DOE/NASA CONTRACTOR REPORT

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SYSTEM DESIGN PACKAGE FOR SIMS PROTOTYPE SYSTEM 2, SOLAR HOT WATER

Prepared from documents furnished by

IBM Corporation
Federal Systems Division
150 Sparkman Drive
Huntsville, Alabama 35805

Under Contract NAS8-32036 with

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For the U.S. Department of Energy

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Solar Energy

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16. ABSTRACT

This report is a collection of documents and drawings that describe a solar hot water system. The report contains the necessary information to evaluate the design and with information sufficient to assemble a similar system.

The International Business Machines Corporation, under NASA/MSFC Contract NAS8-32036, developed prototype system 2 solar hot water for use in a single family dwelling. The system has been installed in Building Number 20, which is a single family residence on the grounds of the Veterans Administration Hospital at Togus, Maine. It consists of the following subsystems: collector, storage, energy transport, and control. It is a design with wide-spread application potential with only slight adjustments necessary in system size.

A small amount of retyping and reformatting has been done to publish this document, in the interest of clarity.

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SYSTEM DESCRIPTION

1.0 INTRODUCTION

A solar energy system for supplying domestic hot water to single family residences has been designed by IBM under contract NAS8-32036 to the National Aeronautics and Space Administration's Marshall Space Flight Center. The prototype system illustrated pictorially in Figure 1-1, is an integration of currently marketed subsystems and has been built and demonstrated as part of the government's National Program for the Solar Heating and Cooling of Buildings.

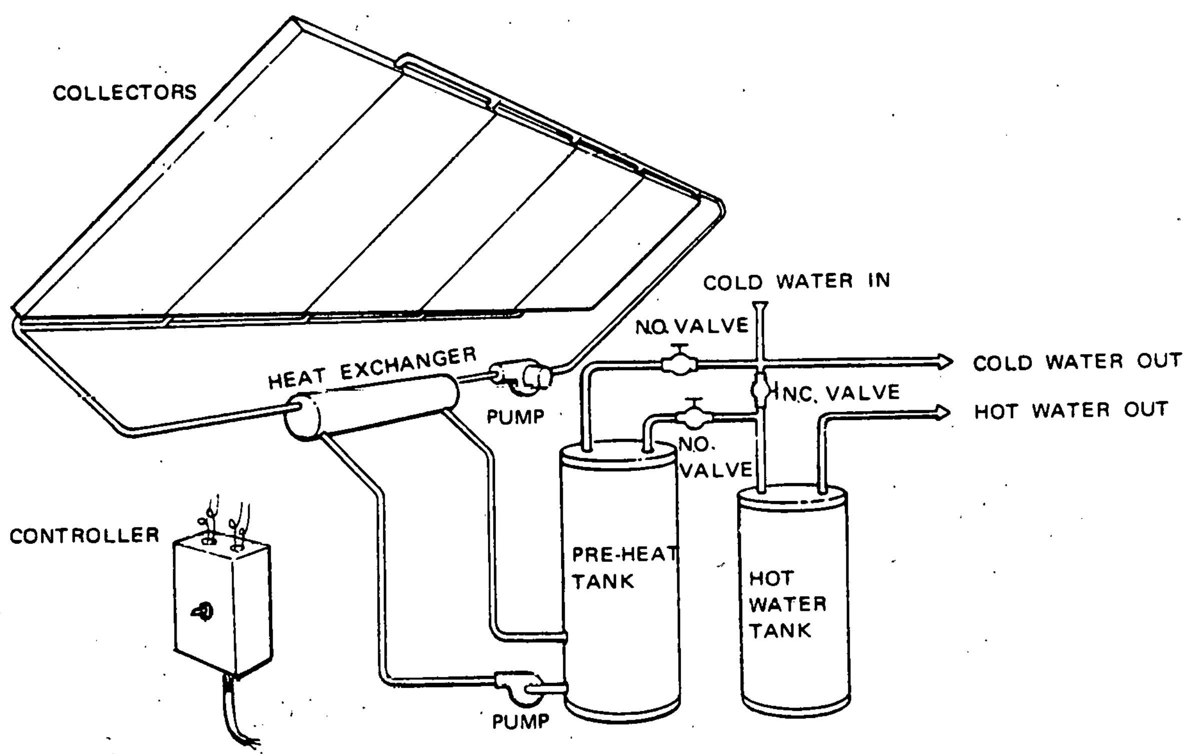


Figure 1-1. System Illustration

2.0 SYSTEM FUNCTIONAL DESCRIPTION AND OPERATION

SIMS Prototype System 2 is a liquid, closed loop, non-draining solar energy system for supplying domestic hot water to single family residences. As shown schematically in Figure 2-1, it consists of solar collectors, storage tank, pumps, heat exchanger and associated plumbing and controls. A silicone fluid circulated through the collector absorbs energy which is transferred by way of a heat exchanger to potable water stored in a preheat tank. The preheat tank, which is used to store solar energy, services a standard domestic hot water (dhw) heater tank which maintains the supply water at a preset temperature level, typically 140°F. City water replenishes that flowing from the preheat tank as water is drawn at the service outlets.

Thus solar energy is used to preheat water for the standard domestic hot water system, which is presumed to exist or be supplied separately and is not part of the solar energy system. The standard dhw system serves as the auxiliary energy source and can supply all hot water needs in the event of extended inclement weather. It is the primary functional interface with the solar energy system.

General features or characteristics of the system design are:

- Single family residence application
- Continental U.S. location
- Liquid flat plate collectors
- Silicone heat transfer fluid (non-toxic)
- Fail-safe double wall heat exchanger
- Automatic operation

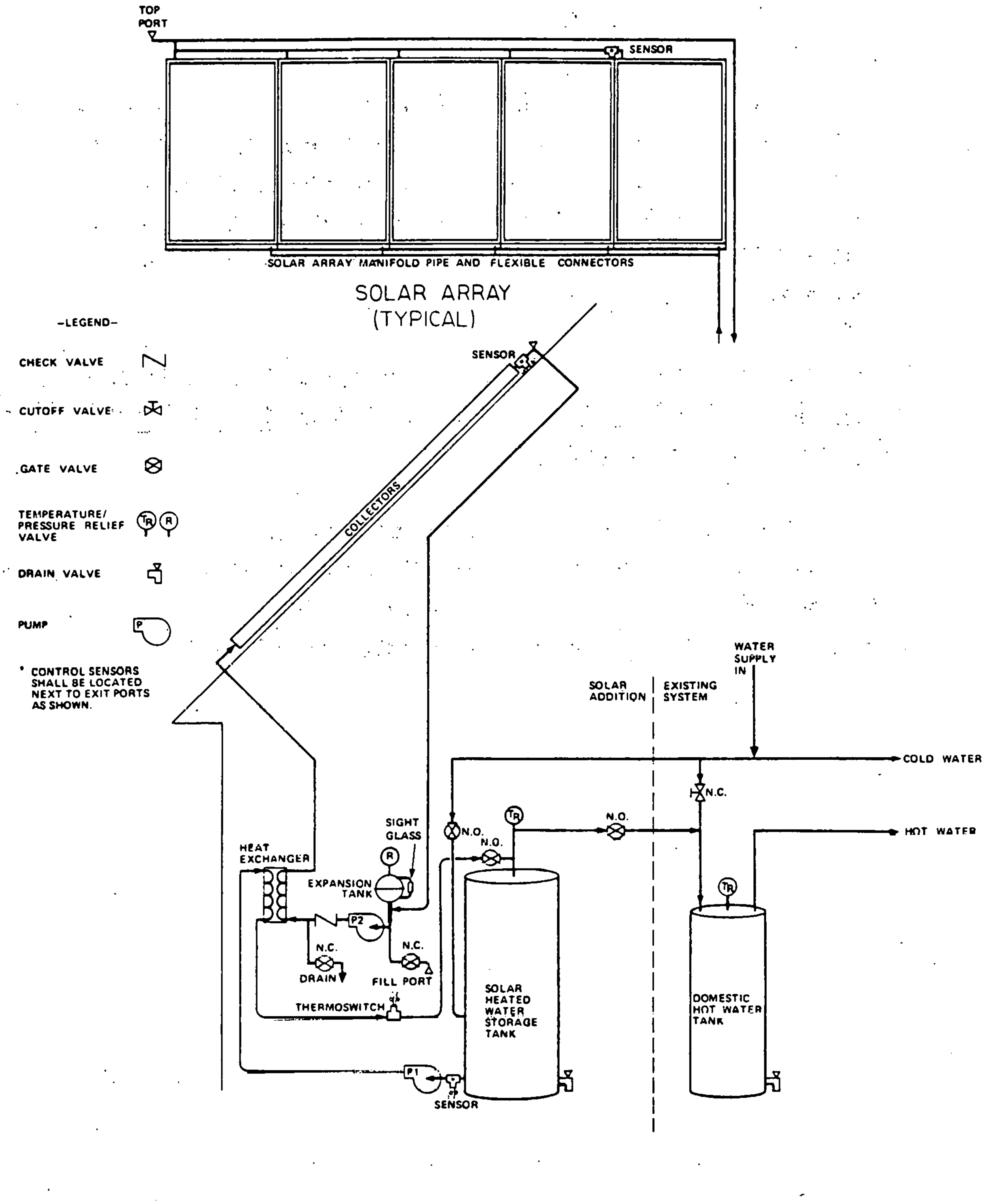


Figure 2-1. System 2 Functional Schematic

- Conventional auxiliary energy dhw system
- Over-temperature protection
- Freeze protected

The baseline system accommodates nominal domestic hot water requirements of 50 to 120 gallons per day at 140°F. This range is sufficient to cover the predominance of American households. The system can be scaled up or down, however, for a wide range of hot water requirements for single family, multi-family, or light commercial application without significant change to the design concept.

The detailed System 2 design is defined by IBM Drawing 7933631-D, SYSTEM 2 (LOF) DESIGN DESCRIPTION; and Drawing 7933449, SYSTEM PERFORMANCE SPECIFICATION FOR SIMS PROTOTYPE SYSTEM NO. 2.

The elements of the system are arranged into subsystems which are described in Section 3. System performance and sizing is addressed in Section 4.0, with an example case for a specific site/application. Vendor data brochures for the major system components are included in Appendix A.

3.0 SUBSYSTEM DESCRIPTION

The major subsystems comprising the solar hot water system are:

- Collector
- Storage
- Energy Transport
- Control.

A summary of the general characteristics of the subsystems is presented in Table 3-1, with a more detailed description in subsequent paragraphs.

Table 3-1. Subsystem Characteristic Summary

Subsystem	Description	Maufacturer/Model*
Collector	84" x 36" x 5.5" flatplate type, liquid, double glazed, non-selective, copper absorber and tubes	Libbey-Owens-Ford/1112 Sun Panel
Storage	80-120 gallon preheat tank	Ford Products Co.
Energy Transport	(1) Circulating pumps	Grundfos/UP25-42SF and UP26-64
	(2) Heat Exchanger	Solar Shop/HE1
	(3) Expansion Tank, 3 gal.	Ace/X8-0
	(4) Silicone Heat Transfer Fluid	Dow Corning/Q2-1132
	(5) Piping, Fittings, Valves	--
Control	(1) Differential Thermostat	Rho Sigma/106
	(2) Thermoswitch	Elmwood/3100
* or approved equivalent		

3.1 COLLECTOR SUBSYSTEM

The Libbey-Owens-Ford (LOF) Company Sun Panel Model 1112 liquid solar collector is shown pictorially in Figure 3-1. The basic collector module is a 7' x 3' rectangular unit housed in an aluminum frame and weighing 150 pounds. The absorber plate is an embossed copper sheet 0.021 inches in thickness with 3/8" diameter copper fluid tubing soldered to the back side. The absorber coating is non-selective flat black paint. Three inches of treated fiber glass insulation under the absorber plate, and side insulation is used to reduce heat loss. The module has two 1/8" thick tempered safety glass covers.

Typically, five (5) collectors are arrayed together with appropriate piping to form the collector subsystem. Section 4.0 describes how to size the array for specific applications. Collector mounting and installation guidelines are addressed in Section 5.0.

The liquid system has a parallel flow pattern designed to provide uniform flow through all tubes. The absorber plate tubes are 3/8" O.D. copper. The internal supply and return manifolds at the upper and lower end of the module are 5/8" O.D. copper. Inlet and outlet fluid connections are 1/2" male NPTF.

The performance of the LOF collector in terms of collector efficiency is as described by Figure 3-2. The parameters are defined as follows:

η = Collector Efficiency

T_{in} = Inlet Fluid Temperature, ^oF

T_{out} = Outlet Fluid Temperature, ^oF

T_{amb} = Ambient Air Temperature, ^oF

I = Insolation, Btu/Hr./Ft^2

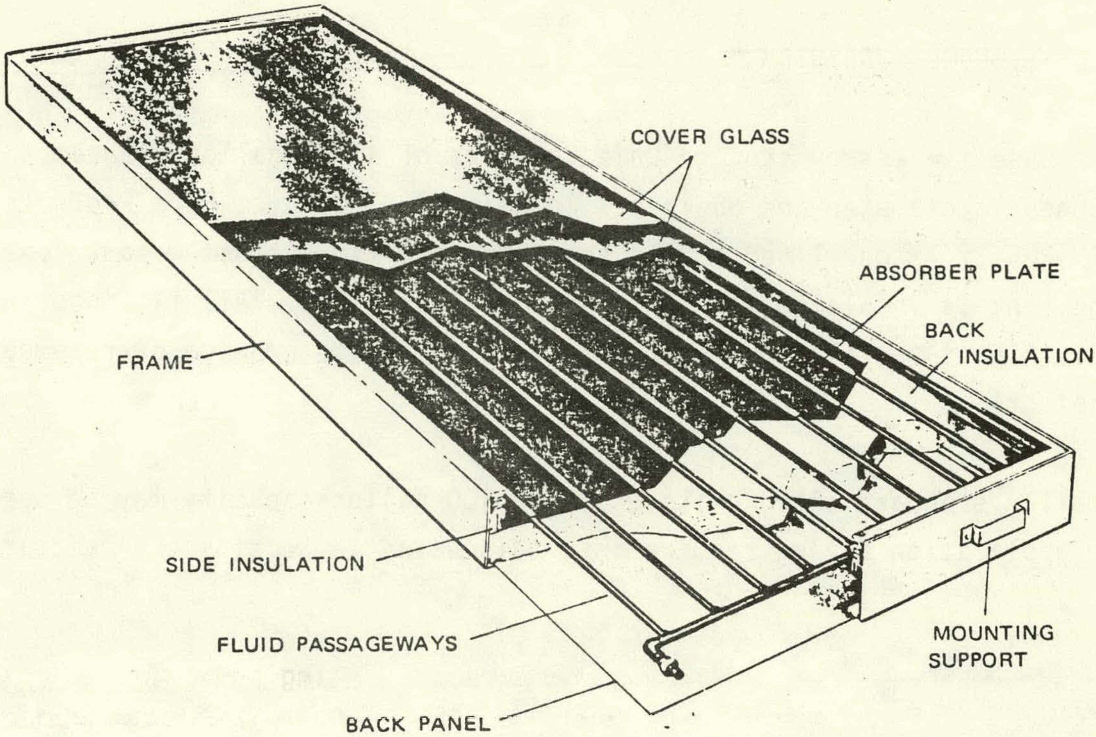


Figure 3-1. Libbey-Owens-Ford Model 1112 Sun Panel Collector

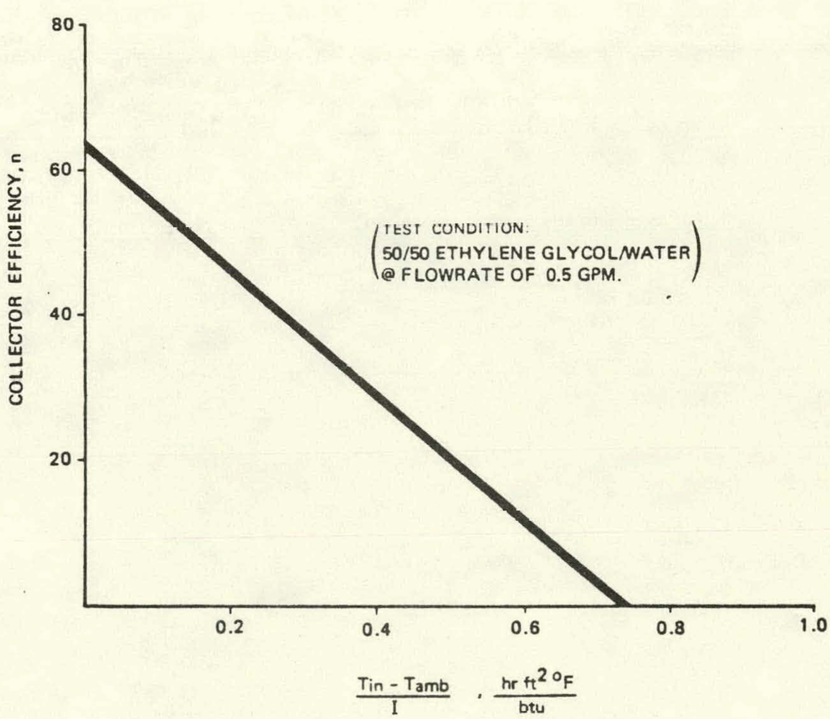


Figure 3-2. LOF Collector Efficiency

3.2 STORAGE SUBSYSTEM

The baseline energy storage unit consists of a 120 gallon preheat tank, 28 inches in diameter and 68 inches in height. The unit, Ford Products Model AB 120S, is stone-lined and of standard domestic hot water tank construction. The tank is insulated with 2 inches of fiber glass. All fittings are 3/4 inch NPT. The integral thermostat will be utilized to provide over-temperature protection.

