow loads. The glass cover system provides transmission of the maximum amount of incident solar energy.

Absorber Plate — The solar absorber is an assembly of parallel copper flow tubes bonded to a formed steel plate and electroplated with a solar selective coating. The special coating (black chrome on bright nickel) applied to the absorber plate provides high solar absorptivity and minimum re-radiation loss. In addition, the coating is extremely durable when exposed to severe ambient conditions, particularly humidity. The steel plate is formed around the copper flow tubes and a high temperature solder bead is added to each tube. This design results in high thermal heat transfer, permanently seals the tubing from oxide corrosion and allows high working pressures. The copper flow tubes are brazed to copper manifold pipes, one at each end. The manifold pipes are capped and have 3/8-18 fpt pipe fittings external to the enclosure, for connection to the supply and return lines of the system or adjacent collectors. Inlet and outlet connections are located in a Z-flow pattern to improve the flow characteristics and facilitate installation.

Insulation — The solar collector has 3-1/2 inch thick insulation beneath the absorber plate and 1 inch around the sides of the collector enclosure. The insulation is a semi-rigid fiberglass board without facing and is capable of withstanding unlikely temperatures up to 550°F without outgassing.

Collector Enclosure — The weather-tight enclosure is constructed of corrosion resistant heavy gauge galvalume steel with a special Lennox "Electro Deposition" process paint finish. Extruded aluminum cover frame is anodized for maximum protection against corrosion. Cover frame is easily removed for complete service access to interior of enclosure. Weep holes are furnished in the enclosure for ventilation and moisture removal in case of any condensation. The absorber plate is mounted on silicone rubber pads isolating the plate from metal to metal contact with the enclosure that would result in any conductivity loss. Two-position mounting brackets on each corner of the enclosure provide flexibility of installation. Piping connections are located external to the enclosure and are equipped with piping collars which reinforce the pipe fittings and allows force to be applied to the connection without stressing the manifolds.

Collector (Transport or Cooling) Fluid — The heat transfer fluid used in the solar collector can range from water to various oils. However, the fluid should exhibit the following properties: low viscosity over the range of ambient temperatures encountered, noncorrosive (with inhibitors if necessary), chemically stable over 15-20 year life, good heat transfer properties, high heat capacity and low freezing point if low ambient temperatures are anticipated. Lennox recommends the use of ethylene-glycol-based antifreeze (Dowtherm SR-1, produced by the Dow Chemical Company). Mixed with water in a 50-50 ratio by volume, SR-1 yields a fluid capable of providing efficient heat transfer over a temperature range of -40°F to 300°F. Dowtherm should be analyzed once per year and inhibitors added if needed.

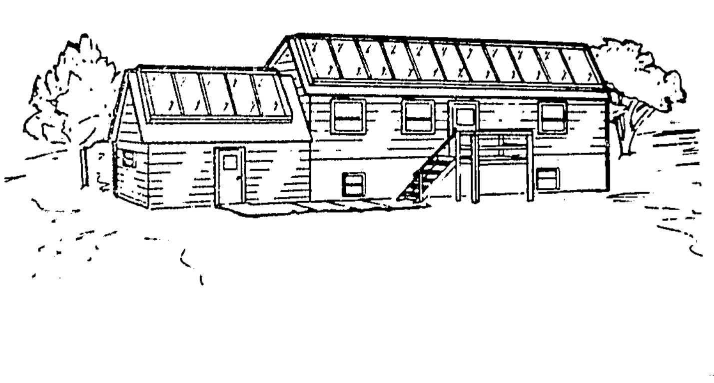
Specifications —

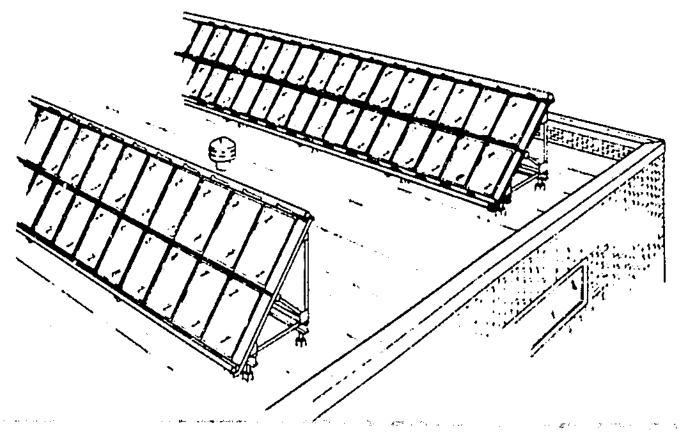
- Collector Model Numbers:
  - — Single Glass Cover LSC18-1S
  - — Double Glass Cover LSC18-1
- Nominal Collector Area — 18 sq. ft.
- Effective Absorber Area — 15.4 sq. ft.
- Ratio Of Usable Absorber Area To Total Surface Covered — 86%
- Glass Cover(s):
  - — 1/8 in. Thick
  - — Tempered-Low Iron-Clear
  - — Transmittance — .96
- Absorber Coating-Black Chrome On Bright Nickel:
  - — Absorptivity — .94
  - — Emissivity — .10
  - — Stable To 850°F

Absorber Construction:
- — Steel Plate
- — Copper Flow Tubes — (10) 1/4 in o.d. (.194 in. i.d.)
- — Tube Spacing — 3 in. On Center
- — Tube Pattern — "Z" Flow
- — Manifold — 1-1/8 in. o.d. (1.079 in. i.d.)
- — Tube Connections To Manifold: ASTM BCuP-3 Brazing Material
- — Bond Between Tubes & Steel Plate — 95-5 Solder
- — Piping Connections (inlet-outlet) — 3/8-18 fpt
- — Manifolds & Tubes Pressure Tested: To 150 psig Working Pressure

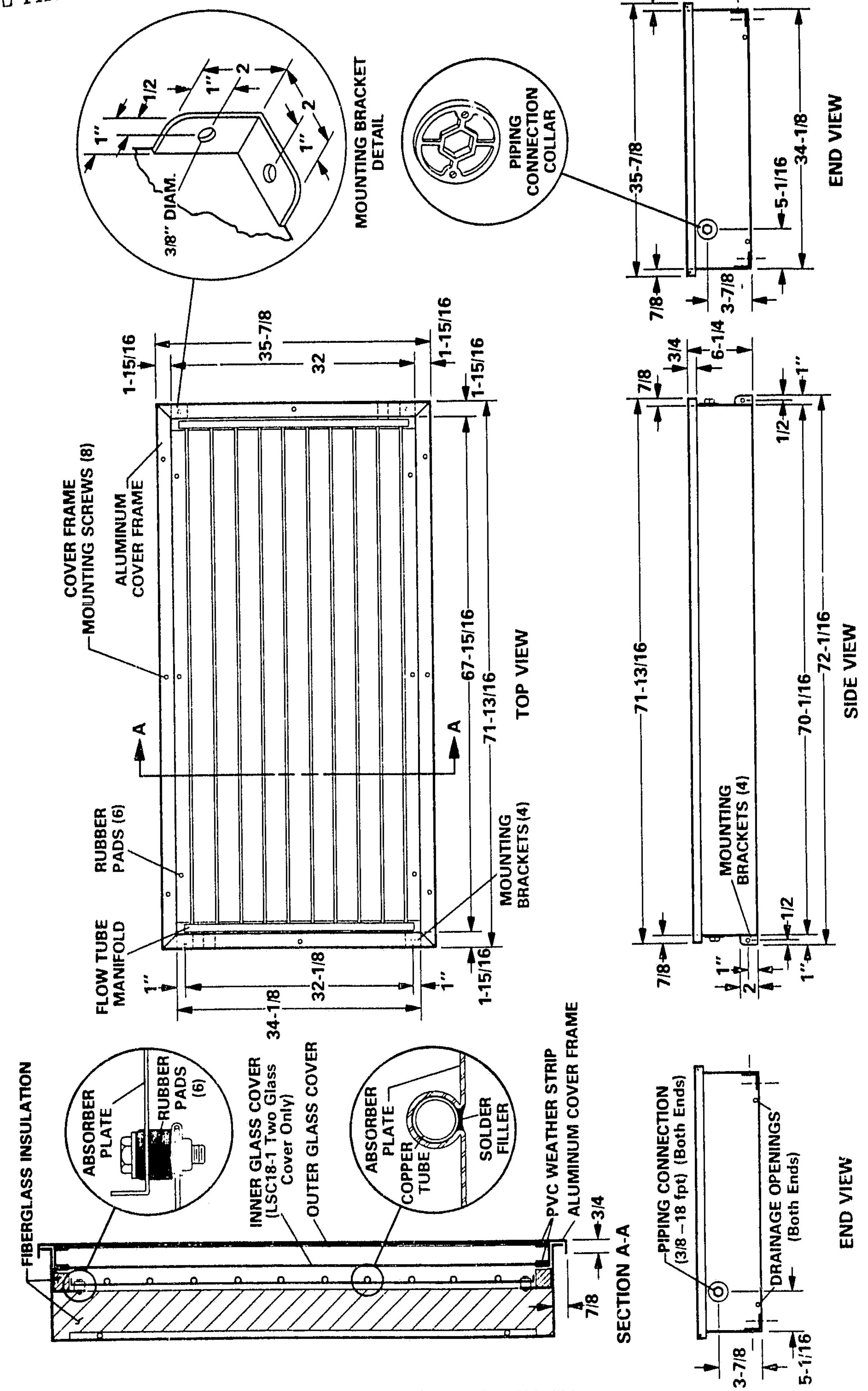
- Recommended Flow Rate Thru Collector — .3 to .7 gpm
- Collector Fluid Capacity — .3 gal.
- Collector Fluid (50-50 Dowtherm SR-1 or Equivalent):
  SR-1 Data:
  - — Density — 1.045 g/ml (at 160°F)
  - — Viscosity — 1.4 centipoise (at 160°F)
  - — Thermal Conductivity — 0.23 Btu/lb-°F (at 160°F)
  - — Specific Heat — 0.85 Btu/lb °F (at 160°F)
  - — Boiling Point — 232°F
  - — Freezing Point — -34°F
- Insulation — Semirigid Fiberglass Board:
  - — Density — 3.0 lb/ft³
  - — Thermal Conductivity — 0.28 Btu in./hr-ft² (at 200°F) (R = 12.5)
  - — Specific Heat — 16 Btu/lb °F
  - — Maximum Temperature — 550°F (without outgassing)
- Collector Shipping Weight (lbs.) — (1 - Package)
  - LSC18-1S — 143
  - LSC18-1 — 170
- Collector Net Weight (lbs.)
  - LSC18-1S — 123
  - LSC18-1 — 150