Smaller standard sized units of 80 or 100 gallon capacity may be used if site or application sizing requirements (discussed in Section 4.0) dictate.

3.3 ENERGY TRANSPORT SUBSYSTEM

The energy transport subsystem is comprised of circulating pumps, a liquid-to-liquid heat exchanger, expansion tank, silicone heat transfer fluid and associated plumbing (piping, fittings and valves).

- Two pumps are utilized in the System 2 design. In the collector loop the fluid is circulated by a Grundfos Model UP26-64 pump, 1/12 horsepower capacity, 110 volts AC. The water loop uses a Grundfos Model UP25-42SF unit of stainless steel construction with 1/20 horsepower, capacity, 110 volts AC. Both units have internal bearings lubricated by the pumped fluid. Fluid line connection at the pumps are by 1 inch female pipe thread fittings. Ball type isolation valves are included at inlet and outlet ports as an integral part of the pumps.

- The heat exchanger between the collector and water loops is all copper and of "fail-safe" double wall construction to preclude leakage of the silicone fluid into the potable water. Overall dimensions are 3 inches diameter by 31 inches long, with 1 inch diameter inlet and outlet connections for the silicone loop and 1/2 inch inlet and outlet connections for the water loop. The heat exchanger is manufactured by Solar Shop, "TRANSOLATOR" Model HE1.

- To compensate for thermal expansion and contraction of the collector fluid, a 3-gallon A.S.M.E. expansion tank is included in the primary loop. The tank is galvanized steel with 3/4 and 1/2 inch pipe thread fittings. Manufacturer is ACE, Model X 8-0.

- The heat transfer fluid used in the collector loop is a dimethyl silicone, Dow-Corning Q2-1132. Characteristics are:

    - Non-toxic
    - Inert, stable
    - Low freezing point (<-120°F)
    - High boiling point (>400°F)
    - Dielectric
    - Acceptable heat transfer and fluid flow properties.

The silicone fluid has a higher propensity for leakage than such liquids as water or ethylene glycol, requiring more stringent design control of fittings and joints.

- Piping is standard Type L copper tubing, one inch diameter in the collector loop and 3/4 inch in the water loop. Flexible couplings, Hydro-Flex Model 904, are used to connect the collectors to the supply and return headers. All valves are of type common to the building construction trades. Sweat joints (soldered) are preferred for the piping system, to minimize the potential for fluid leakage, although threaded fittings are acceptable when necessary. Compression or flare fittings are avoided.

3.4 CONTROL SUBSYSTEM

The control subsystem provides for the following control mode/functions.

A. Normal (Automatic) Collection - This mode provides control for the collection of solar energy when collectable in sufficient quantity to add to the energy state of the preheat tank. This is accomplished with a Rho-Sigma Model 106 differential thermostat, including fluid SP type temperature sensors at the collector outlet and the (lower) preheat tank exit. Circulator Pumps P1 and P2 (See Figure 2-1) are simultaneously turned on when the collector temperature exceeds the tank temperature by 20 F degrees. Pump P2 circulates silicone fluid to transfer absorbed solar energy from the collectors to the primary side of the heat exchanger. Pump P1 circulates preheat tank water through the secondary side of the heat exchanger where it is heated and returned to the tank. Both The pumps are shut off when the differential temperature drops below 3 F degrees.

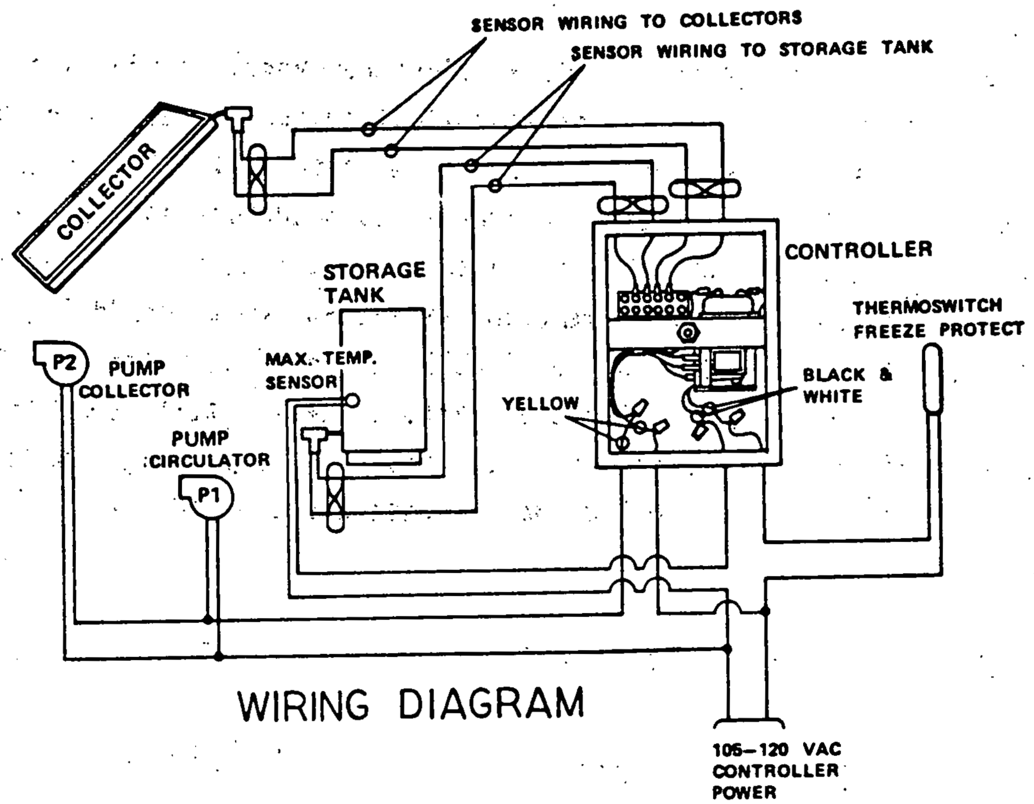
   As domestic hot water is used, city water at line pressure is supplied to the bottom of the preheat tank. Solar heated water from the top of the preheat tank flows into the conventional domestic hot water heater. The latter operates in the conventional fashion, adding auxiliary energy as required to maintain the temperature in the dhw tank at the set point.

B. Over-Temperature Protection - The control subsystem removes power from the controller and hence the coolant pumps when the temperature in the preheat tank exceeds a safe or desirable preset temperature level. This is generally the control temperature of the conventional dhw tank, typically 140°F. The adjustable, normally closed thermostat provided with the preheat tank will provide the sensing and switching for this function.

C. Manual Operation - To support solar system activation, checkout and maintenance operations, a mode of control is provided in which the pumps are powered up continuously regardless of the temperature difference between collector and preheat tank. Note that the solar preheat tank can gain or lose heat depending on the relative collector and tank temperatures. This mode is provided also by the Rho-Sigma differential thermostat via the ON switch.

D. Low Temperature Protection - The control subsystem includes a provision to insure against freezing of the water in the preheat tank under all possible normal operating modes. Such a condition can be envisioned only if the controller is inadvertently left in the Manual Operation ON mode under severe cold weather conditions or if the control system fails. A thermoswitch (Elmwood Co., Model 3100) is mounted to the water pipe between the heat exchanger outlet and the preheat tank. The snap action switch is set to open at $40^{O}F$ on decreasing temperature, removing power from the controller and thus shutting down the pumps.

The Control Subsystem wiring diagram is shown in Figure 3-3.



WIRING TABLE				
CIRCUIT/COMPONENT	POWER RATING AMPS	VOLTS	WIRE	NOTES
COLLECTOR SENSOR			18 ga. TWISTED PAIR	200 FT MAX.
STORAGE SENSOR			18 ga. TWISTED PAIR	200 FT MAX.
COLLECTOR PUMP	1.65	120 ac		YELLOW CONTROLLER WIRES
CIRCULATOR PUMP	0.85	120 ac		YELLOW CONTROLLER WIRES
CONTROLLER	0.05	120 ac		BLACK AND WHITE CONTROLLER POWER WIRES. CONNECT TO 120 VAC THROUGH THERMOSTAT AND MAX. TEMP SENSOR N.C. CONTACTS AS SHOWN.

Figure 3-3. Control Subsystem Wiring Diagram

4.0 SYSTEM PERFORMANCE AND SIZING

The primary system parameters which determine the overall performance of the System 2 design for any given site/application are the collector unit performance,* collector area and, to a much lesser extent, the preheat storage tank size. The sizes selected for a given application of this design are influenced primarily by the local insolation, the cost of auxiliary fuel, and the hot water load (consumption rate). System 2 was designed for nominal values of these conditions applicable to the most statistically significant portions of the continental United States. It thus represents a design with wide-spread application potential with only slight adjustments necessary in system size. The "nominal" conditions as used herein are defined as:

• Insolation, mean daily total,	1200-1700 Btu/Ft^2
• Auxiliary Fuel Cost (Elec.)	0.02-0.04 $/KWH
• Hot water consumption	50-120 gallons/day

A. Collector

Evaluation has shown that the optimum collector area for this system design is one collector panel (19.7 Ft^2) for each 15 gallons per day of hot water consumption. This approximate relationship holds for the range of nominal conditions and results in a solar contribution of from 45 to 65% of the annual dhw load. (For applications where the hot water consumption rate is unknown, a typical single family residence with an automatic washer is some-

* The collector unit performance is fixed since System 2 specifies the LOF collector. Subsequent discussion of system sizes is therefore applicable specifically only to the use of this collector.

times assumed to consume an average of 75 gallons/day, thereby requiring five (5) solar panels.) For locations with higher auxiliary fuel cost, an additional collector panel is cost-justified. Similarly for a site with exceptionally high solar insolation one less panel is recommended.

B. Storage

The optimum preheat tank size is approximately 24 gallons per collector panel. This is based on producing the highest performance return per initial (tank) cost and assumes the use of a preheat tank of a size common to standard domestic hot water tank manufacturer. Sizes in this category in the general range of interest are typically 80, 100 and 120 gallons. The tank size selected should be based on the above criteria, considering these incremental tank sizes and any physical restrictions or limitations that might be imposed by the site.

C. Performance For An Example Site

The initial site for the System 2 baseline design is a single family residence located in Bangor, Maine. Pertinent system/site parameters including collector area and tank sizes are compiled in Table 4-1.

Table 4-1. Example Case Site and System Parameters

Parameter	Value
• Site Conditions	
Location	Bangor, Maine
Application	DHW, Single Family Residence
Hot Water Consumption	75 gallons per day*
Delivery Temperature	$140^{o}F$
Supply Water Temperature	$55^{o}F$, mean
Insolation	1300 Btu/Ft^2, mean daily **
Auxiliary Fuel Cost	0.0268 $/KWH
• System Design	
Number of Collectors	5
Collector Area	98.5 $Ft.^2$
Tilt Angle	45^{o}
Azimuth Angle	0^{o} (due south)
Storage Size	120 Gallons

*Recommended design value for typical residence with automatic washer per NBS 76-1059 "Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems".

** On horizontal plane

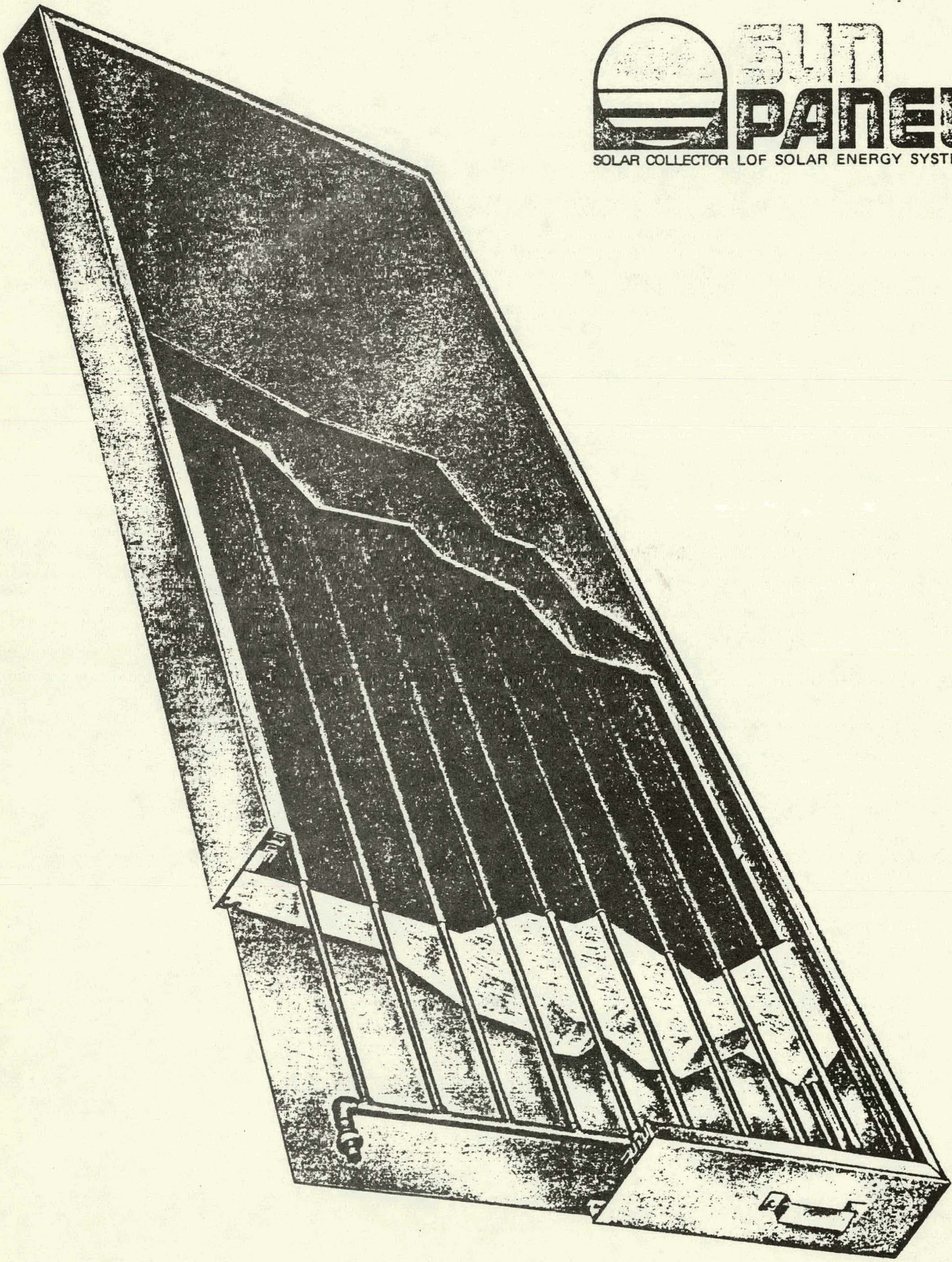
For the above conditions the System 2 design will supply annually approximately 10.89×10^6 Btu to the total hot water load of 19.44×10^6 Btu. This is a percent solar contribution of 56%.