TYPICAL APPLICATIONS

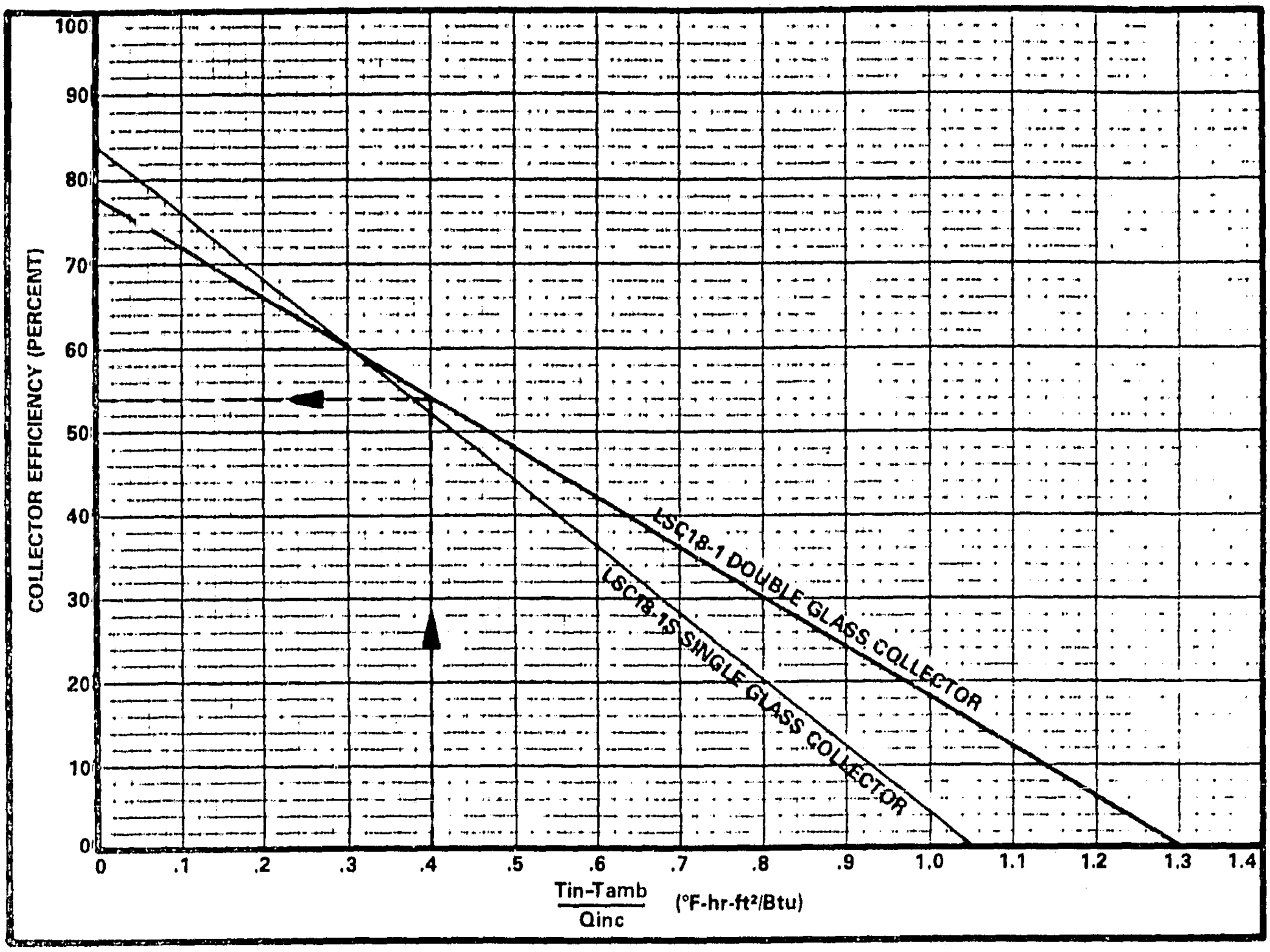




DIMENSIONS (inches)



COLLECTOR PERFORMANCE



Tin = **Fluid temperature at collector inlet (°F).**

Tamb = **Ambient temperature surrounding the collector (°F).**

Qinc = **Incident solar radiation (Btu/hr-ft²).**

$$\frac{\textbf{Fluid Inlet Temperature} - \textbf{Ambient Temperature}}{\textbf{Incident Solar Radiation}}$$

EXAMPLE:

To determine the Btu capacity of the collector the fluid inlet temperature, ambient temperature and incident solar radiation (insolation) of the collector must be determined. Assuming an inlet temperature of 110°F and an ambient temperature of 10°F results in 100°F temperature difference. Dividing the temperature difference (100°F) by the incident solar radiation 250Btu/hr-ft² equals .40 (see sample calculation). Refer to the collector performance chart and following the example line shown from .40 (bottom scale) to the intersecting point with the collector curve and reading across to the collector efficiency scale read 54% efficiency. Thus 54% of the incident solar value of 250 Btu/hr-ft² results in 135 Btu/hr-ft² output capacity of the collector under the conditions used in this example.

For representative values of Incident Solar Radiation (Q inc) see table below or the 1972 ASHRAE Handbook of Fundamentals, chapter 22, pages 388 thru 392.