APPENDIX A

MAJOR COMPONENT VENDOR DATA BROCHURES

SUN PANEL™

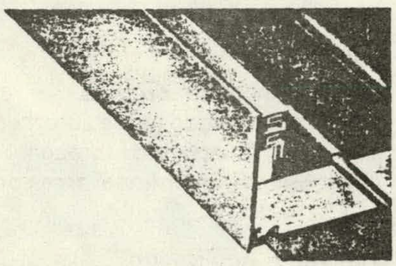
SOLAR COLLECTOR LOF SOLAR ENERGY SYSTEMS



Features

High-Performance Materials Throughout

Internal temperatures up to 400°F. can occur with no-flow conditions on a sunny day. All materials used in a solar collector must have high performance characteristics to withstand these extreme temperatures. Ordinary materials at high temperatures may break down and emit gases, which will gradually coat the inside of the glass cover plates, reducing their transmittance and the operating efficiency of the collector. The SunPanel collector materials have been chosen or treated to prevent offgasing, even at internal temperatures up to 400°F.

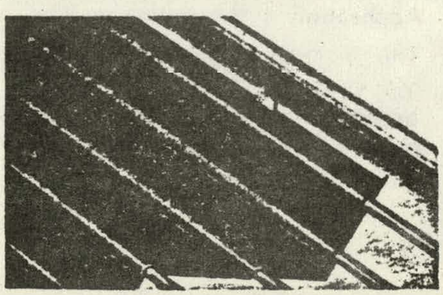


Aluminum Housing

Heavily ribbed extruded frame construction gives the SunPanel solar collector sufficient strength to be used as part of the actual roof. Top and bottom panels are sealed against the elements, yet can be removed if necessary. Insulated support of absorber plate and cover plates minimizes heat loss through the frame. Aluminum frame and bottom cover protect against rust staining.

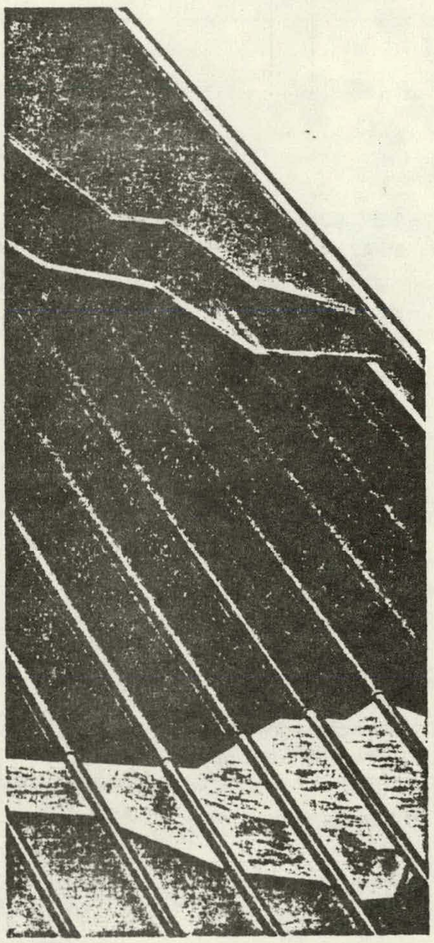
All-Copper Absorber Plate

For long term reliability and good performance, copper is without equal. Its heat transfer characteristic is twice that of aluminum, and eight times that of steel. With excellent corrosion resistance, copper tubing has been used in domestic and commercial plumbing systems for decades.



Fluid Tubing Integral With Absorber Plate

An all-copper liquid system is soldered to the embossed copper absorber plate for maximum heat transfer. A parallel tube pattern provides uniform flow through each panel, and the panels can be connected in either series or parallel arrangements. Inlet and outlet connections are in the same plane as the absorber plate, to prevent vapor blocks and fluid entrapment. The SunPanel collector is designed for an average flow of 0.5 gallons per minute, with pressures up to 100 psi. Pressure drop at this flow is less than 0.5 psi, with a 50% glycol-water solution at 140°F.



Insulation

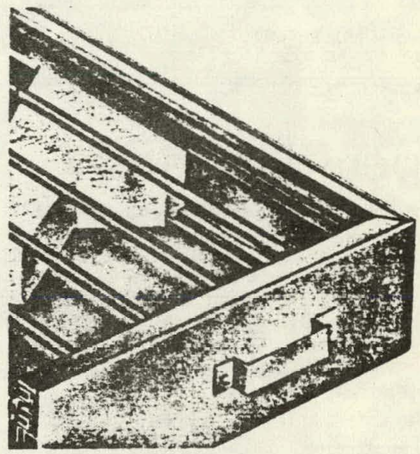
Three inches of treated fiber glass insulation under the absorber plate, and a special side insulation keep the heat where it belongs, both for minimum loss from the system, and protection of building interior when the SunPanel solar collector functions as a roof component. Fiber glass insulation meets all fire codes.

Tempered Glass Cover Plates

Tempered glass is impervious to the ultraviolet rays of the sun, and retains its strength even when exposed to the high temperatures generated inside the collector. Two layers of glass, with an air space between them, give superior thermal insulation, retaining heat in cool ambient situations.

Integral Mounting Supports

Permanently attached mounting supports simplify handling of SunPanel during shipping and installation, then function as brackets for attaching the collector to its framing.



Fluid Connections

Inlet and outlet connections are 1/2" male NPTF. Optional flexible connections, with custom-designed Aeroquip hoses, made of Teflon with stainless steel braided covers, are available.

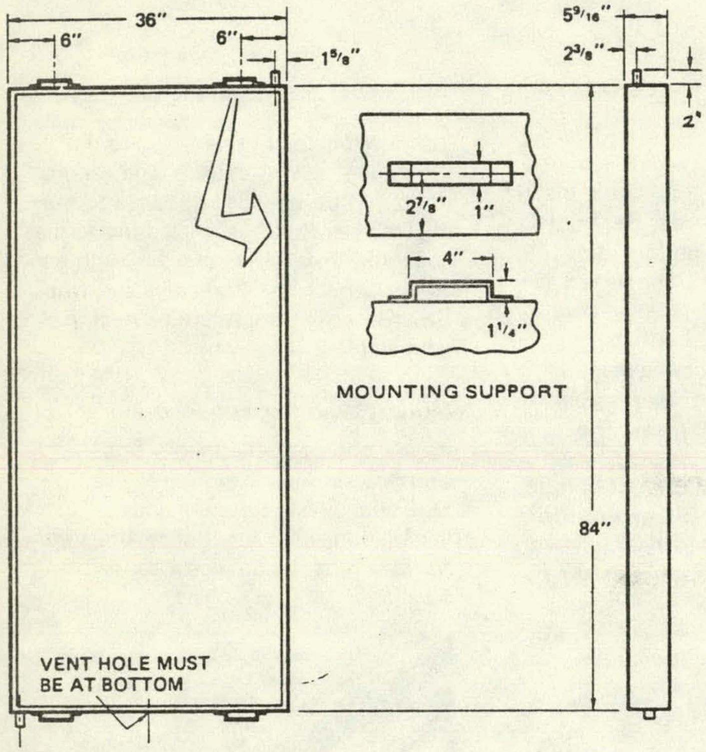
Vented for Moisture Relief

Desiccants are not required with the SunPanel collector design. Pressure equalization passages eliminate condensation, even during idle periods. Any moisture that might collect will be dissipated rapidly during collector operation.

Flat Plate Design

Research shows a flat plate collector provides high overall heat collection with direct and diffuse light, and it need not be critically oriented in relation to the sun. Motor drives and rotation mechanisms are not required for high performance.

Dimensions



Specifications

Cover glass (2) (fully tempered)	– 1/8" TUF-FLEX ® tempered safety glass
Exposed absorber plate area	– 19.47 sq. ft.
Absorber plate	– all copper
Heat transfer fluid system	– all copper
Frame and back panel	– aluminum
Back insulation	– 3" treated fiber glass
Recommended fluid flow rate	– 0.5 gpm
Pressure drop at recom. flow (glycol/water)	– 0.5 psi
Design pressure	– 100 psi
Test pressure	– 200 psi
Burst pressure (calculated)	– 450 psi
No-flow protection required	– none
Maximum internal temperature (no-flow)	– 450° F
Performance test specification	– NBSIR 74-635
Environmental conditions	– -40°F. to +120°F.
Maximum wind or snow load	– 30#/SF
Fluid connections	– 1/2" male NPTF
Installation orientation	– short side horizontal
Min. tilt angle to allow complete draining of panel	– 5° (from horizontal)
Maximum tilt	– 90°
Mounting	– 4-point, on brackets
Panel weight (filled)	– 150 lbs.
Installed load	– 7.5#/SF
Shipping weight	– 160 lbs.

Warranty

We warrant that our SunPanel™ solar collector panel will meet our published specifications and will be free of defects in the material and workmanship for a period of one year from the date of manufacture. This warranty shall not apply to solar collectors which have not been handled, installed, or used in accordance with our published instructions, or to the replacement parts or panels beyond the warranty period applicable to the original solar panels. Our liability under this warranty shall be limited to replacement of the material, FOB, the shipping point nearest the installation, or at our option to refund the purchase price, and we shall not be liable for cost of removal or installation of or any consequential damages or other damages in connection with such collector panel.

We make no warranty of merchantability, no warranty that SunPanel is fit for any particular purpose or use and no other warranty is expressed or implied.

Applications

The SunPanel solar collector is designed to generate heat energy from sunlight, in systems operating at temperatures over 200° F. The actual amount of heat which can be produced depends upon geographic location, season and climatic conditions, sun angle and panel orientation, and system variables such as the specific heat value of the heat transfer fluid, fluid inlet temperature and rate of flow through the collector.

The applications described below represent typical systems using SunPanel collectors. Specific applications should be designed with the help of a professional heating engineer, using data and recommendations from the following pages.

Pump Control

LOF will mount a specified temperature sensor to the absorber plate with 12 inch leads through the housing as an optional accessory.

Hot Water Application

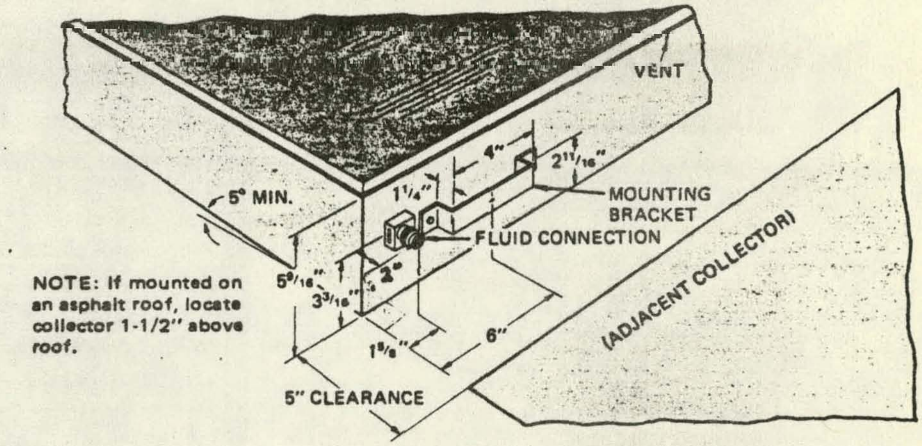
A very simple system in which the hot water supply for the household is heated through a heat exchanger from the solar collectors on the roof. Operation of the pump is controlled by a thermostat, stopping circulation of heat transfer fluid when the water in the tank reaches the desired temperature, or when the temperature of the collectors drops below that of the stored water. A back-up heating element can be installed in the storage tank if necessary.

If freezing temperatures occur, an antifreeze solution is recommended for the heat transfer fluid circulating through the collectors. Local codes should be consulted concerning the type of heat exchanger to be used with antifreeze solutions.

Combination Heating and Hot Water Application

This system contains an additional heat exchanger, a storage tank with a closed liquid circuit to a coil in the plenum of the furnace, and a separate hot water heater.

Collector Installation



Mounting

SunPanel collector is 36" x 84" in size, and requires a nominal 5" wide space at the top and bottom, for mounting, pipe fittings and pipe insulation. Allow 1/8" – 1/4" clearance between side-by-side panels for thermal expansion. In designing layout, provide for collector servicing, including removal and replacement of individual collectors if required. Cover glass may be replaced without removing entire panel.

Position panels with vent opening at bottom. For adequate draining, collectors must be tilted at least 5 degrees from horizontal, with the short side level.

SunPanel is designed to be supported from the four mounting brackets, permitting a variety of mounting arrangements without disturbing the watertight integrity of the collector housing. However, direct contact of the collector housing with dissimilar metals must be avoided to prevent galvanic corrosion.

If the panel is mounted on an asphalt roof, support it a minimum of 1-1/2" above the surface to allow water runoff. The collector can become an integral part of the roof. The collector must be supported by the roof framing. An asphalt roof surface is not intended for structural support due to asphalt's softening characteristics during warm weather.

For other types of roofing consult specific roofing manufacturers.

Piping

SunPanel collectors can be connected in series or parallel arrangements. Follow good piping practice, with connections to be as short and direct as possible, and also allow for pipe expansion and contraction. Include balancing valves in multiple panel circuits to permit equalization of flow through each collector. Provide air vents at high points in the piping system, and include an expansion tank in any closed loop system. Insulate all piping to minimize heat loss and to improve system performance.

Select pumps, valves and heat exchangers to be compatible with heat transfer fluid or antifreeze to be used in system. Isolate dissimilar metals in system to prevent galvanic action.

Handling

Store SunPanel collectors in a dry, protected place prior to installation, and handle with care. The cover plates are fully tempered glass which is resistant to some impact loads. However, they can be broken by mishandling.

If a cover glass is broken, replacements are available for immediate shipping. To replace the glass, cut the caulking beads around the edge of the frame. Release the glass retaining member from the frame with a thin screwdriver. The lower glass is held in place with a spacer, which can be lifted out. Be sure the glass support gasket is smooth, clean and flat before replacing retainers. Recaulk around the glass with LOF recommended glazing material, along the raised edge of the frame, and along the diagonal seams at the corners.

Protect the collectors during construction activity in the area. Sparks from welding operations can damage the glass and the aluminum housing. Run-off from alkaline materials or oxidizing steel, if allowed to remain on the collector surfaces, can cause stains. It may be necessary to clean the panels frequently during construction and for a period after completion. Dirt, dust and deposits will reduce collector performance.

Usually during normal operation the collector panels are self-cleaning through rain and wind. In especially dusty locations, however, they may require periodic inspection and cleaning to retain high performance.

Caution: Before handling or cleaning collectors that have been exposed to sunlight, make sure they are not too hot to touch. Glass and metal surfaces above 150 degrees F. will burn unprotected skin.

Support Structure

Support structure for ground or roof installation must be properly anchored. Ground collector supports must extend below the frost line. All supports must be designed to structurally support the collectors and resist design snow and wind loads.

The structural design of the support structure should be sufficient to prevent deflection, racking or twisting of the individual collectors for dead and live loads. Local building codes must be consulted to determine the design snow and wind loads. If the collectors are to be installed on or near large buildings or other geographical features which may have unusual shapes and affect the normal wind velocity, additional design factors may be required.