SAMPLE CALCULATION:

$$\frac{\text{Tin} - \text{Tamb}}{\text{Qinc}} = \frac{110 - 10}{250} = 0.40$$

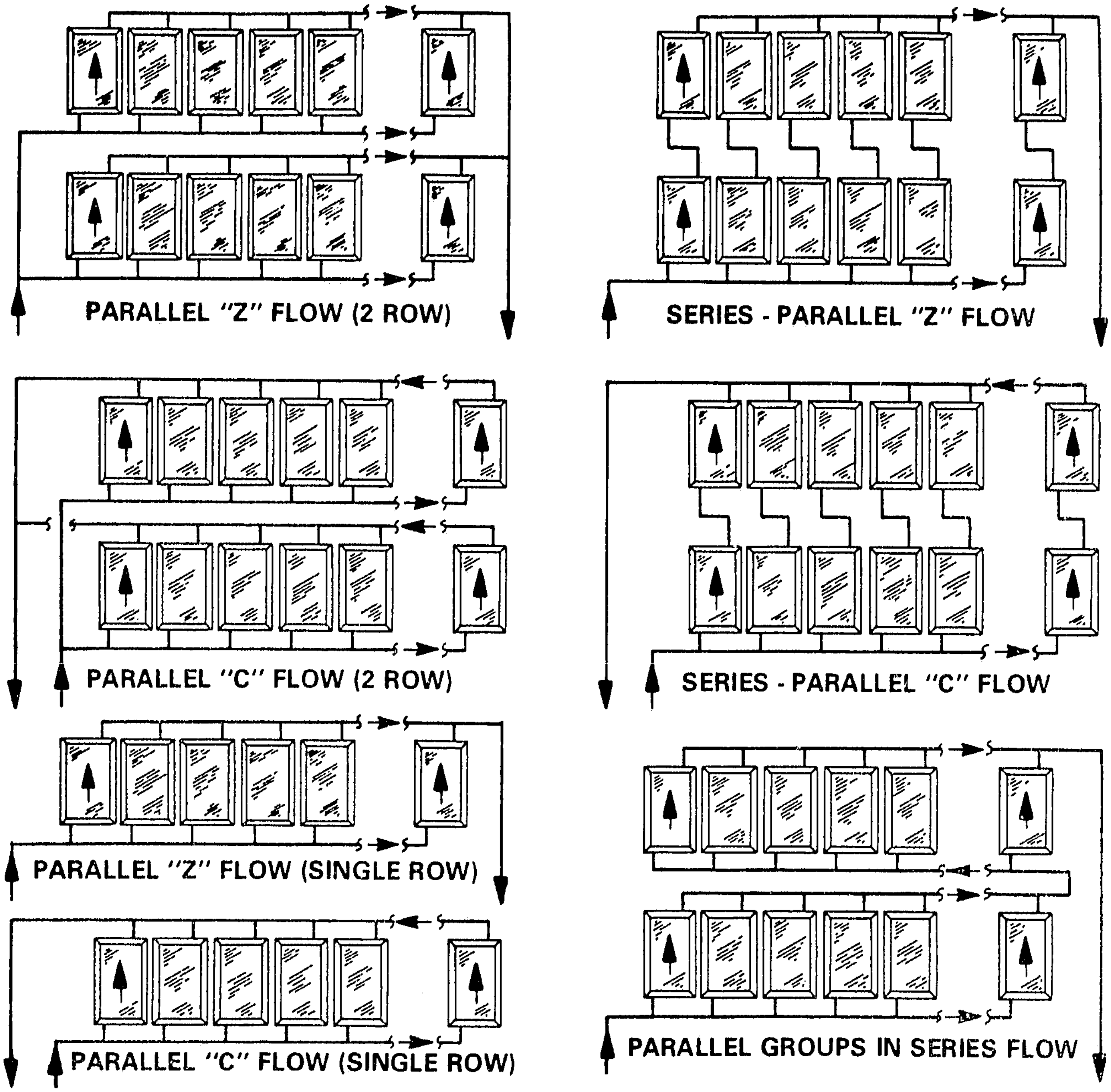
Qinc x 0.54 = 135 Btu/hr-ft² Output

ANNUAL MINIMUM AND MAXIMUM DAYS OF SOLAR INCIDENCE (Clear Sky)

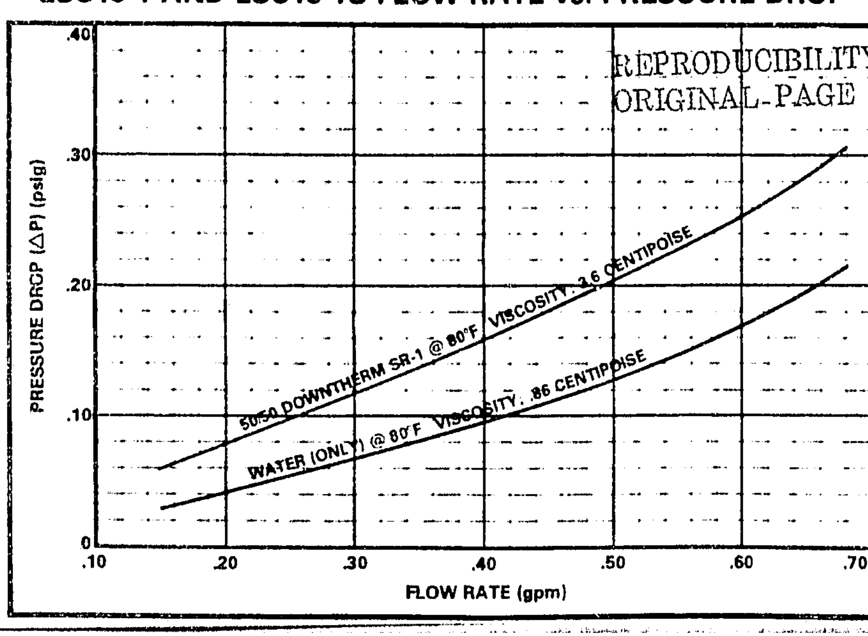
SOLAR TIME	24° North Latitude		32° North Latitude		40° North Latitude		48° North Latitude		56° North Latitude	
	INCIDENT SOLAR RADIATION (Q inc) Btu/hr-ft²									
	Dec. 21	June 21	Dec. 21	June 21	Dec. 21	June 21	Dec. 21	June 21	Dec. 21	June 21
6 A.M.	----	97	----	130	----	154	----	172	----	185
7 A.M.	29	200	----	209	----	215	----	219	----	221
8 A.M.	225	242	176	244	88	246	----	245	----	243
9 A.M.	281	262	257	263	217	262	140	260	5	256
10 A.M.	304	273	287	273	261	272	214	269	113	264
11 A.M.	314	279	300	278	279	276	242	273	165	268
12 NOON	317	280	304	280	284	278	250	275	180	270
1 P.M.	314	279	300	278	279	276	242	273	165	268
2 P.M.	304	273	287	273	261	272	214	269	113	264
3 P.M.	281	262	257	263	217	262	140	260	5	256
4 P.M.	225	242	176	244	88	246	----	245	----	243
5 P.M.	29	200	----	209	----	215	----	219	----	221
6 P.M.	----	97	----	130	----	154	----	172	----	185

TYPICAL FLOW PATTERNS

NOTE – Various flow patterns are shown to illustrate several methods possible for meeting physical/structural requirements and/or for high temperature rise advantages. Utilize the flow rate vs. pressure drop curves to estimate pressure drop for each unique pattern.



LSC18-1 AND LSC18-1S FLOW RATE vs. PRESSURE DROP



APPENDIX B

PRELIMINARY SPECIFICATIONS

DIVISION 15 - MECHANICAL

SECTION 15A - GENERAL PROVISIONS

15A-1 Scope:

a) The work included under this division of the specification shall consist of the furnishing of all labor and materials necessary for the complete installation of heating, ventilating, air conditioning, temperature control systems and site data acquisition system as shown on drawings and/or as specified herein.

b) All work shall be completed and shall be left in operating condition. System start-up and control system checkout shall be conducted under Honeywell, Inc. supervision.

c) The Contractor shall furnish and install all minor items which are obviously and reasonably necessary to complete the installation and usually included in similar work even though not specifically mentioned in the Contract Documents. Such items are bolts, nuts, anchors, brackets, sleeves, drains and air vents, minor offsets in duckwork and piping because of unforeseen obstructions, etc.

15A-2 Standards:

a) The following is a list of organizations and their abbreviations where referred to in the specifications as standards of construction.

1. NFPA - National Fire Protection Association
2. ASTM - American Society for Testing and Materials
3. NBFU - National Board of Fire Underwriters
4. AWWA - American Water Works Association
5. ASME - Americal Society Mechanical Engineers
6. ASHRAE - Americal Society of Heating, Refrigeration and Air Conditioning Engineers
7. AGA - American Gas Association
8. ANSI - American National Standards Institute
9. UL - Underwriter's Laboratories, Inc.
10. FIA - Factory Insurance Association
11. FM - Factory Mutual
12. SMACNA - Sheet Metal and Air Conditioning Contractors National Association
13. AMCA - Air Moving and Conditioning Association, Inc.
14. ARI - Air Conditioning and Refrigeration Institute
15. AABC - Associated Air Balance Council

b) Comply with the requirements of all State and Local codes.

Furnish equipment and supplies that meet the following standards: U.S.A. Standards, I.A.N.P.O. Standards, A.S.T.M. Standards, N.S.S. Standards, and all other standards indicated in various sections of these specifications.

All reference symbols on the plans are standard ASME symbols.

15A-3 Equipment Drawings:

a) Equipment drawings shall be furnished for the following items or equipment supplied by the Government.

Collectors
Headers
Purge Unit
Control valves
Heat Exchanger
DHW Storage
System Storage
Pumps
Rankine Cycle Chiller
Cooling Tower

Collector Structure

Controls Site Data Acquisition System

b) Shop drawings or catalog cuts shall be submitted for items of equipment purchased and or supplied by the contractor in accordance with Division I - General Requirements.

It is not intended that these drawings replace or be substituted for final drawings, wiring diagrams, operation and maintenance manuals, etc. required by other sections of the specifications. System drawings shall be marked to as-built configuration and supplied to Project Manager.

15A-4 Chases, Sleeves and Wall Openings:

a) The Contractor shall be responsible for the placing of sleeves in walls, floors, etc., where required.

b) See Section 15C for requirements of sleeves.

15A-5 Manner of Running Piping and Ductwork:

a) All piping and ductwork shall be run in the most direct, straight and mechanical manner and everywhere properly graded. Offsets in vertical pipe will be allowed only when unavoidable. All pipe connections shall be so made as to allow for perfect freedom of movement of the piping during expansion and contraction without springing.

b) It is the intent of these plans and specifications that most piping and ductwork will be concealed. Where they are exposed, they shall be run as close to ceilings and/or walls as possible and installed parallel with adjacent structural or architectural elements. Minimize number of fittings and joints in exposed piping. All piping shall be tested before concealing.

c) The Contractor operation under this section of the specifications shall coordinate his work with that of all other trades, properly grouping piping with other pipes. Pipes and ductwork shall be run as shown on the drawings, but the Contracting Officer reserves the right to make slight changes in runs to avoid interference with other work or structural conditions without extra charge by the Contractor.

d) Pipes shall be run with proper grading to provide easy drainage. Pipes shall be thoroughly reamed and cleaned before hanging.

e) Piping systems shall be installed in accordance with the sizes and locations shown on the drawings. The Contractor shall lay out his work, properly locate the apparatus and take his own measurements at the building site.

f) Water heating mains shall be pitched 1/4" in 10'-0" in the direction of flow, except for horizontal solar piping which shall be installed level. Reducting fittings on horizontal pipe shall be eccentric. Vents shall be installed where indicated and at all points where air can lodge.

g) Positive shut-off valves shall be installed where indicated on drawings so that in the normal servicing of each unit, it will not be necessary to drain any riser or shut-off main lines.

h) Horizontal runouts from mains and/or risers shall be made with swing joints and shall be of sufficient length to absorb vertical expansion or contraction of risers and horizontal expansion or contraction of mains.

i) All under ground piping shall have 3'-0" of earth cover. Reference Division 2 - Sitework.

15A-6 Installation Procedures:

a) General:

1. Provide pipe anchors and guides where shown on drawings and where they are otherwise needed to prevent excessive movement of piping and/or excessive strain on piping and equipment connections. Provide expansion loops and offsets in piping as required to prevent excessive strain or pipe displacement between anchors, at piping take-offs, and at equipment connections. Provide spring hangers and guides where shown on drawings to prevent excessive forces from being transmitted to building structure.

2. Piping to pumps shall be run line size close as possible to pump connections. Pump shut-off valves, strainers, and flexible connections shall be line size. Provide eccentric reducer, flat on top at pump suction to reduce from line size to pump suction connection size. Provide concentric increaser at pump discharge to increase from pump discharge connection to line size. Long radius reducing elbows may be substituted for reducers and increasers specified above if radius of turn is in the vertical plane.

3. All pump seal cavities or pump base plates shall be piped to drain, except when drawings or specifications indicate no drain piping for small pipe-mounted or floor-mounted pumps which have mechanical seals.

4. All connections to apparatus and equipment shall be with flanges, unions, etc., for easy removal.

5. Piping shall be arranged to provide access to openings and to permit convenient removal of heads and pulling of tubes when heads or tubes are portions of equipment. Removal of heads and pulling of tubes shall be accomplished without disturbing equipment shutoff valves and by the removal of a minimum amount of piping between shutoff valves and equipment. Provide additional flanges or unions as required to provide these features.

6. Install manual drain valves at every low point of water piping systems and a manual air vent at every high point of water piping systems. Drain valves attached to piping sizes 4" and larger shall be 2" size. Drain valves attached to piping smaller than 3" shall be 3/4" size.

7. Changes in pipe sizes shall be made with reducing elbows, reducing tees or increasers. Increasers may be concentric. Reducers shall be eccentric; flat on top for water.

8. Piping to automatic control valves shall be run line size close as possible to valve connections unless otherwise specified. Concentric increasers at valve outlets may be used. Use eccentric reducers at valve inlets; flat on top for water. Strainers shall be line size. Provide unions or flanges for easy removal of automatic control valves.

9. All piping up to 2" inclusive shall be reamed after cutting.

10. All piping shall be blown out with compressed air or otherwise cleaned internally immediately proir to installation into the pipe line.

11. Cap or cover all open piping during erection to prevent entry of foreign material.

b) Interior Water Piping Installation:

1. All piping shall be installed parallel with the lines of the building. Piping shall be concealed in the ceiling spaces, wall construction or pipe spaces.

2. Pipe shall be cut accurately and shall be worked into place without springing or forcing. Connections to risers shall be provided with swing joints at point of connection to main. All changes in pipe size shall be accomplished through the use of reducing fittings or reducing sockets. The use of bushings will not be approved.

3. All piping shall be properly graded to drain to a low point where drains can be accessible located and no portion of the system shall trap water. Drains shall consist of a hose bibb or 1/2 inch globe valve with hose nipple unless specified otherwise. The piping system shall be arranged to permit venting through fixture connections where possible.

15A-7 Electrical:

a) Unless otherwise specified herein, all conduit disconnects, and power wiring shall be furnished and installed under Division 16 of this specificatior

b) All control and interlock wiring shall be furnished under Division 16 unless noted otherwise elsewhere in these specification.

SECTION 15B - HYDRONIC HEATING AND COOLING SYSTEM

15B-1 Scope:

a) The contractor shall furnish all labor, materials and equipment (not furnished by the Government) for the installation of a complete and acceptable heating and cooling system as described herein, and including the following major components furnished by Government (See Dwg. M16)

15B-2 Heat Exchangers and DHW Storage Tank:

a) Install where indicated on the drawings, the following water to water heat exchangers.

15B-3 Circulating Pumps

a) The circulating pumps located inside the building in the hydronic heating/cooling system shall be base mounted as indicated on the drawings. These units shall be furnished with heavy cast iron base by the Government and installed by the Contractor. Pump and motor shall be realigned by the Contractor after grouting of base and connection of piping.

b) Submersible Pumps

1. The circulating pumps located in the sump area shall be submersible type. These units shall be furnished by the Government and installed by the Contractor as indicated on the drawings.

c) In-line Pump

1. The recirculating pump located in the DHW return line shall be furnished by the Government and installed by the Contractor as indicated on the drawings.

15B-4 Purge Unit

a) A CBW3-185 purge unit furnished by the Government shall be installed in the cooling complex as directed in the engineering bulletin. Air flow shall be directed vertically by duct work furnished by Contractor. A three way control valve shall be located on the side panel (see drawing detail).

15B-5 Solar Collector Panels and Structure

a) The solar collector panels will be Lennox Industries, Inc. Model LSC18-1, size 35-7/8" x 71-13/16" overall by 6-1/4" deep, double glass covers, having a shipping weight of approximately 170 lb. each and will be furnished by the Government. Mounting a collector: Collector mounting consists of bolting 2 clamps to each collector, sliding collector into place, bolting four collector corners to structure. During installation of the collectors, mounting clamps will be used and field inter-connections (spring clips) using 3/4" diameter silicone hose will be made. The solar collector layout and piping are shown on drawings.

b) Install support I-beams, and structural steel framework (supplied by the Government) to support solar collectors and headers, mounted two-high at 30° from horizontal in rows on existing foundation posts.