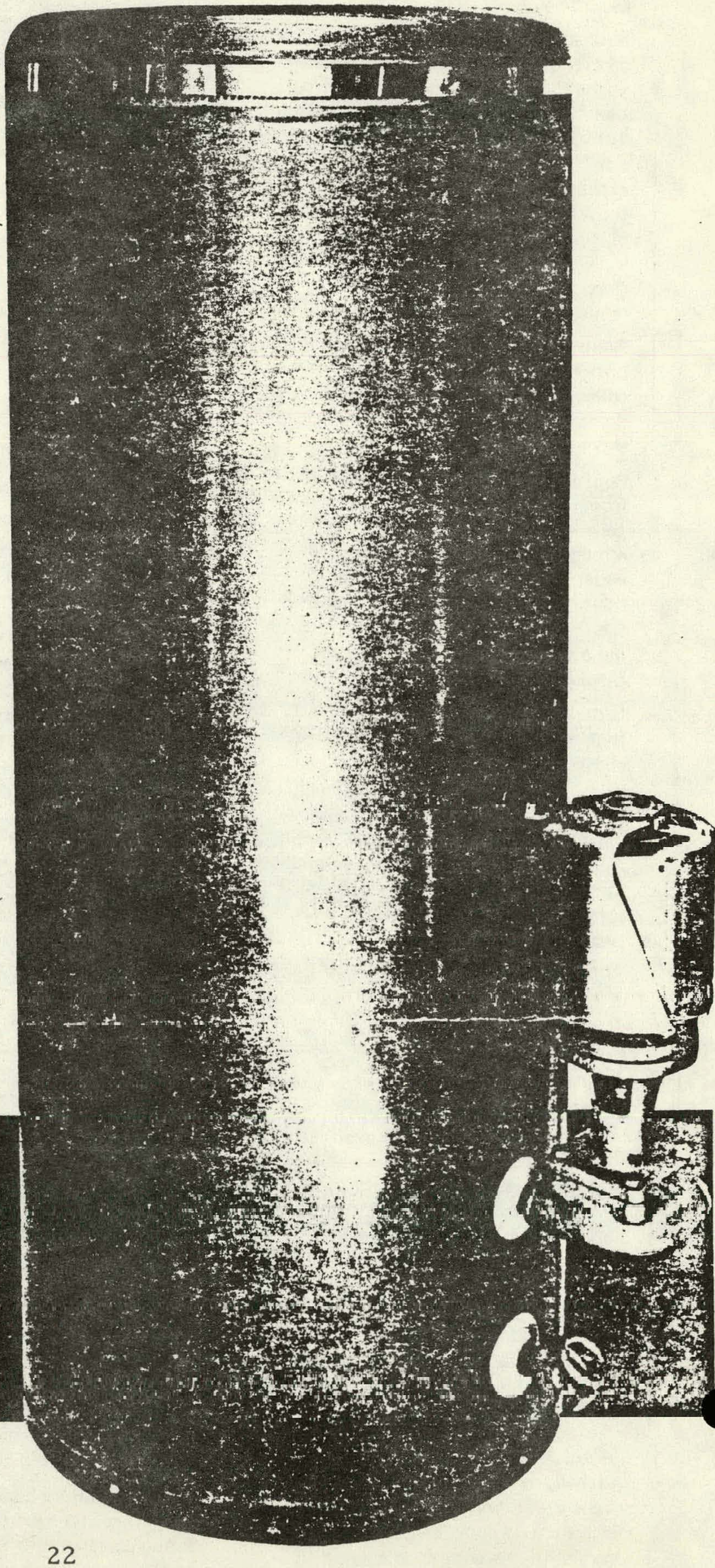
Any support system used should be designed to last the life of the collectors, and should be constructed or treated so it will not rust or cause staining of adjacent materials. The system should also be materially compatible with the collector housing.

The mounting and tie-down system for support racks can be accomplished by the four (4) mounting brackets which are also used as handles during installation. (See illustration.)

Support hardware is available for pitched roofs, to allow mounting the collectors at the roof pitch or various angles.

Further detailed installation information is available in our Solar Collector Installation brochure, SE 3-76.

FORD AQUA BOOSTER

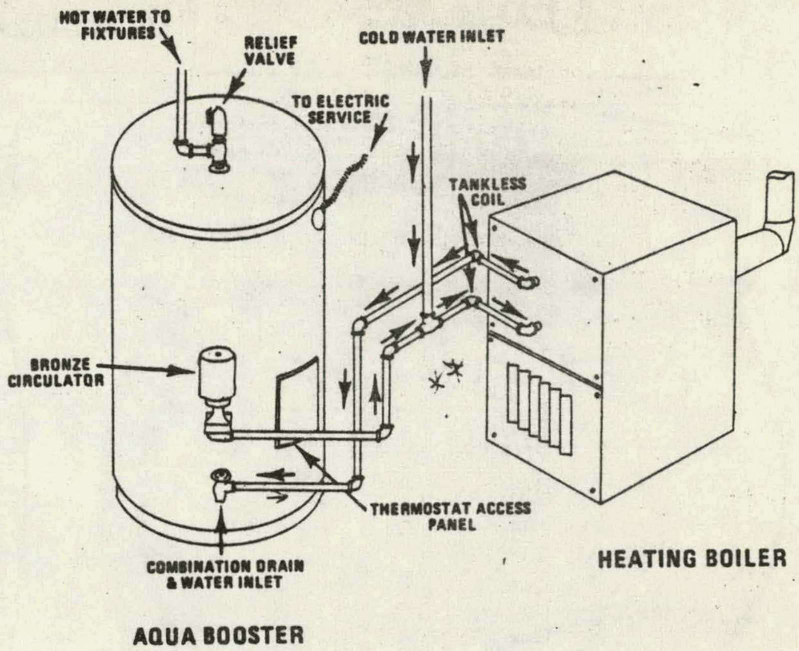


An Economical
Reserve Hot
Water Storage
Tank from

FORD
products
corporation

- Stone or glass lined steel tank with fiberglass insulation
- Water temperature adjustable from 120° to 180°
- Easy to install—factory wired and piped, requires no chimney connection
- Corrosion-proof bronze circulator
- Sparkling enamel jacket—easy to keep clean

IMPORTANT: INSTALL WITH RELIEF VALVE



SPECIFICATIONS

STONE LINED MODELS 10 YEAR STRAIGHT GUARANTEE (Do Not Require Anode)				
Model	AB40S	AB65S	AB80S	AB120S
Capacity Gallons	40	65	80	120
Height	53½"	55¼"	69½"	68"
Overall Diameter	20"	24"	24"	28"
Floor to Drain	6½"	7½"	7½"	7½"
Circ. Disch. to Floor	12⅝"	13½"	13½"	13½"
Max. Width	27"	31"	31"	35"
Water Connections	¾"	¾"	¾"	¾"
Weight, Lbs.	230	340	400	510

GLASS LINED MODELS 5 YEAR STRAIGHT GUARANTEE		
Model	AB30GM	AB40GM
Capacity Gallons	30	40
Height	50"	60"
Overall Diameter	16"	16"
Floor to Drain	6"	6"
Circ. Disch. to Floor	12"	12"
Max. Width	23"	23"
Water Connections	¾"	¾"
Weight, Lbs.	100	115

The Ford Aqua Booster is a reserve storage tank that uses the present boiler and burner to supply abundant hot water. It hooks up to the tankless coil of a boiler and stores 30 to 120 gallons (depending on tank size) of constant temperature hot water.

The Aqua Booster solves one of your toughest customer complaints: not enough hot water from an undersized boiler coil.

Commercial accounts and other high-volume hot water users are also prospects.

LIBERAL WARRANTY

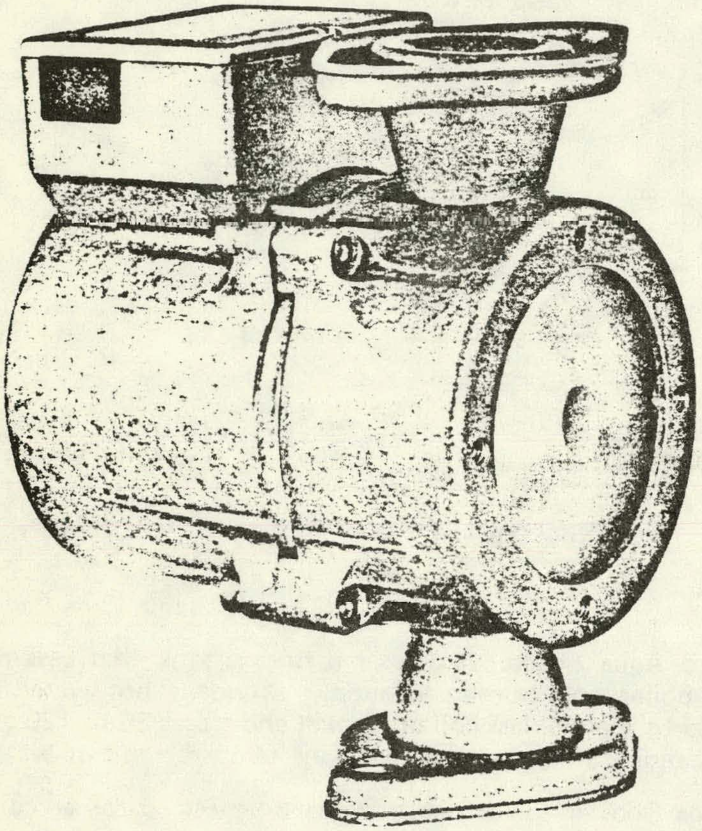
A new storage tank; including the casing, but less the circulating pump, will be furnished if tank leakage occurs within five years on glass-lined models and within ten years on stone-lined models. Unit must be installed with a relief valve. All other parts are covered under one year warranty. Labor, freight or delivery charges are not included.

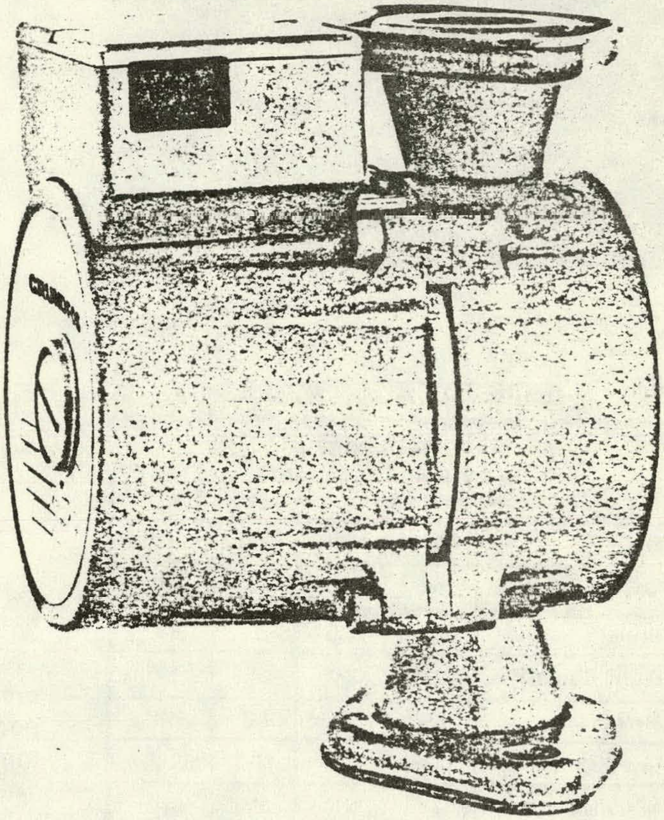
FORD products corporation

Ford Products Road, Valley Cottage, New York 10989 / Phone: (914) 358-8282

PRODUCT EXCELLENCE: AQUA BOOSTERS, AQUA COILS, FURNACES AND WATER HEATERS

GRUNDFOS	STAINLESS STEEL CIRCULATOR PUMPS	UP 25-42 SF





INFORMATION: Stainless steel circulator pump—UP 25-42 SF

The UP 25-42 SF is a revolutionary circulator pump. The water passing through the pump touches nothing but high quality fabricated stainless steel. The volute section, for example, is constructed of type 316 stainless. As with all Grundfos circulators, the UP 25-42 SF is engineered to be interchangeable with the pumps of all other major manufacturers.

CONSTRUCTION

The UP 25-42 SF is a water lubricated pump. However, in order to protect the rotor and bearings from damaging impurities which may be present in the circulating water, they are separated from the stator and the pump chamber by a liquid filled rotor can. The motor shaft extends out from the rotor can, into the pump chamber through the aluminum oxide bearing, which also functions as a seal. During initial operation, the pump is automatically self-vented; however, due to the isostatic principle, there is no further recirculation of water into the closed rotor can.
The pump's "diamond-hard" aluminum oxide bearing construction, combined with the high starting torque of the motor, ensures re-start after shutdown.

MATERIALS

Stainless steel:........................ Pump chamber, rotor can, shaft, rotor cladding, bearing plate, impeller, thrust bearing cover.

Aluminum oxide: .... Top bearing, shaft ends, bottom bearing.

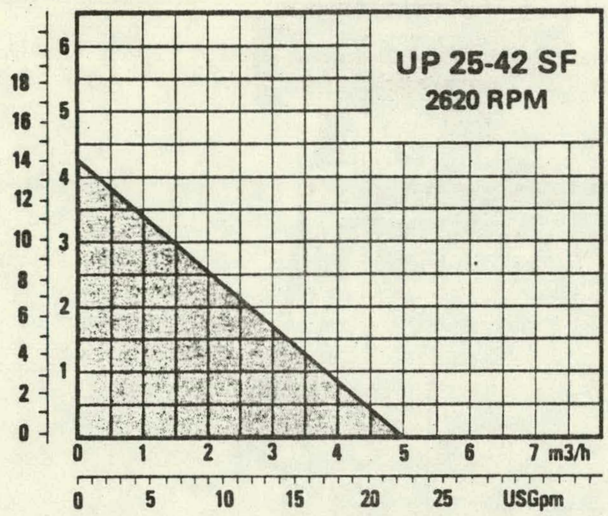
Carbon/aluminum oxide:............ Thrust bearing.
Aluminum:.......................... Motor housing, pump housing cover.
Ethylene/propylene rubber: .... O-rings, gasket.
Silicon rubber:....................... Winding Protection.

APPLICATIONS

The UP 25-42 SF is particularly suited for open and potable systems. The stainless steel construction protects the pump from the corrosion that has plagued cast iron and bronze-lined pumps in these types of applications. The pump is intended for circulation and booster applications in domestic water systems.

GRUNDFOS GRUNDFOS GRUNDFOS

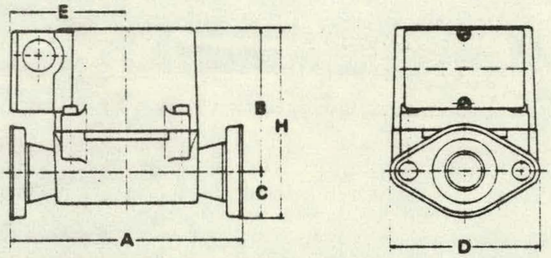
PERFORMANCE CURVE UP 25-42 SF



ELECTRICAL AND PERFORMANCE DATA

The UP 25-42 SF is operated by an energy-conserving 1/20th HP (0.85 amp) motor which has built-in overload protection. However, because of advanced engineering design, the pump produces up to 14 feet of head or a flow of up to 23GPM. The pump's small size and high efficiency make it suitable for many varied applications and greatly reduces installation problems.

DIMENSIONS UP 25-42 SF

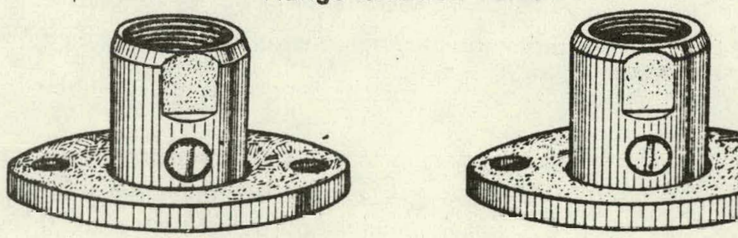


Type	A mm inches	B mm inches	C mm inches	D mm inches	E mm inches	H mm inches	Packing 1xwxh mm/"	Ship. vol. m3 Cbft.	Weight Kg Lbs.
UP 25-42 SF (w/flanges)	165 6 1/2	109.5 3 3/4	33.5 1 1/3	106 4 1/4	82 3 1/4	129 5 1/8	200 x 180 x 160 7 7/8 x 7 x 6 1/4	0.005 1/5	3 6 1/2

ISOLATION VALVES

GRUNDFOS recommends the use of isolation valves with circulation pumps in all systems.

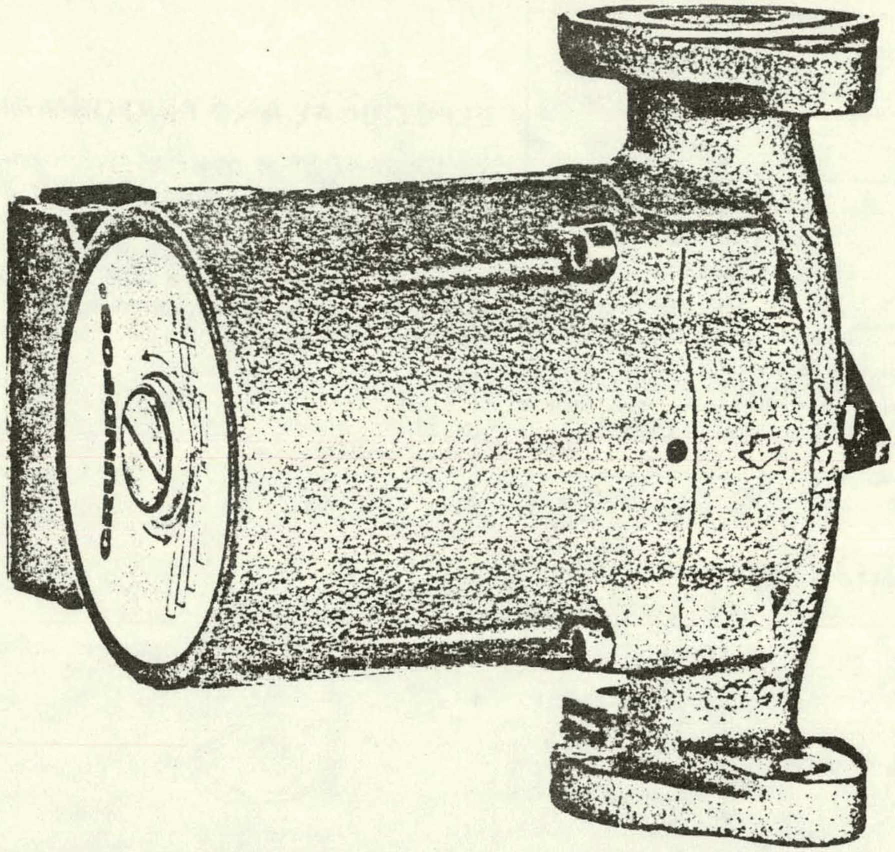
Flange Isolation Valve



ORDER NUMBERS

		Bronze Flanges		Flange Valves	
Type	Order No.	Dim.	Order No.	Dim.	Order No.
UP 25-42 SF with flanges	51.06 21 13	3/4" 1" 1¼"	51.96 51 51.96 52 51.96 53	1"	51.97 72

GRUNDFOS	VARIABLE HEAD CIRCULATOR PUMP	UP 26-64



INFORMATION Variable Head Circulator Pump—UP 26-64

The UP 26-64 is fitted with variable-head-control. This innovative mechanism, which controls both the head and the flow produced by the pump, allows the installer, by a simple hand adjustment, to precisely match the UP 26-64 to the demands of many varying systems.

CONSTRUCTION

The UP 26-64 is a water lubricated pump. However, in order to protect the rotor and bearings from damaging impurities which may be present in the circulating water, they are separated from the stator and the pump chamber by a liquid filled rotor can. The motor shaft extends out from the rotor can, into the pump chamber through the aluminum oxide bearing, which also functions as a seal. During initial operation, the pump is automatically self-vented; however, due to the isostatic principle, there is no further recirculation of water into the closed rotor can.
The pump's "diamond-hard" aluminum oxide bearing construction, combined with the high starting torque of the motor, ensures re-start after shutdown.

MATERIALS

Stainless steel: .... Rotor can, shaft, rotor cladding, bearing plate, impeller, variable flow adjustment plate, thrust bearing cover.

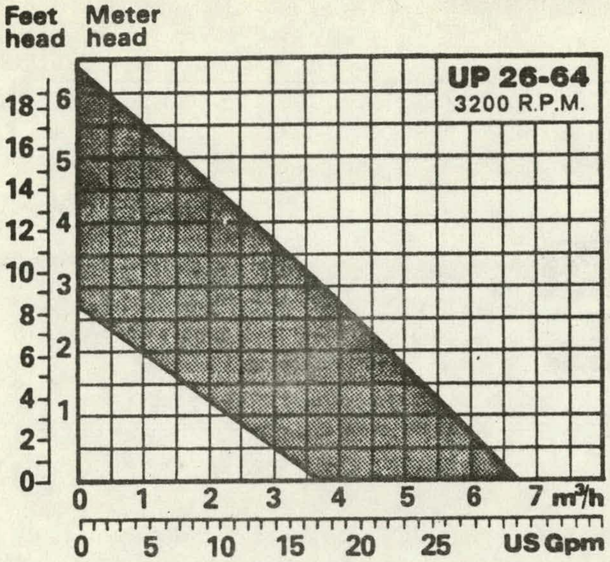
Aluminum oxide: .... Top bearing, shaft ends, bottom bearing.

Carbon/aluminum oxide:........... Thrust bearing.
Cast iron .... Pump housing.
Ethylene/propylene rubber: .... O-rings, gasket.
Silicon rubber: .... Winding Protection.

APPLICATIONS

The UP 26-64 should only be used in closed systems (i.e. solar, hydronic). The pump is intended only for the circulation of water. However, solutions such as ethylene glycol can be used without hindering pump performance. For open system applications ask for Grundfos' stainless steel volute circulator pumps.

RFORMANCE CURVES UP 26-6



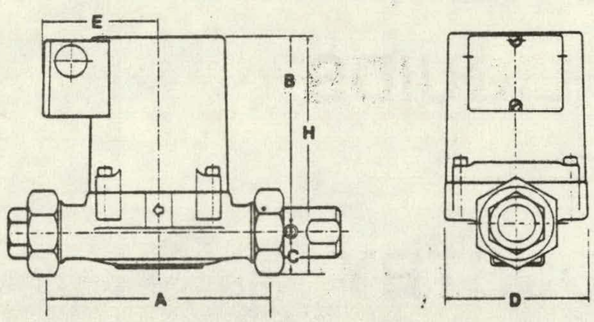
ELECTRICAL AND PERFORMANCE DATA

The UP 26-64 is operated by an energy-conserving 1/12th HP (1.65amp) motor, which has built-in overload protection. However, because of its advanced design, the pump produces heads from 8 to 20 feet or flows from 16 to 30 GPM. The pump's small size and high efficiency make it suitable for many varied applications and greatly reduces installation problems.

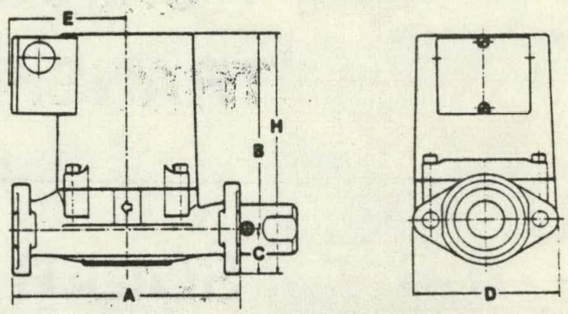
Contact Grundfos for information regarding the complete line of circulator pumps and twin pumps.

DIMENSIONS

UP 26-64 U



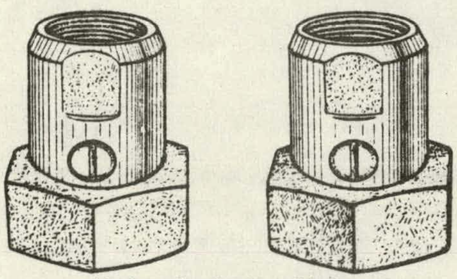
UP 26-64 F



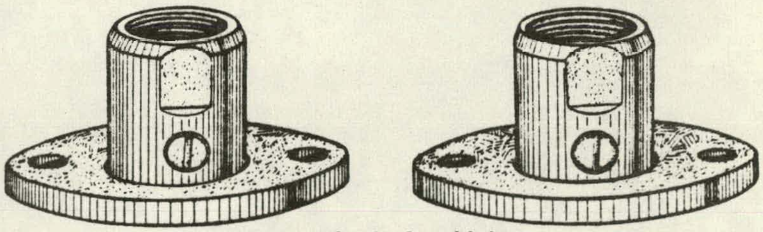
Type	A mm inches	B mm inches	C mm inches	D mm inches	E mm inches	H mm inches	Packing 1xwxh mm/"	Ship. vol. M^3 Cbft.	Weight kg Lbs.
UP 26-64U with unions	180 7 1/16	236 9 1/4	32 1 1/4	102 4 1/8	80 3 3/16	165 6 1/2	195 x 200 x 200 7 3/4 x 7 7/8 x 7 7/8	0.008 1/4	5.5 12 1/8
UP 26-64F with flanges	165 6 1/2	128 5 1/16	33.5 1 3/8	106 4 1/4	82 3 1/4	161.5 6 3/8	195 x 200 x 200 7 3/4 x 7 7/8 x 7 7/8	0.008 1/4	5.5 12 1/8

ISOLATION VALVES

GRUNDFOS recommends the use of isolation valves with circulation pumps in all systems.



Union Isolation Valve



Flange Isolation Valve

ORDER NUMBERS

		Unions		Flanges		Flange Valves Union Valves	
Type	Order No.	Dim.	Order No.	Dim.	Order No.	Dim.	Order No.
UP 26-64F with flanges	52.22 30 13	3/4" 1"	51.95 21 51.95 22	3/4" 1"	51.96 01 51.96 02	1"	51.97 72
UP 26-64U with unions	52.25 20 13			1 1/4" 1 1/2"	51.96 03 51.96 04	1"	51.98 72

DOW CORNING

SILICONE HEAT TRANSFER LIQUIDS FOR SOLAR INDUSTRY APPLICATIONS

DOW CORNING® Q2-1132 SILICONE HEAT TRANSFER LIQUID

Description

Dow Corning® Q2-1132 Silicone Heat Transfer Liquid is a water clear liquid having a viscosity of 20 centistokes (77°F). It is fluid from −50°F to 600°F, exhibits heat stability, oxidation resistance, very low vapor pressure and a high flash point. It is essentially noncorrosive to common engineering metals and is virtually nontoxic. This fluid has a high dielectric strength and, as such, will not promote galvanic corrosion.

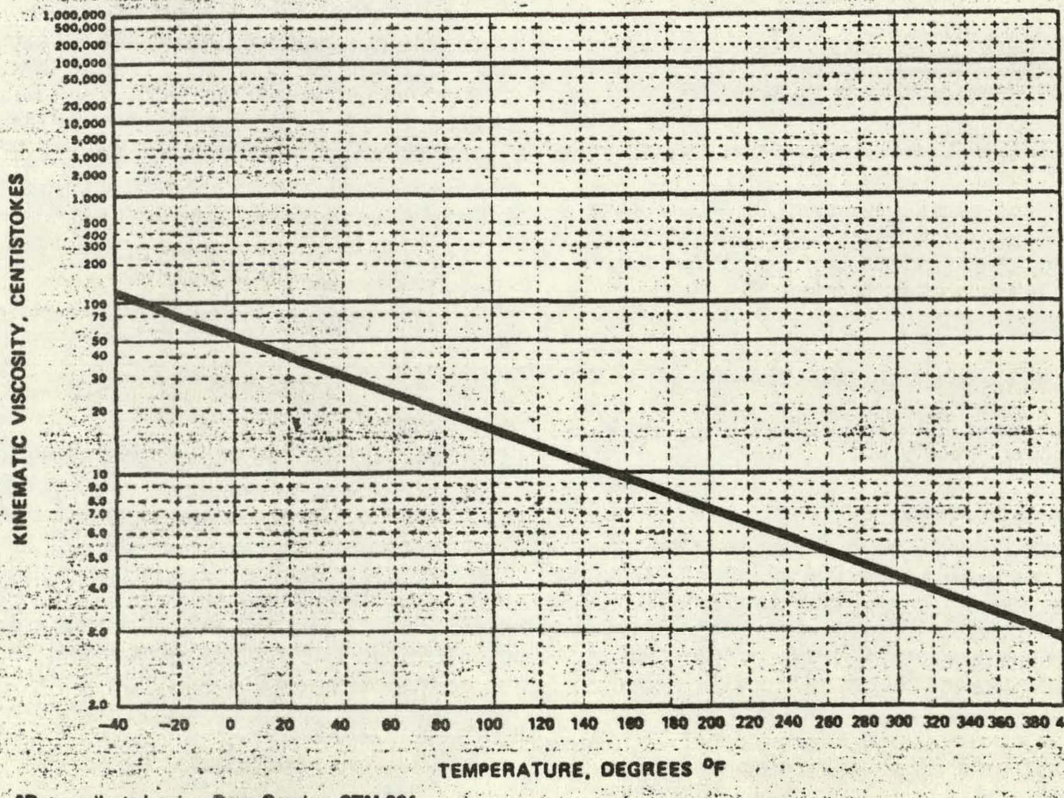
Use

Dow Corning® Q2-1132 Silicone Heat Transfer Liquid is intended for use in the collection loop of liquid solar systems to take energy from the solar collector panels and carry it to the thermal load or thermal storage. It is intended for operation in the temperature range of −50°F to 400°F with intermittent exposure to 450°F in systems that are essentially closed.

Typical Properties			CTM*
Flash point, open cup		450°F	0021
Fire point		500°F	0052
Viscosity, centistokes @	77°F	20.0	0004
	140°F	11.5	
	210°F	7.0	
Specific heat, BUT/lb/°F @	104°F	0.37	
	212°F	0.39	
	392°F	0.42	
Thermal conductivity BTU/hr/ft² °F/ft @	0°F	0.086	0773
	100°F	0.083	
	200°F	0.080	
Density @	77°F	0.946	
	140°F	0.918	
	180°F	0.898	
	220°F	0.880	
	300°F	0.842	
Pour point		−121°F	0133
Coefficient of Expansion, cc/cc/°C		0.00107	0420
Vapor pressure, 400°F, mm.Hg.		5.0	0803

*Corporate Test Methods.

VISCOSITY TEMPERATURE CHART*
FOR DOW CORNING Q-2-1132 SILICONE HEAT TRANSFER FLUID



*Data collected using Dow Corning CTM 004

Solar System Design Considerations

Physical Properties

The relatively flat temperature-viscosity slope for Dow Corning® Q2-1132 Silicone Heat Transfer Liquid allows for the fluid to be pumped at −50°F and it generates essentially no vapor pressure at 400°F. This obviates the need for freeze protection through system draining procedures. The low vapor pressure allows for a simple closed loop design with no provisions for stagnation conditions. When the system load and storage capacity have been satisfied, the solar panels simply sit with the fluid in them. Compared to solar systems using other fluid this can eliminate an expensive network of high temperature sensors, control valves, and "excess-heat" exhaust systems.

Fluid Stability

The thermal stability of Dow Corning® Q2-1132 Silicone Heat Transfer Liquid was studied in closed systems at 600°F and 650°F. Based on these studies and extrapolating back, the data indicates the thermal degradation in closed systems to be negligible at 400°F.

The oxidative stability of Dow Corning® Q2-1132 Silicone Heat Transfer Liquid was studied at 392°F by aging the fluid in combination with various metals including magnesium, copper, tin, aluminum and brass. After 1000 hours in essentially open systems the fluid exhibited excellent viscosity stability.

Table 1 Dow Corning® Q2-1132 Silicone Heat Transfer Liquid. Aged 1000 hr/392°F With Various Materials in Fluid.

Material	Viscosity Cs. @ 73°F	Specific Gravity	% Wt. Loss, Fluid
Control	20.0	0.962	(Not Aged)
Aluminum	23.4	0.966	5.30
Copper	22.0	0.952	4.37
Tin	28.4	0.957	1.85
Brass*	40.0	0.962	7.87
Magnesium *	40.5	0.964	0.43

* The viscosity drift after 1000 hours under these conditions is likely due to the high activity of magnesium and the zinc in the brass.

Flammability

The flash and fire points of Dow Corning® Q2-1132 Silicone Heat Transfer Liquid are 450°F and 500°F respectively and as such are above the maximum stagnation temperature of most nonconcentrating solar collectors.

Toxicity

Extensive testing has shown Dow Corning® Q2-1132 Silicone Heat Transfer Liquid to be among the least toxic chemicals available. Copies of several studies in this regard are available on request.

Corrosion Characteristics

Based on over 30 years in the manufacture of this basic silicone fluid with processing temperatures reaching 600°F, our experience indicates Dow Corning® Q2-1132 Silicone Heat Transfer Liquid is essentially noncorrosive to common engineering metals. Specific corrosion tests on this polydimethylsiloxane fluid as part of Dow Corning's brake fluid and electrical transformer fluid program further confirm the noncorrosive nature of Dow Corning® Q2-1132 Silicone Heat Transfer Liquid at temperatures as high as 392°F. Typical test results from the humidified fluid corrosion test as per SAE XJ 1705 are listed below.