Height and plate orientation on foundation posts shall accommodate leveling of I-beams and effective beam-to-plate welding.

The beams shall be primered ASTM-A35 steel, cross-section, and continuous length or spliced where noted on drawing. Top of beam shall have no protruding splices or weldments; leveling requirements are noted on drawing. The beam-to-beam braces (12 ga. steel) shall be welded to the I-beam. All splices and weldments shall be performed by a certified welder in accordance with AISC specifications. Remaining assembly of the structure onto the braces is accomplished with bolt-together sections. All bolts indicated on drawings shall be installed and tightened to manufacturer's specifications. Structure components, including header supports, shall be located and oriented as noted on drawings, insuring that slope, alignment, and spacing between collectors are maintained. All bolts installe and torqued according to manufacturer's specifications. Pre-cut member lengths shall not be shortened.

The design life of the finish or covering provided for all collector support structure components and its foundation is 20 years. The I-beam and all weldments shall be adequately prepared, primered, and painted as called for by contractor. The redwood header supports and header insulation shall be enclosed within a weatherproof cover. The structure framework members and fittings are galvanized with exposed ends similarly protected. Damaged finish or exposed metal resulting from approved design changes shall be prepared, primed with zinc chromate, and painted by contractor as described.

15B-6 Storage Tank:

a) Install the insulated, non-pressurized, 8' dia. x 21' long (approx. 8,000 gallons), all welded 3/8" steel hot water storage tank as shown on dwgs. Each of the three, flat-based (1'0" x 8'0") support saddles shall rest on a 2" thick CCA Exterior Pressure Treated lumber which extends 2" beyond saddle bases.

b) Furnish and install interior lining, to be Pre-Krete C-17 Calcium Oxide Corrosion Resistant Cement (Pocono Fabricators), or approved equal, to be applied over the sandblasted interior. Lining shall not restrict flow through outlets nor interfere with threads of interior fitting extensions. Precautions shall be taken to avoid damage to tank insulation and covering. Surface preparation, application, and curing of the interior lining shall be strictly in accordance with manufacturer's specifications

15B-7 Force Air Heating System:

15B-8 Rankine Cycle Chiller:

a) Install where indicated one (1) nominal 25 ton, Rankine Cycle Chiller.

b) The unit shall be shipped as a complete unit, factory tested and with all valves, controls, flow switches, interlock devices necessary for satisfactory operation. The Contractor shall provide piping to the unit for solar water, condenser water, and chilled water and electrical interlock wiring from the RCC unit to the magnetic starters of the chilled water and condenser water pumps. The Contractor, under Division 16, shall provide power wiring to the control panel furnished with the RCC unit.

c) The installation shall be made under the supervision of the manufacturer and factory trained service personnel shall be employed to provide the start-up of the unit.

15B-9

15B-10 Cooling Tower:

a) Inspect and install, as shown on plans, one (1) factory assembled induced draft cross-flow cooling tower with horizontal discharge. The tower shall be a Marley Aquatower Model 4755 furnished by the Government.

b) Install, in correct mounting holes, a spearately packaged two (2) HP motor and belt guard, furnished with installation instructions by the cooling tower manufacturer.

c) Align the fan belt and adjust to proper tension in accordance with manufacturer's recommendations.

d) Remove the 3/4" dia. shoulder type make-up water float control valve located in the tower basin and close opening through side casing sheet with removable pipe plug.

e) Install, as per dwgs., pipes leading to sump from the suction and drain openings in cooling tower gasin. Suction is a 4" dia. threaded male connection provided in the cold water basin end at the louvered face. Drain consists of a 2" dia. threaded female fitting installed in the basin floor.

f) Close the 2" dia. overflow fitting wit'ꜣ ꜣ removable pipe plug.

f) Inspect final assembly and follow proper start-up procedures outlined in the instruction manual provided by manufacturer.

15B-11 Miscellaneous:

a) Furnish and install a fill opening with funnel in the ethylene glycol piping to facilitate the addition of antifreeze to the solar panel piping system. The Contractor shall install the amount of ethylene glycol heat transfer fluid necessary to provide a 25% solution (by volume) in the entire solar panel piping circuit including the collector panels and heat exchangers. The heat transfer fluid shall not contain any type of "stop leak" additives. Glycol shall be furnished by Government.

b) The Contractor shall be responsible for thoroughly cleaning and flushing the entire solar system as recommended by the manufacturer of the ethylene glycol heat transfer fluid before introducing the fluid into the system.

SECTION 15C - BASIC MATERIALS AND METHODS

15C-1 Materials:

a) The manufacturer's mark or name shall be attached to each length of pipe fitting, fixture and/or device employed in the piping system.

b) Solar Collector Fluid Piping (Header to Supply Main)
   1. Type "L" hard drawn copper tubing with wrought copper or bronze fittings, use 95-5 solder for piping.

c) Domestic Water Piping (CW,HW)
   1. Above Grade - All sizes; Type "L" hard drawn copper tubing with wrought copper or bronze fittings, use 50-50 solder for piping.

   2. Tubing shall be cut square with tubing cutter or hacksaw with suitable blade. All burrs shall be removed from interior of tubing and exterior of tubing and socket of fitting shall be thoroughly cleaned with steel wool or emery cloth until surfaces are bright and free from discoloration. A thin coating of a non-corrosive flux shall be applied from fitting toward tube. Only after tube and fitting are heated to proper temperature shall solder be applied to the joint at one or two points. Solder shall be applied until a complete ring of solder appears around the full circumference of the joint. Remove excess solder after it has cooled to a plastic state. Joints shall be made up utilizing 50-50 solder.

   3. Modify meter locations as shown on drawings.

d) Solar Water Heating, Chilled Water (SWS,SWR,CWR,H/CS,H/CR,SLS & SLR)
   1. Schedule 40 black steel pipe, seamless or resistance welded ASTM A53, Grade A or B, with 150 lb. malleable or 125 lb. cast iron screwed fittings for 2-1/2" and smaller and with butt welded fittings for piping 3" and larger.

e) Condenser Drain Piping (CDS, CDR)
   1. Piping shall be Type "L" hard drawn copper.

15C-2 Pipe Welding:

a) Standard butt weld fittings shall be used with all welded pipe.

b) Back-up rings shall be used with all butt weld fittings.

c) Under no circumstances shall any pipe connection be made by punching a hole in pipe and inserting or saddling a branch take-off.

15C-3 Piping Specialties:

a) Straıners - Install as indicated on drawings.
   1. Strainers shall be Y-Pattern type, cast iron or semi-steel (Bronze when installed on copper or brass pipe), pressure rated for intended service. Strainers shall have standard brass screen, gasketed machined flanged cap with threaded blow down opening. Strainers shall be screwed for sizes 2" or smaller and flanged for 2-1/2" or larger. Strainer to have a minimum effective straining ratio of 4 to 1.

b) Pressure and Temperature Test Stations:
   1. Provide a 1/4" MPT fitting, to receive either a temperature or pressure probe, 1/8" O.D. Fitting shall be solid brass with valve core of Nordel (Max. 275°F) fitting with a gasketed cap and rated at 1,000 psig.

   2. Install a test fitting on each side of all pumps and where otherwise indicated.

c) Air Vents:
   1. Furnish manual air vents at all high points in the hydronic piping system, at water coils and where otherwise indicated.

d) Unions:
   1. Furnish and install 150 lb. malleable iron, brass ground joint unions in steel piping to 3" size. For same piping 3" and over, use 125 lb. galvanized case iron gasket type flange unions and/or flanged fittings. For hard drawn copper piping use ground joint unions. Above unions shall be used adjacent to all equipment automatic valves, etc. as applicable to facilitate repairs.

2. Dielectric Unions - Where copper water pipe is connected to steel pipe, steel tanks, etc., connections shall be made with dielectric unions. Lines 2" and larger shall have insulating flanges having one brass component and one steel component.

e) <u>Nipples</u>:
   1. Shall be the same material, composition and weight classification as the pipe with which they are installed. Close or running thread nipples shall not be used.

f) <u>Floor, Wall and Ceiling Plates</u>:
   1. For uncovered pipe through finished areas shall be provided except within closed cabinetwork. Plates shall be chrome plated and have raised edges to accomodate extended sleeves where required.

g) <u>Valves</u>:
   1. General:
      a. Furnish (except Government furnished equipment) and install where required and/or indicated on the dwgs. for the control, operation and maintenance of all mechanical equipment and systems. Valves shall be installed as shown on dwgs. to permit maintenance without shutting down the service of the piping systems in the building.

      b. Valves shall be as shown on dwgs.

      c. Valves shall be for not less than 125 lbs. water working pressure, and in any event shall be compatible in working pressure to the pipe and fittings to which they are attached. Valves shall be designed for the service for which installed.

      d. Valves 2" and smaller, shall have screw end or solder end connections except as otherwise shown in these specifications or plans. Valves 2½" and larger shall have flange end construction except as otherwise shown in these specifications or plans.

      e. Each main or branch valve size 2½" or larger installed in equipment room shall be installed with the handwheel in a horizontal plane.

   2. Valves:
      a. <u>Gate Valves, 2" and smaller</u>: 125# bronze, screwed end, solid disc, rising stem - season changeover valves V_{16}, V_{17}, V_{18})

      b. <u>Gate Valves, 2" and smaller</u>: 125# bronze, screwed end, solid disc, non-rising stem.

      c. <u>Gate Valves, 2½" and larger</u>: 125# iron body, bronze mounted, outside screw and yoke, rising stem, bolted bonnet, solid wedge disc, flange end.

d. Globe Valves, 2" and smaller: 125# bronze, screwed, bronze disc.

e. Check Valves, 2" and smaller: 125# bronze, screwed, bronze disc, swing check.

f. Check Valves, 2½" and larger: 150# cast steel, flanged end, swing check, bronze disc, bronze seat ring.

g. Balancing Valves, 3" and smaller: Ball valves with glass reinforced Teflon seats and stem seals, balancing stop, chrome plated brass ball, blow out proof brass stem and vinyl grip on handle.

h. Globe and Angle Valves, 2½" and larger: 125#, iron body, bronze mounted, outside screw rising stem, bolted bonnet, renewable disc and seat flange end.

15C-4 Hangers and Supports:

a) The hangers shall adequately support the piping system. They shall be located near or at changes in pipe direction and at concentrated loads. They shall provide vertical adjustment to maintain pitch required for proper drainage. They shall allow for expansion and contraction of the piping.

b) Hangers shall be constructed of malleable or wrought iron and hangers supporting copper piping shall be copper plated. Supports used at collector field shall be constructed as specified on drawings.

1. Where groups of three or more pipes occur, they may be supported with trapeze hangers using two hangers as specified with a capped pipe-cross number.

c) Horizontal piping shall be supported as follows:

Pipe Size	Hanger Rod Diameter	Maximum Spacing
1/2"	3/8"	6'0"
3/4" to 1"	3/8"	8'0"
1-1/4" to 2"	3/8"	10'0"
2½" to 3½"	1/2"	12'0"

d) Hangers and supports for cold and hot water piping shall be large enough to encompass the insulation and the metal saddle for same. Provide at hanger point cellular glass insulation in sections 2" longer than saddle. Insulation to have same finish as adjacent covering and same thickness as adjacent insulation.

e) Saddles for 4" and smaller piping shall be fabricated of 16 guage galvanized iron. Saddles shall encompass one half the diameter of the covering and lengths shall be 12" long.

15C-5 Pipe Sleeves:

a) All pipe sleeves through slabs, walls, and partitions shall be 1/2" greater in inside diameter than the external diameter of pipe passing through. Domestic cold water and chilled water pipe sleeves shall be 1/2" greater in diameter than pipe insulation. All sleeves shall be fabricated of new material, cut square and reamed.

b) Sleeves through partition walls shall be schedule #40 steel pipe extending through the full thickness of the wall, and shall be flush with the finished surfaces. Seal space between piping and sleeve with oakum caulking.

c) Generally no sleeves will be required throughslabs on grade.

d) Sleeves shall be set and maintained in place at required locations during the progress of the work.

15C-6 Vibration Isolation:

a) Mechanical equipment shall be provided with vibration isolation devices as herein described.

b) Vibration isolators shall be selected in accordance with weight distribution of the equipment being isolated to provide reasonably uniform deflection.

c) Where isolators are installed exposed to the weather, springs and hardware shall be cadmium plated or hot dipped galvanized. Housings shall be galvanized or be coated with red lead primer and neoprene paint.

d) Types of Vibration Isolation Devices

Type 1 - Spring type isolators shall be free standing and laterally stable without any housing and complete with 1/4" neoprene acoustical friction pads between the baseplate and the support. All mountings shall have leveling bolts that must be rigidly bolted to the equipment. Spring diameters shall be no less than 0.8 of the compressed height of the spring at rated load. Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. Submittals shall include spring diameters, deflections, compressed spring height and solid spring height.

Type 2 - Vibration hangers shall contain a steel spring and 0.3" deflection neoprene element in series. The neoprene element shall be molded with a rod isolation bushing that passes through the hanger box. Spring diameters and hanger box lower hole sizes shall be large enough to permit the hanger rod to swing thru 30° arc before contacting the hole and short circuiting the spring. Springs shall have a minimum additional travel to solid equal to 50% of the rated deflection. Submittals shall include a scale drawing of the hanger showing the 30° capability.

Type 3 - Single flanged arch type pump connectors, minimum 6" long face to face. They shall be constructed of Tee-molded black teflon bellows suitable for 1" to 10" diameter pipes. These bellows shall have reinforcing monel rings, duct iron integral flanges with 150# ASA Standard drillings and control units suitable for temperature to 250F and have dynamically rated working pressures to 150 psi with adequate safety factor. Each piping expansion joint shall include control cables to prevent elongation when joint is unrestrained and subject to maximum design working pressure. Rubber washers shall prevent metal to metal contact of control rods with stretcher bolt plates.

Recommended maximum temperature shall be no less than 180°F for cold and chilled water lines and no less than 260°F for hot water lines.

c) Schedule of Usage for Vibration Isolation Devices

1. Type 1 - Spring Isolators:

2. Type 2 - Spring Hangers: Pump suction and discharge piping located within mechanical rooms

3. Type 3 - Pump Connectors: Suction and discharge ends of base mounted pumps.

SECTION 15D - MECHANICAL SYSTEM INSULATION

15D-1 Scope:

a) The work covered by this specification consists in furnishing all labor, equipment, accessories and materials and in performing all operations necessary for the installation of thermal and sound insulation for the plumbing, heating, and air conditioning piping in strict accordance with the insulation section of this specification and applicable drawings.

b) Insulation shall be installed by skilled workmen regularly engaged in this type of work.

c) Contractor shall submit a list of insulation materials for approval prior to beginning any application work.

15D-2 General Insulation Requirements

a) Materials

1. Unless specifically excluded, all insulation shall have composite (insulation, jacket, or facing, and adhesive used to adhere the facing or jacket to the insulation) fire and smoke hazard ratings as tested by procedure ASTM E-84 not exceeding:

Flame Spread	25
Smoke Developed	50

2. Accessories, such as adhesives, mastics, cements, tapes, glass fabric and asbestos cloth for fittings shall have the same component ratings as listed above.

3. All products or their shipping cartons or packages shall bear a label indicating that flame and smoke ratings do not exceed above requirements.

b) Jacket and Facing Descriptions:

1. ASJ glass cloth (All Service Jacket), white, factory sizes, beach puncture 150 oz. in./in/tear,tensile strength 100 lbs. per inch width,mullen burst 300 psi with saran vapor barrier. Water vapor permeability .02 perms. All piping within the building exposed and concealed.

2. FSK reinforced foil and paper (Foil Scrim Kraft). Aluminum foil (minimum .75 mil. thick) reinforced with fibreglass yarn mesh and laminated to 40 lbs. chemically treated fire resistant Kraft U/L rated.

3. Dura Mesh glass fabric shall be white resin coated 10 x 10 mesh.

4 Bituthene waterproofing membrane shall be used for underground application. All seams must be overlapped at least $2\frac{1}{2}$".