Table 2 Humidified Fluid Corrosion Test

Metal	Max. Wt. Change mg/cm²	Actual Wt. Change mg/cm²
Tinned Iron	0.1	0.01 Bright
Aluminum	0.1	0.01 Bright
Steel	0.1	0.01 Bright
Cast Iron	0.1	0.01 Bright
Brass	0.2	0.02 Light Stain
Copper	0.2	0.02 Medium Stain

Residential Construction Materials

Preliminary testing on Dow Corning® Q2-1132 Silicone Heat Transfer Liquid was conducted to determine the effect of spills or system leaks on common materials of home construction such as roofing shingles, painted wood, asphalt floor tile and foam-backed carpet. No permanent damage was noted and normal cleaning methods are effective in clean-up.

Competitive Fluids

Any one or more of the following characteristics can be experienced with other heat transfer fluids.

- Freezing
- High pressure
- Corrosion
- Corrosion Inhibitor Depletion
- Frequent Fluid Replacement
- Fluid Breakdown to Tars and Acids
- Sludge Formation
- Scale Buildup
- Property Damage
- Low Flash Point
- Periodic Maintenance

Most of these shortcomings can be effectively designed for by employing more expensive metals, more sophisticated controls, pressure relief systems, and "excess-heat" exhaust hardware while requiring periodic fluid quality checks and more frequent fluid replacement.

When looking at total solar system costs, it is often the case that a simple on-off collection loop using Dow Corning® Q2-1132 Silicone Heat Transfer Liquid is the least expensive from both an initial cost and operation standpoint.

Low maintenance costs and long life further add to the cost effectiveness and reliability of a solar system utilizing Dow Corning® Q2-1132 Silicone Heat Transfer Liquid.

Field Testing

Solar systems that utilized a Dow Corning silicone heat transfer liquid have been installed and tested (ERDA contract W-7405-ENG. 36). These tests confirm the system effectiveness and stability of this fluid even under stagnation conditions.

A solar hot water system specifically designed for rapid recovery was installed in Vermont utilizing 240 ft² of solar panels with two series connected 80 gallon water tanks. This system uses Dow Corning® Q2-1132 Silicone Heat Transfer Liquid and has been in operation for over 12 months. As the residence was unoccupied for eight months of the first year, the total stagnation time is estimated at over 1000 hours. The panels are aluminum Rollbond® and no mechanical provisions are made for freezing or high temperature stagnation. To date the system is meeting all the performance expectations. Analysis of the fluid shows no degradation or breakdown.

®Rollbond is a Registered Trademark of Olin Corp.

Over sixty residential solar hot water systems utilizing Q2-1132 silicone heat transfer fluid hace been installed commercially to date. Several thousand solar hot water systems utilizing Dow Corning® Q2-1132 are expected to be installed by mid-1977. Performance data from this level of field usage can be made available to solar systems suppliers interested in supplying warrantable and cost effective residential solar systems.

Design Considerations

Dow Corning Q2-1132 Silicone Heat Transfer Liquid is designed to last for the life of your solar system. Therefore careful consideration must be given to system design, materials of construction and field installation in order to insure long lived, maintenance free operation.

Pumps

Canned hot water circulating pumps are recommended for pumping Dow Corning Q2-1132 Silicone Heat Transfer Liquid. Good field experience with Grundfos® variable head circulator pump model, UP 26-64, is available. Currently the model UP 26-64, a 1/12 H.P. size, is the largest canned pump available in the United States from Grundfos®, although models up to 3 H.P. are available in Europe. Grundfos® Pump Corporation plans to manufacture by April of 1977 additional models of ⅓, ½, ¾, 1½, 2 & 3 H.P. in the United States in the same canned configurations. Other manufacturer's canned pumps are expected to be suitable for Dow Corning Q2-1132 Silicone Heat Transfer Liquid pumping.

Good field experience with hot water circulating pumps using external motors is not yet available in silicone liquid solar loops. Dow Corning's Technical Service and Development Department is currently working with leading pump & packing manufacturers to test and specify the proper shaft seals and body gaskets for this application.

The sizing of the pump for the requirements of the job should be done with the help of the specific pump manufacturer. He will need to know head requirements, flow rates, and liquid properties. Dow Corning Q2-1132 has a lower specific heat than water and the flow rate must be increased by a factor of 2 to 2.5. This will increase the pumping head. The capacity of the pump will be lowered due to Q2-1132's higher viscosity.

Heat Exchangers and Tanks

Dow Corning Q2-1132 Silicone Heat Transfer Liquid can be used with copper, brass, bronze, aluminum, black iron, and galvanized tanks, tubing, and collectors. Dissimilar metals may be used in any combination within the system as Q2-1132 silicone heat transfer liquid is inert to these metals. When joining dissimilar metals, external corrosion can result under humid conditions and this should be taken into consideration.

The question is frequently asked as to whether double walled heat exchangers are needed between silicone liquids and potable water. Dow Corning feels that the systems manufacturer should make this decision and refers the manufacturer to the publication "Toxicology of the Silicones", Publication Number 22-379.

Heat exchanger and tank sizings to meet the requirements of the job should be done with the help of the manufacturer.

Piping, Joints, Valves, Vents, and Ancillary Equipment

Common high quality plumbing and heating equipment appears to work satisfactorily with Dow Corning Q2-1132 Silicone Heat Transfer Liquid systems according to current field experience. All seals and gaskets should be chosen for high temperature operation. Viton and ethylene propylene rubbers are generally acceptable. Copper, black iron, aluminum and galvanized piping may be used. Plastic piping should be avoided. Viton and EPDM high temperature hose is generally satisfactory for flexible connections.

Mechanical Construction

Mechanical joints must be carefully made. Sweat copper joints are the most preferable as threaded joints are a potential source of leaks and should be kept to a minimum. All threaded joints should either be made with Teflon tape plus Teflon pipe dope or with Dow Corning Flurosilicone Sealant. Standard silicone sealants cannot be used. Fluxes should be non-acidic, non-aggressive types. Gross contamination with dope and fluxes will color the fluid.

Quality mechanical construction is essential for leak prevention. After construction is completed, the system should be air pressure tested for 24 hours. The system must be clean and free of water. Upon filling, the system should be carefully purged of air.

Packaging

Dow Corning® Q2-1132 Silicone Heat Transfer Liquid is available in 55 gallon drums [440 lbs. (200 Kg.) net].

Shipping Limitations

None

Storage and Shelf Life

Dow Corning® Q2-1132 Silicone Heat Transfer Liquid has an unlimited useful life when stored at 77°F.

Warranty

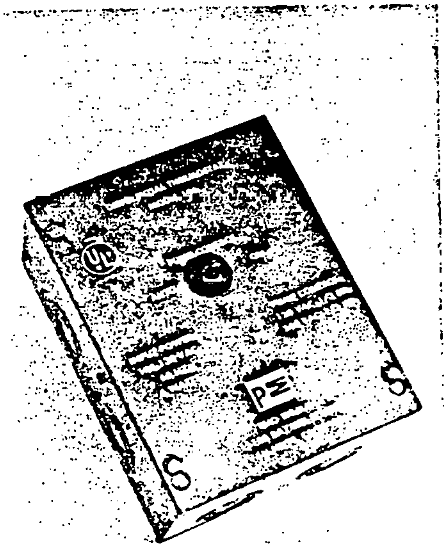
This product is presently available on an introductory basis to solar original equipment manufacturers and future availability is dependent on industry acceptance.

The information and data contained herein are based on information we believe reliable. You should thoroughly test any application, and independently conclude satisfactory performance before commercialization. Suggestions of uses should not be taken as inducements to infringe any particular patent.

Specification writers, please contact Dow Corning Corporation, Midland, MI 48640, before writing specifications on this product.

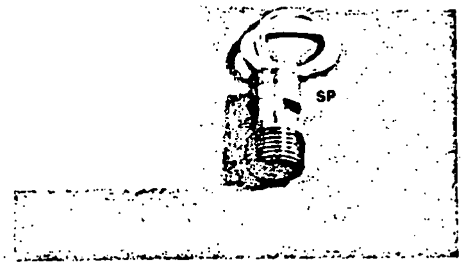
For further information, contact Technical Service and Development, (517) 496-5823.

RS 106



Differential Thermostat
Input: 120 VAC
Standard Output:
SPDT Relay rated at 10 amps.
⅓ hp at 120 VAC
½ hp at 240 VAC
Switch with manual ON-OFF-AUTO positions.
Relay contacts make when
ΔT on = T(collector) - T(storage) > 20° ± 3°F
Relay contacts break when
ΔT off = T(collector) - T(storage) < 3° ± 1°F
Housed in standard NEMA box to assure compatibility with standard electrical trade hardware.
Wiring connections made by standard electrical trade procedures.
Optional outputs:
2PDT relay, 10 amp per contact.
3PDT relay, 10 amp per contact.
Factory adjustment of T on and T off can be made to customer specifications.

SENSORS



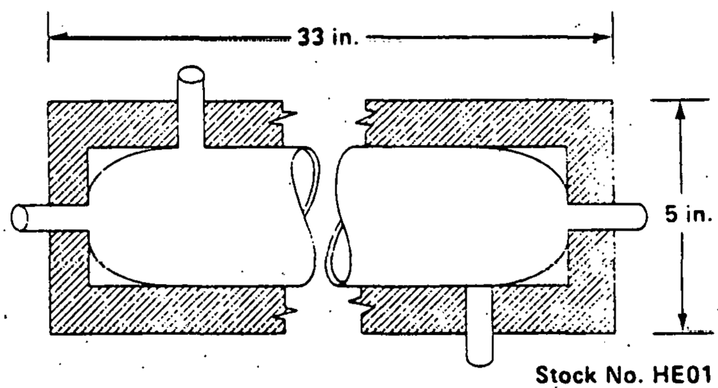
All Rho Sigma sensors are electrically identical and interchangeable and are designed to withstand stagnation temperatures of solar collectors. Two and only two sensors are required with each differential thermostat.

The **SP Sensor** is epoxied into a rugged brass housing with standard ½" pipe threads for easy installation into standard plumbing fixtures.

HEAT EXCHANGERS

SOLAR SHOP'S "TRANSOLATOR" MODEL HE1

- DESIGNED AND BUILT SPECIFICALLY FOR SOLAR WATER HEATING SYSTEMS
- ALL–COPPER CONSTRUCTION ENSURES CORROSION–FREE LONG LIFE AND EFFICIENT HEAT TRANSFER
- DOUBLE–WALL CONSTRUCTION PROTECTS DOMESTIC HOT WATER FROM CONTAMINATION
- LARGE SHELL SIDE HEAT TRANSFER AREA AND LOW PRESSURE DROP
- MEETS ALL U. S. PLUMBING CODES
- CONFORMS TO THE SOLAR HEATING SYSTEM INTERIM PERFORMANCE CRITERIA ESTABLISHED BY HUD AND ERDA REQUIRING DOUBLE–WALL CONSTRUCTION OF HEAT EXCHANGERS USED FOR DOMESTIC HOT WATER HEATING
- SIZED TO OPERATE EFFICIENTLY WITH UP TO 100 ft^2 OF SOLAR COLLECTORS
- DESIGNED FOR USE WITH VISCOUS HEAT–TRANSFER FLUIDS SUCH AS SILICONE OIL
- OPERATES EFFICIENTLY WITH WATER AND ANTIFREEZE SOLUTIONS
- ALL CONNECTIONS ARE 1/2–in. NOMINAL STANDARD COPPER TUBING (OTHER SIZES AVAILABLE UPON REQUEST)



Stock No. HE01

DWG NO 7933449

A

REVISIONS

CHK	ENGRG NOTICE	LTR	DESCRIPTION	DATE	APPROVED
	66333VM	—	RELEASE	7/29/77	
	66333BT	A	SEE EN	10/10/77	

CONTR NO.	INTERNATIONAL BUSINESS MACHINES CORP. FEDERAL SYSTEMS DIVISION HUNTSVILLE, ALA. 35807
PREPARATION V A Johnson	TITLE SYSTEM PERFORMANCE SPECIFICATION FOR SIMS PROTOTYPE SYSTEM DESIGN NO. 2
DSGN CHK	
DWG CHK	
DSGN APPROVAL Kraske 1-21-77	SIZE A · CODE IDENT NO. 20234 · DWG NO. 7933449
	SCALE · WT · SHEET 1 of 17

5-1685-0

7933449

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1.0 INTRODUCTION

This performance specification establishes the requirements for the design and performance of the solar domestic hot water system. It designates the Interim Performance Criteria applicable to this type system and defines the deviations. The appendices specify the system performance for each defined site location and system size, the installation drawings, and the detailed configuration diagrams and drawings.

2.0 APPLICABLE DOCUMENTS

The following documents form a part of this specification to the extent specified herein. Specific document reference made in subsequent shall be by basic title or reference number only.

2.1 Government Documents

Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings, January 1, 1976, U. S. Department of Housing and Urban Development.

Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems, April, 1976, NBSIR 76-1059, U. S. Department of Housing and Urban Development.

SIMS Contract Statement of Work, NAS8-30236, April 4, 1976 (with current modifications).

2.2 IBM Documents

The following document is referenced for information only:

System Two Design Description, 7933631

3.0 APPLICATION OF INTERIM PERFORMANCE CRITERIA BY TYPE OF SYSTEM

The application of each paragraph of the Interim Performance Criteria (IPC) to this type of system is provided in Table I. Since this system provides only domestic hot water, system type "HW" designates the IPC application to this system.

4.0 DEVIATION FROM INTERIM PERFORMANCE CRITERIA

The IPC deviations identified by subsystem evaluation are listed in the following paragraph.

4.1 Deviations to Residential IPC

The collector subsystem evaluation has identified several areas of non-conformance as tabulated below. No vendor analysis or test data was available to substantiate that these requirements can be met.

Paragraph	Description
3.1.2	Service loads
3.2.1	Ultimate load combinations
3.2.4	Load capacity
3.3.1	Resistance to damage
3.3.2	Glazing design
5.1.1	Solar degradation
5.2.1	Thermal degradation

4.2 Deviations to Commercial IPC

Not applicable.