5. Aluminum jacketing (Lock-on Type rolled smooth with factory attached moisture barrier) 3/16" thick shall be used for outside above-grade installation.

c) Insulation Descriptions:

1. Glass fibre insulation having average thermal conductivity not exceeding .23 BTU in. /sq.ft./^{O}F/hr at mean temperature of 75^{O}F. Glass fibre insulation shall be rated for 370^{O}F hot water.
2. Cellular glass insulation having an average conductivity not exceeding .36 BTU in./sq. ft./ ^{O}F/hr. at mean temperature of 75^{O}F, and having a water-vapor permeability of 0.00 pirm-in.

3. Pre-molded Urethane pipe insulation, having an average conductivity not exceeding .14 BTU in./sq.ft./^{O}F/hr. at mean temperature of 75^{O}F. Urethane insulation shall be rated for 225^{O} hot water.

4. Armaflex pipe insulation having an average conductivity not exceeding 0.28BTU in./sq.ft./^{O}F/hr. at mean temperature of 75^{O}F. Insulation should be rated at 220^{O}F for hot water and having a water vapor permiability not exceeding 0.2 pirm-in.

d) General Application Requirements:

1. Install insulation continuously through wall, floor and ceiling openings and through sleeves, except for runouts at connection to radiation.

2. Insulation shall be applied on clean,dry surfaces.

3. At transition points (inside to outside or above grade to below grade) all joints shall have smooth finish and be weatherproof.

15D-3 SPECIFIC INSULATION REQUIREMENTS

a) Domestic Water Piping (HW)

1. All new domestic hot water piping shall be insulated with 1-1/2" fiberglass insulation, or approved equal for sizes 2" and larger with 3/4" Armaflex for 1-1/2" and smaller.

2. Exposed and concealed areas shall have fibreglass insulation anr shall be finished with factory applied "ASJ"

3. ASJ and end laps shall be sealed with adhesive applied to both surfaces.

4. Fittings, valve bodies and flanges shall be covered with mitered pipe insulation (Armaflex or fibreglass) segments secured with 3-ply jute twine with one coat of insulating cement. After cement is dry, fittings shall be finished with two coats of sealer, reinforced with Duramesh glass fabric membrane.

b) Solar Water Supply and Return (SWS, SWR) and Storage Lines (SLS,SLR)

1. Inside Building - All hot water or Glycol piping specified above should be covered with fiberglass insulation furnished with ASJ and conforming with the following recommended thickness:

Pipe Size	Insulation Thickness
2" and larger	1-1/2"
1½" and smaller	1"

Fittings, valve bodies and flanges shall be covered with mitered fiberglass insulation, segments secured with 3-ply jute twine with one coat of insulating cement. After cement has dried two (2) coats of sealer shall be applied and reinforced with Duramesh glass fabric.

2. Outside Building (Below Grade) - All hot water or Glycol Piping specified shall be covered with a factory supplied white FRJ. Fittings shall be covered with same insulation and jacket of same thickness and the entire piping system shall be installed and sealed water right by wrapping with Bituthene waterproof membrane according to manufacturer's recommendation.

3. Outside Building (Above Grade) - Same insulation as Below Grade but Bituthene membrane to be superceded by a rolled aluminum jacket with factory attached moisture barrier (Lock-On Type) installed according to the manufacturer's recommendations Fittings, valve bodies and flanges shall be insulated as described in Section b)1.

c) <u>Hot Water/Chilled Water Supply and Return Lines</u> (CWS,CWR,H/CS,H/CR)

1. <u>Inside Building</u>- All piping shall be insulated with cellular glass or Armaflex piping insulation as shown in table below. The seams and joints shall be fully covered with adhesive and the surface nearest pipe shall be pressed together first and evenly before joining entire surface. Exposed and concealed areas with cellular glass insulation shall be finished with applied vinyl/aluminum laminated jacketing. End laps shall be sealed with adhesive applied to both surfaces. Fittings, valve bodies and flanges shall be insulated as Described in Section b)1.

Pipe Size	Insulation Thickness and Type
1" and smaller	3/4" Armaflex
1-1/2"	1" Cellular Glass
1" and larger	1-1/2" Cellular Glass

2 <u>Outside Building (Below Grade)</u> - Same as Section b)2.

3. <u>Outside Building (Above Grade)</u> - Same as Section b)3.

d) <u>Insulation Table</u>

Piping Loop	Location	Type of Insulation/Jacket	Thickness
SWS,SWR	Storage Room	Fiberglass/ASJ	1-1/2"
SLS,SLR	Storage Room	Fiberglass/ASJ	1"
SWS,SWR	Outside-Below Grade	Urethane/Bituthene	1-1/2"
SLS,SLR	Outside-Below Grade	Urethane/Bituthene	1-1/2"
SWS,SWR	Outside-Above Grade	Urethane/Aluminum	1-1/2"
SLS,SLR	Outside-Above Grade	Urethane/Aluminum	1-1/2"
CWS,CWR	Storage Room	Armaflex	3/4"
CWS,CWR	Outside-Below Grade	Urethane/Bituthene	1-1/2"
CWS,CWR	Outside-Above Grade	Urethane/Aluminum	1-1/2"
H/CS,H/CR	Storage Room	Cellular Glass	1" for pipe size 1½" or smaller 1½" for pipe size 2" or larger
HW	Inside Building	Fiberglass	1½" for pipe size 2" or larger
		Armaflex	3/4" for pipe size 1½" or smaller
CDS,CDR	No Insulation outside		

e) Storage Tank:

1. All surfaces shall be covered with 3" thick fiberglass, 2" thick fiberglass (storage tank), minimum 4-1/4 lb. density.

2. Insulation shall be banded in place, tightly butted, joints staggered and secured with 1/2" x .015" thick galvanized steel bands on 12" centers. Where required, welded studs, clips or angles shall be provided as anchors for bands.

3. Over the insulation 1" galvanized hexogonal wire mesh shall be tightly stretched in place and secured by wiring to anchors with edges tied together.

4. Finish shall be hydraulic insulating cement applied min. 1/2" thick and trowelled smooth.

5. Apply a 10 x 10 Dura Mesh glass fabric over cement between coats of sealer.

SECTION 15E - PAINTING AND IDENTIFICATION

15E-1 Work Included

a) The Contractor shall perform all painting and identification of mechanical equipment, piping, etc., within equipment rooms and elsewhere as specified herein in accordance with the painting section of the specification.

b) All exposed insulated surfaces in the equipment rooms shall be painted with two (2) coats of insulation coating. The first coat shall be mixed with not more than 25% by weight of water and the second coat shall be only slightly diluted.

c) All prefinished mechanical equipment such as pumps, fan units, etc., shall be touched up to match existing shop finish.

d) Identification of piping shall be accomplished by stenciling black letters on a yellow background in accordance with ANSI standards. Letters to be stenciled using black stenciling paint and stenciling brushes. Stenciling of direction of flow shall be accomplished by stenciling a black arrow on a yellow background. Minimum height of letters shall be 1".

e) Identification shall be provided for all exposed piping within the building and also in accessible concealed spaces, such as at access panels.

f) The following abbreviations shall be used when identifying piping:

1.	Domestic Cold Water	CW
2.	Solar Water Heating Supply	SWS
3.	Solar Water Htg. Return	SWR
4.	Chilled Water Supply	CWS
5.	Chilled Water Return	CWR
6.	Condensate Drain Supply	CDS
7.	Condensate Drain Return	CDR
8.	Domestic Hot Water	DHW
9.	Supply Heating/Cooling	H/CS
10.	Return Heating/Cooling	H/CR
11.	Storage Loop Supply	SLS
12.	Storage Loop Return	SLR

SECTION 15 - TESTING AND BALANCING

15F-1 General:

a) All piping systems shall be leak tested at 60 psi with air after erection and before concealing or covering. Any materials or workmanship found faulty shall be immediately replaced or repaired and sections or systems retested.

b) Any damage resulting from leakage of piping during the testing or guarantee periods shall be repaired at the expense of the Contractor.

c) Tests shall be made in the presence of the Honeywell Quality representative.

d) Certificates shall be furnished to Honeywell Quality representative that tests have been satisfactorily completed.

15F-2 Hot Water and Chilled Water Systems:

a) Testing and balancing of all hydronic systems shall be performed by the Contractor in conformance with the requirements of this section of the specifications and under the presence of a Honeywell representative.

b) These systems shall be tested under air pressure of 60 psig.

c) Tests shall be applied to all piping and equipment which is part of these systems, including pumps, and valves, except items that might be damaged because of excessive pressure.

d) The Contractor shall support the starting of the hot water and chilled water systems and shall follow the procedure to be outlined in a startup-operation and maintenance manual.

e) Balancing.

1. Honeywell Quality representative will witness and certify all the balancing.

2. Check all the flows with the use of the flow balancing valves and adjust to specified values.

3. Check the system flows, pressure and temperature and control system logic utilizing the SDAS installed by the Government. The Contractor shall provide corrective effort as necessary to establish proper flows.

f) Tests and Adjustments:

1. All interior and exterior water piping shall be tested at 60 psig maintaining the pressure for four hours with not more than one (1) percent drop in pressure. The system shall be filled with water which shall remain in the system until the water and the piping are the same temperature. If water pipe testing is under the jurisdiction of the local inspector, his requirments shall be used; however, they shall be not less than specified herein. The tests shall be performed in the presence of the representative of the Architect and to his satisfaction.

2. All exterior or interior piping shall be tested and approved before backfilling or concealing. Failure to secure the approval of the Architect's representative makes it mandatory for the Contractor to completely expose the piping for testing. All expense involved in the uncovering of the piping for the test shall be borne by the respective Contractor with no change in contract.

3. Sterilization - After pressure tests have been made, the entire new domestic water-distribution system to be sterilized shall be thoroughly flushed with water until all entrained dirt and mud have been removed before introducing chlorinating material. The chlorinating material shall be either liquid chlorine conforming to Federal Specification BB-C-120 or hypochlorite conforming to Federal Specification O-C-114, type II, grade B, or Federal Specification O-S-602, grade A or B. The chlorinating material shall provide a dosage of not less than 50 parts per million and shall be introduced into the system in an approved manner. The treated water shall be retained in the pipe long enough to destroy all non-spore-forming bacteria. Except where a shorter period is approved, the retention time shall be at least 24 hours and shall produce not less than 10 p.p.m. of chlorine at the extreme end of the system at the end of the retention period. All valves in the system being sterilized shall be opened and closed several times during the contact period. The system shall then be flushed with clean water until the residual chlorine is reduced to less than 1.0 p.p.m. During the flushing period all valves and faucets shall be opened and closed several times. The sterilizing shall be repeated until tests indicate the absence of pollution for at least 2 full days. The system will not be accepted until satisfactory bacteriological results have been obtained.

SECTION 16F - CONTROL SUB-SYSTEM

16F-1 Work Included

a) The Contractor shall install all control equipment and electrical wiring necessary for proper operation of the solar heating and cooling system.

b) The Mechenical Contractor is responsible for installation of sensor wells and Electrical Contractor is responsible for sensor and wiring installation.

16F-2 Warranty

a) The Contractor shall warrant above work for a period of one year after completion.

16F-3 Procurement of Control Equipment

a) Control equipment to be supplied by the Government thru Honeywell shall consist of:

1. All motorized control valves
2. All control valve motors and linkages.
3. All aquastats and control sensors.
4. All thermostats.
5. System Control Panel.

The Contractor shall install all above equipment. Honeywell personnel will assist in the start-up and checkout of the Control system.

16F-4 Basic Materials

a) The Contractor shall provide all materials required for a complete installation of above equipment.

16F-5 Electrical Wiring

a) Electrical wiring shall be in accordance with Division 16 and the National Electrical Code.

SECTION 16G - SITE DATA ACQUISITION SUBSYSTEM

16G 1 Purpose

a) A Site Data Acquisition Subsystem (SDAS) will be installed to evaluate the performance of the solar heating and cooling system as well as determine the contribution of collected solar energy in reducing the consumption of conventional energy. The Site Data Acquisition Subsystem components will be furnished by NASA, consisting of instrumentation sensors, junction box, Site Data Acquisition Subsystem Module and a telephone interface.

b) Note that all materials and labor in the Site Data Acquisition Subsystem are to be clearly identified as an alternate to the Base Bid.

16G-2 Required Work

a) Instrumentation Installation

1. The Contractor will install all sensors listed in the instrumentation schedule. The sensor locations are shown on the Site Data Acquisition Subsystem Schematic and the mechanical plans. The Contractor shall install the sensors in the locations shown so as

to provide for accessibility and ease of servicing.

b) Instrumentation Wiring
   1. The Contractor shall perform all electrical wiring from each sensor back to the Junction Box as shown on details and described below.

c) Watt Transducer Installation
   1. Contractor shall install and wire watt transducers on or near equipment served, and revise factory wiring as required. See Watt Transducer details.

d) Site Data Acquisition Subsystem Module
   1. The Site Data Acquisition Subsystem Module will be furnished by NASA, and installed by the Contractor. The installation location will be as shown on mechanical plans.

e) SDAS Telephone Interface
   1. NASA will provide the telephone installation required for the SDAS.

f) SDAS Electrical Interface
   1. The SDAS will interface with a standard 110-125V, 60 Hertz, 1 phase, 3 amp service. A standard 3 wire interface (safety ground, power and return) with a standard twist lock outlet, located within six feet of the SDAS, shall be provided by the Contractor. NASA shall provide a three pin twist lock connector and cable to interface the SDAS with the power outlet.

16G-3 Required Work

a) Junction Box
   1. NASA shall provide a Junction Box to the Contractor for installation in a location as shown on mechanical plans. The Junction Box shall be located so that it is accessible for wiring connections from the sensors into the top and is within four feet of the SDAS location. At the required mounting location, the Junction Box shall be mounted using the four mounting feet located at the top and bottom of the unit. Depending on the characteristics of the mounting surface, molly bolts, wood screws or bolt/nut combinations shall be used to mount the unit. The Junction Box shall be installed in a top-up orientation.

b) Junction Box/Sensor Interface
   1. NASA will establish the wire run list which identifies where each sensor wire attaches to the Junction Box. The Junction Box will be prewired from the terminal strips to output connectors by NASA prior to delivery to the site. Each applicable sensor detail illustrates the sensor to Junction Box wiring. The Contractor shall connect sensor wires to Junction Box terminals according to a wiring diagram to be provided by NASA.

c) Junction Box/SDAS Module Interface Cables
   1. NASA will install the cables between the Junction Box and the SDAS module.

16G-4 Restrictions on use of Instrumentation

a) No monitoring, indicating or readout devices are to be connected to the Instrumentation sensors, i.e., paralleled with the Site Data Acquisition Subsystem, without prior approval of NASA.

16G-5 Failed Sensor Replacement

a) The improperly operating sensor will be identified to Honeywell ERC after examination of the sensor for signs of physical damage such as broken wires, loose connectors, loose terminals, etc. If no physical damage is apparent in the inspection, NASA shall be notified for further instructions. If mechanical damage is apparent, the sensor shall be replaced by the Contractor with a sensor supplied by NASA. The defective sensor shall then be returned to NASA for failure analysis.

16G-6 Installation Materials and Methods

a) Wiring from the sensors to the Junction Box shall be performed by the Contractor utilizing wire supplied by the Contractor. The wire size and number of conductors required for each sensor type is specified in list below and each sensor detail. The Sensor-to-Junction Box wire shall be UL approved, color-coded, audio and instrumentation grade cable of the following manufacture or equal:

Alpha O/N 2421-18 guage, 2 conductor
Dearborn P/N 972202-18 guage, 2 conductor
Alpha P/N 2424-18 guage, 4 conductor
Dearborn P/N 971804-18 guage, 4 conductor

All externally exposed wire in the outdoor environment or buried shall be in conduit.

Wire nuts will be utilized for terminations at the following sensors:

Temperature Sensors
Relative Humidity Sensor
Pyranometer
Gas Meter

Wire nuts shall be replaced with a butt splice in areas where the connections are exposed to vibration.

Ring terminals will be used to terminate the wires at the following sensors:

Flow Meter (Liquid)
Watt Transducer
Flow Meter (Air)

If terminations conflict with local codes, local codes shall be applicable.

b) Other Materials

1. All other materials necessary for installation of the sensors shall be provided by the Contractor. This would include but not be limited to, pipe fittings, fasteners, electrical enclosures, terminal blocks, electrical wiring, electrical conduit, and any other materials necessary for a complete installation of all sensors.

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