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TABLE I

RESIDENTIAL SYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

Sheet 1 of 7

APPLICATION	TYPE SYSTEMS
A - APPLICABLE TO SYSTEMS INDICATED	H - HEATING
I - APPLICABLE TO SYSTEM AND BUILDING	HC - HEATING AND COOLING
NA - NOT APPLICABLE	HW - HOT WATER ONLY

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW	RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW
1.1 H and HC System Performance	NA	1.3.1 Collector Efficiency	A
1.1.1 Heating Design Temperatures	NA	1.4 Thermal Storage	NA
1.1.2 Cooling Design Temperatures	NA	1.4.1 Storage Capacity and Rate	NA
1.1.3 Relative Humidity and Water Vapor Pressure	NA	1.5 Habitability of Occupied Spaces	A
1.1.4 Solar Contribution	NA	1.5.1 Heat or Humidity Transfer Effects	I
1.1.5 Operation Impairment	NA	1.6 Energy Transport Efficiency	A
1.2 HW System Subsystem Performance	A	1.6.1 Thermal Losses and Electrical Power	A
1.2.1 Water Design Temperature	I	1.7 Control Operation Instructions	A
1.2.2 Storage Design Capacity	A	1.7.1 Installation and Maintenance	A
1.2.3 Solar Contribution	A	1.7.2 Manual Adjustment	A
1.2.4 Operational Impairment	A	1.7.3 Inhabited Space Temperature	NA
1.3 Collector Performance	A	1.7.4 Hot Water Temperature	A
		1.8 Auxiliary Energy	A
		1.8.1 Design Loads	A

TABLE I (CONTINUED)

RESIDENTIAL SYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

Sheet 2 of 7

APPLICATION

A - APPLICABLE TO SYSTEMS INDICATED
I - APPLICABLE TO SYSTEM AND BUILDING
NA - NOT APPLICABLE

TYPE SYSTEMS

H - HEATING
HC - HEATING AND COOLING
HW - HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW	RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW
2.1 System Design Conditions	A	2.3 Leakage Prevention	A
2.1.1 Equipment Capabilities	A	2.3.1 Pressure Test Nonpotable Fluids	A
2.1.2 Noise or Erosion-Corrosion	A	2.3.2 Pressure Test: Potable Water	A
2.1.3 Operating Conditions	A	2.3.3 Air Transport Systems	NA
2.1.4 Fluid Flow in Collectors	A	2.4 Collector Adjustment	A
2.1.5 Entrapped Air	A	2.4.1 Orientation and Tilt	A
2.1.6 Thermal Expansion of Fluids	A	2.4.2 Mutual Shadowing	A
2.1.7 Pressure Drops	A	2.5 Subsystem Isolation	A
2.1.8 Condensate Removal	NA	2.5.1 Shutdown in Multi-family Housing	A
2.2 Mechanical Stresses	A	2.6 Heat Transfer Fluid Quality	A
2.2.1 Vibration Stress Levels	A	2.6.1 Liquid Quality	A
2.2.2 Vibration from Moving Parts	A	2.6.2 Air Quality	NA
2.2.3 Water Hammer	A	2.6.3 Fluid Quality	A
2.2.4 Vacuum Relief Protection	A	2.6.4 Freezing Protection	A
2.2.5 Thermal Changes	A	2.7 Piping Supports	A
2.2.6 Flexible Joints	A	2.7.1 Applicable Plumbing Standards	A

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TABLE I (CONTINUED)

RESIDENTIAL SYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

Sheet 3 of 7

APPLICATION

A - APPLICABLE TO SYSTEMS INDICATED
I - APPLICABLE TO SYSTEM AND BUILDING
NA - NOT APPLICABLE

TYPE SYSTEMS

H - HEATING
HC - HEATING AND COOLING
HW - HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM H	RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEMS HW
2.8 Excessive Pressure and Temperature Protection	A	3.5.1 Design Provisions	I
2.8.1 Relief Valves and Vents	A	3.6 Creep and Residual Deflection	I
3.1 Structural Design Basis	A	3.6.1 Deflection Limitations	I
3.1.1 Applicable Standards	A	3.7 Hail Resistance	A
3.1.2 Service Loads	A	3.7.1 Hail Size and Loading	A
3.2 Failure Loads and Load Capacity	A	3.8 Constraint Loads	I
3.2.1 Ultimate Load Combinations	A	3.8.1 Foundation Settlement	I
3.2.2 Ice Loads	A	3.8.2 Constrain Loads	A
3.2.3 Vehicular Loads	I	3.9 Ponding Condition	A
3.2.4 Load Capacity	A	3.9.1 Design Provisions	A
3.3 Damage Control	A	4.1 Plumbing and Electrical Installation	A
3.3.1 Resistance to Damage	A	4.1.1 Plumbing Codes	A
3.3.2 Glazing Design	A	4.1.2 Electrical Codes	A
3.4 Cyclic Loads	A	4.2 Fail-Safe Controls	A
3.4.1 Deflection Limitations	A	4.2.1 System Failure Prevention	A
3.5 Cutting of Structural Elements	I	4.2.2 Automatic Pressure Relief Valves	A

TABLE I (CONTINUED)

RESIDENTIAL SYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

Sheet 4 of 7

APPLICATION

A - APPLICABLE TO SYSTEMS INDICATED
I - APPLICABLE TO SYSTEM AND BUILDING
NA - NOT APPLICABLE

TYPE SYSTEMS

H - HEATING
HC - HEATING AND COOLING
HW - HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW	RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW
4.3 Fire Safety	A	4.7 Excessive Surface Temperatures	A
4.3.1 Applicable Fire Standards	A	4.7.1 Protection from Heated Components	A
4.3.2 Penetrations through Fire Rated Assemblies	I	5.1 Effects of External Environment	A
4.4 Toxic	A	5.1.1 Solar Degradation	A
4.4.1 Provisions of Catch Basins	I	5.1.2 Soil Corrosion	A
4.4.2 Detection of Toxic and Flammable Fluids	A	5.1.3 Airborne Pollutants	A
4.5 Safety	I	5.1.4 Dirt Retention on Cover Plate Surface	A
4.5.1 Emergency Egress and Access	I	5.1.5 Abrasive Wear	A
4.5.2 Identification and Location of Controls	A	5.1.6 Fluttering by Wind	A
4.6 Protection and Potable Water and Circulated Air	A	5.2 Temperature and Pressure Resistance	A
4.6.1 Contamination by Materials	A	5.2.1 Thermal Degradation	A
4.6.2 Separation of Circulation Loops	A	5.2.2 Deterioration of Heat Transfer Fluids	A
4.6.3 Backflow Prevention	A	5.2.3 Thermal Cycling Stresses	A
4.6.4 Growth of Fungi	A	5.2.4 Leakage	A
		5.2.5 Deterioration of Gaskets and Sealants	A

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TABLE I (CONTINUED)

RESIDENTIAL SYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

Sheet 5 of 7

APPLICATION

A - APPLICABLE TO SYSTEMS INDICATED
I - APPLICABLE TO SYSTEM AND BUILDING
NA - NOT APPLICABLE

TYPE SYSTEMS

H - HEATING
HC - HEATING AND COOLING
HW - HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW	RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW
5.2.6 Transmission Losses Due to Outgassing	A	6.1.5 Filters	A
5.3 Chemical and Compatibility of Components	A	6.1.6 Potable Water Shutoff	A
5.3.1 Materials/Transfer Fluid Compatibility	A	6.2 Installation, Operation and Maintenance Manual	A
5.3.2 Corrosion of Dissimilar Materials	A	6.2.1 Installation Instructions	A
5.3.3 Corrosion by Leachable Substnace	A	6.2.2 Maintenance and Operation Instructions	A
5.3.4 Effects of Decomposition Products	A	6.2.3 Maintenance Plan	A
5.4 Components Involving Moving Parts	A	6.2.4 Replacement Parts	A
5.4.1 Wear and Fatigue	A	6.3 Repair and Service Personnel	A
6.1 Accessibility for Maintenance	I	6.3.1 Maintenance of H and HC Systems	NA
6.1.1 Access for System Maintenance	I	6.3.2 Maintenance of DHW System	A
6.1.2 Access for System Monitoring	I	7.1 Design	I
6.1.3 Draining and Filling of Liquids	A	7.1.1 Dwelling Design	I
6.1.4 Flushing of Liquids Subsystems	A	7.1.2 Mobile Home Design	I
		7.1.3 Site Design	I
		7.1.4 Passive Use of Solar Energy	I

TABLE I (CONTINUED)

RESIDENTIAL SYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

Sheet 6 of 7

APPLICATION	TYPE SYSTEMS
A - APPLICABLE TO SYSTEMS INDICATED	H - HEATING
I - APPLICABLE TO SYSTEM AND BUILDING	HC - HEATING AND COOLING
NA - NOT APPLICABLE	HW - HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW
7.2 Adequate Space	I
7.2.1 Collector Area	A
7.2.2 Storage Area	I
7.2.3 Utility Chases	I
7.3 Functioning of Dwelling Site	I
7.3.1 Space Use	I
7.3.2 Shading of Adjacent Structures	I
7.3.3 Impact on Environment	I
7.3.4 View	I
8.1 Interference with Mechanical Operation	I
8.1.1 Blockage of Solar Subsystem	I
8.1.2 Shading of Collector	I
8.1.3 Sensor Location	I
8.2 Mechanical and Electrical Functioning of Dwelling Site	I
8.2.1 Exhaust and Venting	I
8.2.2 Utilities	I
8.3 Mechanical and Electrical Functioning of Connections	I
8.3.1 Plumbing Connections	I
8.3.2 Electrical Connections	I
9.1 Structures Integrity	I
9.1.1 Movement in Adjacent Structures	I
9.2 Structural Integrity of Dwelling	I
9.2.1 Loads	I
9.2.2 Penetration of Structural Members	I
9.3 Structural Connections	I
9.3.1 Structural Connections	I
9.3.2 Brittle Subsystem	I
9.3.3 Strength and Stiffness	I
10.1 Safety of Dwelling and Site	I

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TABLE I (CONTINUED)

RESIDENTIAL SYSTEMS, INTERIM PERFORMANCE CRITERIA SUMMARY

Sheet 7 of 7

APPLICATION	TYPE SYSTEMS
A - APPLICABLE TO SYSTEMS INDICATED	H - HEATING
I - APPLICABLE TO SYSTEM AND BUILDING	HC - HEATING AND COOLING
NA - NOT APPLICABLE	HW - HOT WATER

RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW	RESIDENTIAL INTERIM PERFORMANCE CRITERIA PARAGRAPH	TYPE SYSTEM HW
10.1.1 Fire	I	12.2.1 Accessibility	I
10.1.2 Accidents	I	12.2.2 Ice Dams	I
11.1 Durability	I	12.3 Connections	I
11.1.1 Vegetation	I	12.3.1 Accessibility	I
11.2 Durability and Reliability of Dwelling and Site	I	13.1 Visual Characteristics of Dwelling and Site	I
11.2.1 Chemical Corrosion	A	13.1.1 Dwelling	I
11.2.2 Heat and Moisture	I	13.1.2 Neighborhood	I
11.2.3 Exterior Penetrations	I		
11.3 Durability and Reliability of Connections	A		
11.3.1 Material Compatibility	A		
12.1 Maintainability of H, HC, HW Systems	I		
12.1.1 Accessibility	I		
12.1.2 Misuse	I		
12.1.3 Permanent Maintenance Accessories	I		
12.2 Maintainability of Dwelling and Site	I		

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5.0 GOVERNMENT FURNISHED PROPERTY

The following items shall be provided by the Government:

(1) Collector subsystem: Five (5) Libbey-Owens-Ford Solar Collectors (Model 1110)

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6.0 GOVERNMENT DIRECT REQUIREMENTS

The following requirements are specified in NAS8-32036 and by verbal direction from the contract officer:

(a) IBM shall deliver one (1) system of the following type:

- o Single Family Building
- o Solar Domestic Hot Water

(b) All hardware and subsystems, except collectors, shall be purchased by IBM to good commercial practices as off-the-shelf hardware.

(c) Collector and storage sizing may be adjusted for each specific site.

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7.0 GEOGRAPHICAL AREA

This hot water system is designed for a single family residence located in the United States. Areas of application include all regions of the U. S. for which freezing temperatures are common.

7.1 Typical Geographical Locations

The system design accommodates variation in insolation within the following range:

Mean Daily Insolation 400 to 1900 BTU/Ft^2

Typical Standard Metropolitan Statistical Areas (SMSA's) within these ranges are:

- Austin, TX
- Phoenix, AZ
- Sacramento, CA
- Columbia, SC
- Memphis, TN
- Seattle, WA
- Cincinnati, OH
- St. Louis, MO
- Philadelphia, PA
- Omaha, NEB
- Fargo, ND
- Portland, ME
- Minneapolis, MN

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APPENDIX A

A-0 SYSTEM IDENTIFICATION

This Appendix defines the performance, configuration, and installation drawings for SIMS Prototype and Hot Water System, IBM Corporation, System Model Number 2A.

A-1 SYSTEM PERFORMANCE SHEETS

Site -

The system shall be installed in a single family residence in the city of Togus, State of Maine. This location has an annual average insolation of 0.472×10^6 BTU/FT^2 measured on the horizontal. System performance is based on collector orientation of 45° tilt and due south azimuth.

Space Heating Capacity -

The system will provide solar energy for N/A percent of the space heating load during the heating season based on an average annual space heating load of N/A BTU and a peak space heating load of N/A BTU/Hr.

DHW Heating Capacity -

The system will provide solar energy for 56 percent of the average hot water heating load, based on an average hot water heating load of 1.6×10^6 BTU/Month (75 gallon/day at a ΔT of 85°F).

Space Cooling Capacity -

The system will provide solar energy for N/A percent of the average total cooling during the cooling season, based on an average total cooling load of N/A BTU/Month and a peak cooling load of N/A BUT/Hr.

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Auxiliary Energy

The total average annual rate of auxiliary energy supplied for space heating, cooling and hot water shall be no greater than 8.5×10^6 BTU nor greater than 44% of the total load.

Operating Requirements

The maximum electrical power required to drive the solar portion of the system at its rated capacity shall be no greater than 320 watts. The maximum electrical power required to drive the complete system shall be no greater than 4.7 K.W. The average yearly electrical energy required to drive the system shall be no greater than 515 K.W.H. Water requirements for cooling condensers and/or air humidification shall be no greater than <u>N/A</u> gal/hr.

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Physical Data - Table III

The following subsystems shall have:

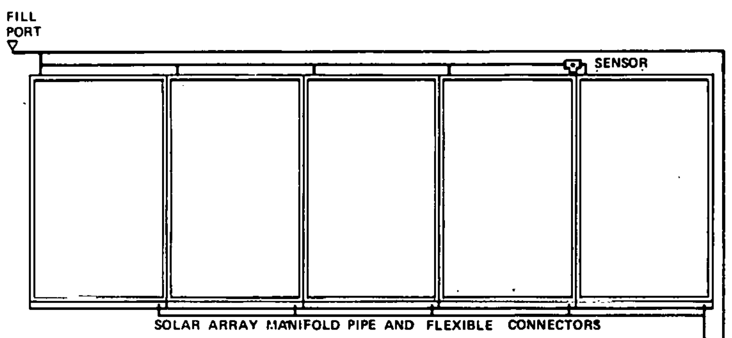
	Design life no less than	Weight (filled) no greater than	Installation* dimensions
Heating	N/A years	N/A lbs	________
Cooling	N/A years	N/A lbs	________
Auxiliary Energy	10 years	500 lbs	________
Storage	10 years	1500 lbs	________
Collector	20 years	1500 lbs	________
Energy Transport	20 years	100 lbs	________
Controls	20 years	10 lbs	________

***See Installation Drawings**

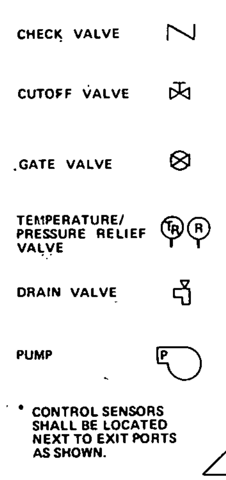
RELEASED FOR ASM	QTY	TECHNICAL APPROVAL			SYM	DATE	CHANGE NO	SYM	DATE	CHANGE NO
		ELEC			—	7-28-77	66333 VM			
		METAL								
		PLASTIC								

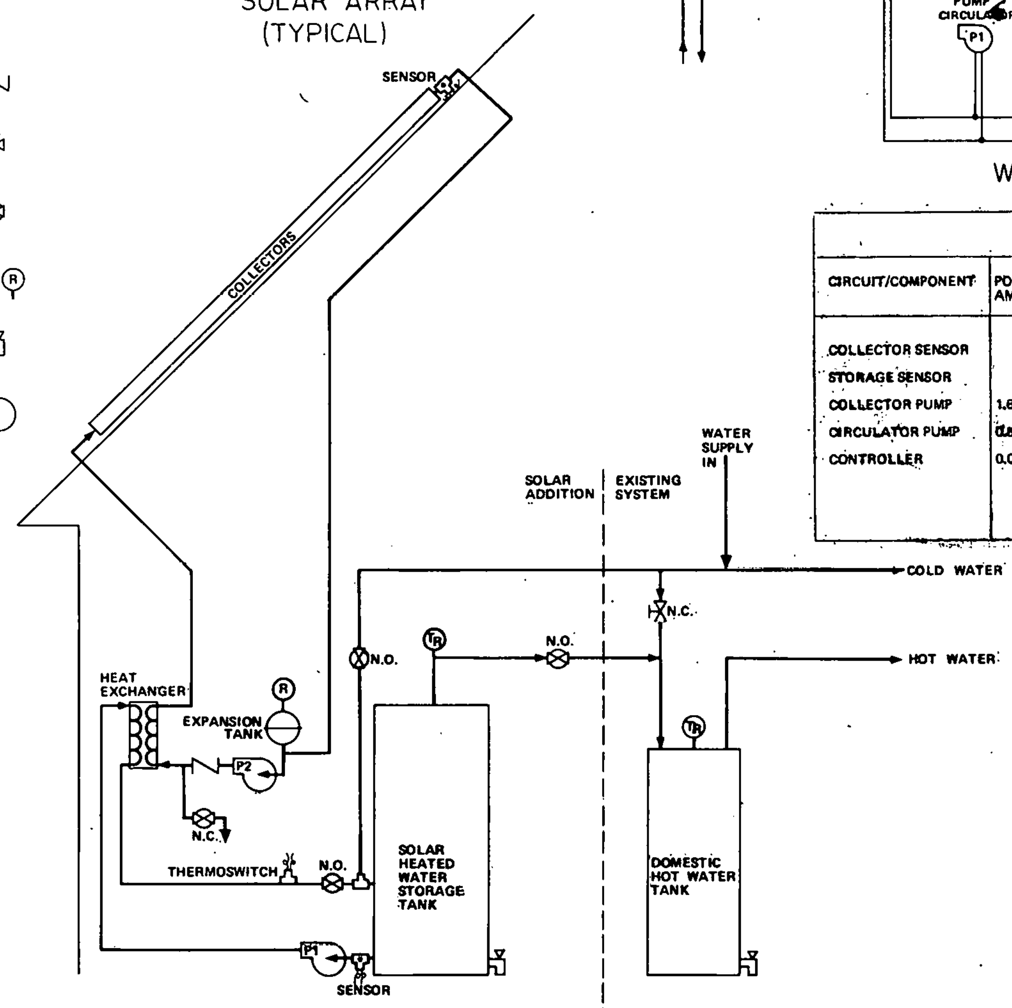
7933631

DEVELOPMENT NO | Q/M

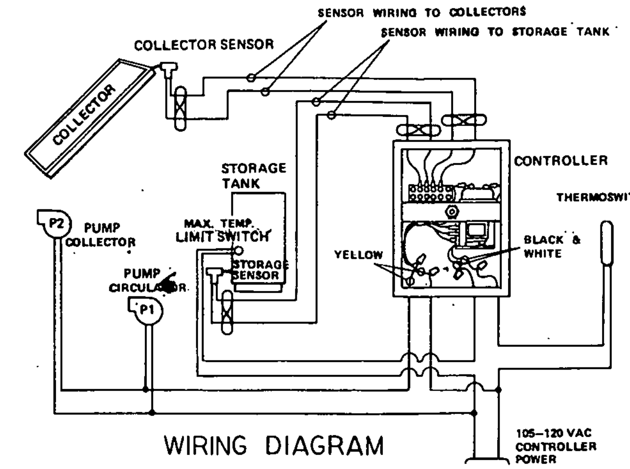


SOLAR ARRAY (TYPICAL)





SYSTEM 2 DIAGRAM



WIRING DIAGRAM

WIRING TABLE				
CIRCUIT/COMPONENT	POWER AMPS	RATING VOLTS	WIRE	NOTES
COLLECTOR SENSOR			18 GA. TWISTED PAIR	200 FT. MAX.
STORAGE SENSOR			18 GA. TWISTED PAIR	200 FT. MAX.
COLLECTOR PUMP	1.85	120 AC		YELLOW CONTROLLER WIRES
CIRCULATOR PUMP	0.85	120 AC		YELLOW CONTROLLER WIRES
CONTROLLER	0.05	120 AC		BLACK AND WHITE CONTROLLER POWER WIRES. CONNECT TO 120 VAC THROUGH THERMOSWITCH AND MAX. TEMP. LIMIT SWITCH N.C. CONTACTS AS SHOWN.

RELATED DOCUMENTS

Data Collection System	2A	7933632
Data Collection System	2B	7933632-1
Performance Specification	2A	7833449
Performance Specification	2B	7833449-1
Installation Drawing	2A	7933633
Installation Drawing	2B	7933634

GENERAL NOTES

PIPING: One inch type L copper tubing shall be used in the collector loop with 3/4 inch copper tubing in the water loop. Total piping length in each loop cannot exceed 50 feet. All piping runs should be made with a minimum of turns, fittings and piping lengths. All piping must be installed in such a way that the system can be completely drained. High temperature solder such as 95% tin, 5% silver or equivalent must be used for sweat fittings in the collector loop. For the lower temperature water loop, 50% tin/50% lead solder should be used. A mild flux such as Nokorode (paste flux) should be used throughout. Where threaded fittings are required, Teflon tape plus Teflon pipe dope must be used. Compression and/or flare fittings should be avoided.

INSULATION: All piping and pumps shall be insulated with a minimum R value of 5. Tanks and heat exchanger shall be insulated with a minimum R value of 11.

INSTALLATION REQUIREMENTS: Unless otherwise stated, standard building and plumbing practice must be used throughout.

CODES AND STANDARDS: System installation must comply with all building and plumbing codes for the location. The system must comply with the Interim Performance Criteria documents for both residential and commercial solar hot water heating.

COLLECTOR ORIENTATION AND INSTALLATION: The collectors must be mounted with tilt angle equal to the latitude and facing due south. Deviations in orientation will result in decreased performance and must be evaluated and approved prior to installation. The collector array including the manifolds must be framed in a weather-tight aesthetically pleasing enclosure. Flexible connectors must be installed between the collectors and the manifold tubing.

COMPONENT LOCATIONS: All water piping, the heat exchanger and preheat tank must be located in a heated area to prevent freezing.

COLLECTOR LOOP CHARGING: Prior to charging with the silicone fluid, the collector loop piping must be free of moisture and free of leaks. Dry air or dry nitrogen shall be used to purge the loop. After the loop is purged the dry air or nitrogen shall be used to pressurize the loop to approximately 75 psi. If the leak down rate is measurable after 1 day, all fittings must be checked for leaks and repaired, if necessary.

The silicone fluid can be pumped into the collector loop from the drain at the low point in the loop or poured into the collector return piping at the high point in the loop. The pump should be run briefly after the loop is filled to remove any trapped air and more fluid added if necessary. The plug at the top of the loop must then be closed tightly.

COMPONENT SCHEDULE

CONTROLLER: Packaged differential thermostat pump control with two temperature sensors capable of switching 10 amps at 110 vac. Pump to turn ON when the collector sensor temperature exceeds the storage sensor temperature by $20 \pm 2^{o}F$ and revert to OFF when storage sensor temperature is within $3 \pm 2^{o}F$ of collector sensor temperature. Switch points must be field adjustable. UL approved. Rho Sigma Model 106 with SP type sensors. A switch guard preventing unauthorized selection of "ON" mode should be added.

HEAT TRANSFER FLUID: Dimethyl silicone liquid which shall remain in a liquid state over a temperature range of -50 to $+400^{o}F$ without abrupt changes in the temperature/viscosity curve. Open cup flash point shall be above $400^{o}F$. Chemical stability up to $+400^{o}F$ is required. Dow Corning Q2-1132 or approved equivalent.

SOLAR STORAGE TANK: The tank must be either stone-lined or glasslined. At least one (preferably two) solar connections must be available on the side of the tank. A 120 gallon size tank is specified; however, smaller standard sizes are permissable upon approval. Ford Products or approved equivalent with thermostat.

SIZE (Gal)	FORD PRODUCTS
120Δ	AB120S
100*	—
80*	AB80S

Δ Specified size
* Permissible alternate sizes with approval (100 gallon size not available from Ford Products.)

SOLAR COLLECTOR PANELS: Flat plate liquid solar collector panels, approximately 84 x 36 x 5½ inches size and 150 pounds in weight. Number of collectors is site dependent and is specified in the site installation drawings. Libbey-Owens-Ford Company - Sun Panels.

THERMOSWITCH: Snap-action switch, to open at 40 $\pm 6^{o}F$ on decreasing temperature. UL 5 amp at 120 VAC. Elwood Company 3100 with 8208 Bracket or equivalent.

CIRCULATING PUMPS: Single stage, centrifugal design units for service listed. Suction and discharge shall be flanged with integral isolation valves. For 110 VAC operation and with all rotating parts enclosed. P1 stainless steel construction and potable rated. P2 construction compatible with silicone Q2-1132 service between $-50^{o}F$ and $400^{o}F$. Grundfos or approved equivalent.

Pump	Fluid	Min. Flow GPM	Head Ft.	Motor Hp	Grundfos
P1	Water	1.5	12	1/20	UP25-42SF
P2	Q2-1132			1/12	UP26-64
	@ $77^{o}F$	3	10		
	@ $180^{o}F$	5.5	9		

EXPANSION TANK: Galvanized steel three gallon A.S.M.E tank. Aos X 8-0 or approved equivalent.

FLEXIBLE CONNECTORS: Five to ten inch flexible copper connectors. Hydro-flex 904 7 inch solar connectors or approved equivalent.

MAX. TEMP. LIMIT SWITCH: The storage tank is purchased with an integral N.C. thermostat. Rewire thermostat as shown to remove controller power when max. temp. limit is exceeded.

HEAT EXCHANGER: Liquid to liquid design compatible with silicone fluid in the primary side and city water in the secondary side. A "fail safe" double wall design is required. Silicone fluid flow rate in primary side of 4 gpm at $100^{o}F$ shall not produce a head greater than 6.6 feet (H_2O). While a water flow rate in the secondary side of 1.5 gpm shall not produce a head greater than 3 feet (H_2O). Halstead and Mitchell Model HX-1 or approved equivalent.

CONTROL SEQUENCE

The solar system is activated by moving the controller mode switch from OFF to either the AUTO or ON position. AUTO is the normal mode for both summer and winter automatic operation. ON mode is used only for maintenance or manual back-up control.

AUTOMATIC OPERATION: In the AUTO position the controller, a differential thermostat between the collector discharge and the bottom of the pre-heat tank, determines when the solar energy is available.

Circulator pumps P1 and P2 are turned on when the collector temperature exceeds the tank temperature by $20^{o}F$. Pump P2 circulates silicone heat transfer liquid to transfer absorbed solar enrgy from the collector to the heat exchanger primary. Pump P1 circulates storage tank water through the heat exchanger secondary where it is heated and returned to the tank.

The pumps are cycled OFF when the collector temperature exceeds the preheat tank water temperature by less than $3^{o}F$.

As domestic hot water is used, city water enters the bottom of the storage tank. Solar heated water from the top of the storage tank flows into the conventional domestic hot water heater.

The hot water heater adds auxiliary heat as required to maintain the DHW temperature set point.

MANUAL OPERATION: With the mode switch in ON position, Pumps P1 and P2 operate continuously regardless of the temperature difference. The solar storage tank will gain or lose heat depending on the collector and tank temperatures.

LOW TEMPERATURE LIMIT: System operation is terminated under any operating conditions that cause the water in the heat exchanger loop to drop below $40^{o}F$. This is accomplished by the the thermoswitch opening at water loop termperatures below $40^{o}F$, which removes power from the controller, thereby cycling pumps P1 and P2 off.

7933631 - D

IBM

NAME	SYSTEM 2 DESIGN DESCRIPTION
DESIGNER	M. Strickland 2-7-77
DETAILER	Jerry W. Perry Feb. 7, '77
DWG CHK	
DSGN APPRO	2-7-77
CLASSIFICATION	

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DWG NO. 7933443

CHK	ENGRG NOTICE	LTR	DESCRIPTION	DATE	APPROVED

REVISIONS

REVISION A
DATE: 4 APRIL 1977 DCN-1

CDRL ITEM NO'S -2a
-13

CONTR NO. NAS8--32036	INTERNATIONAL BUSINESS MACHINES CORP. FEDERAL SYSTEMS DIVISION HUNTSVILLE, ALA. 35807
PREPARATION J.G. Daniel 1-12-77	TITLE VERIFICATION PLAN/PROCEDURE FOR PROTOTYPE SOLAR ENERGY HOT WATER SYSTEM MODEL NO. 2
DSGN CHK	
DWG CHK	
DSGN APPROVAL V H Johnson 1/12/77	SIZE A · CODE IDENT NO. · DWG NO. 7933448
	SCALE · WT · SHEET

955-1685-0

1. PURPOSE

1.1 The purpose of this document is to present the plan/procedure for verifying the requirements of prototype solar energy hot water system Model No. 2 performance specification.

2. SCOPE

2.1 This document describes the plan/procedure for performing prototype systems verification and includes development, qualification, and acceptance verification. Requirements for analysis verification and/or test verification are included in this plan/procedure.

3. APPLICABLE DOCUMENTS

3.1 The following documents form a part of this plan to the extent specified herein:

- Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings, HUD - January 1, 1975

- Performance Specification for Prototype Hot Water System Model No. 2.

4. VERIFICATION APPROACH

4.1 Prototype system verification to the requirements of the system performance specification and interim performance criteria will be accomplished in three verification phases — development, qualification, and acceptance. The verification methods utilized for system verification will be similarity, analysis, inspection, demonstration and test.

Prototype system verification will commence with a detailed analysis of all system hardware, components, and subsystems and progress through system evaluation and testing. Figure II of this plan depicts a summary flow for system verification.

A detailed system test procedure for performing the test requirements of this document will be prepared and submitted to MSFC for review and approval. This procedure will describe the methods and procedures for conducting prototype system test on the MSFC system test breadboard facility.

Following completion of verification program, a final system verification report will be prepared and submitted to MSFC. Report will contain all information pertinent to system verification.

5. DEVELOPMENT VERIFICATION REQUIREMENTS

5.1 Hardware/Component/Subsystem Verification - All hardware, components and subsystems that comprise the prototype system shall be verified to be in accordance with the requirements of the prototype system performance specification and the interim performance criteria. Verification of hardware, components, and subsystems will be accomplished by engineering analysis, similarity, inspection, demonstration and/or testing methods.

Subsystem test evaluation will be conducted on the system collectors, controller, and data acquisition system. All other prototype system subsystems, hardware and components will be verified individually by analysis and/or during prototype system verification.

5.2 System Development Verification - Development verification will be conducted on prototype system M/N 2 to ensure that system will perform to the requirements of the system performance specification and interim performance criteria. Development verification will consist of the following:

- Analysis of hardware, component, and subsystem evaluation data for compliance to system performance specification and interim performance criteria requirements.

- Analysis of system design for compliance to system performance specification and interim performance criteria requirements.

- System testing on MSFC System Test Breadboard Facility. Tests to be conducted are as follows:

  - System operational functional test

  - System capacity for control, energy collection, storage, and distribution to load at outside ambient weather conditions.

5.2.1 System Operational Functional Test - A system operational functional test shall be conducted on prototype system M/N 2. Operational functional test shall consist of the following:

- System pressure/leakage test

- Operation of system pumps

- Operation of system controller

- Measurement of system flow rate and pressure drop across collector array.

- Measurement of solar system pump pressure drop and dead head pressure.

- Measurement of pressure drop across heat exchanger (oil and water side).

5.2.1.1 System Operational Functional Procedure

(a) Install prototype system on breadboard test stand in accordance with test setup schematics and system drawings. Figure I of this document depicts the system test setup configuration.

(b) Connect domestic hot water system (water side) to City water supply and fill system pre-heat tank, domestic hot water tank, heat exchanger, pump and water lines.

(c) Pressurize system (water side) to 140 ± 5 psi for one hour and check system for leaks. Special emphasis shall be placed on leak testing soldered joints and mechanical connections. There shall be no leaks.

DCN-1 (d) Connect solar portion (collectors, heat exchanger, expansion tank, pump and transport lines) of system to a pneumatic supply and pressurize to 70 ± 5 psi for a minimum of two hours and check system for leaks. Leak test all soldered and mechanical joints with soap solution and measure pressure decay on system to verify no system leakage.

(e) Following step (d) and when the system is free of leakage, charge the solar portion of the system with the transfer fluid specified in system M/N 2 design documentation.

(f) Verify operation of the system pumps.

(g) Verify operation of the system controller.

DCN-1 (h) Activate system pumps and adjust flow rate of solar fluid loop to 425 ± 20 pounds per hour per solar panel.

(i) Measure pressure drop across collector array, pump and heat exchanger (oil side).

DCN-1 (j) Measure flow rate and pressure drop of heat exchanger (water side). Flow rate should be 800 lbs/hr ± 10%.

(k) Conduct dead head pressure test on pump (solar side).

5.2.2 System Test at Outside Weather Conditions - Prototype system M/N 2 shall be tested to evaluate system capacity for control, energy collection, storage and distribution to load at outside ambient weather conditions.

Prototype system M/N 2 shall be tested at outside weather conditions the maximum number of days possible contingent on system delivery schedule and breadboard facility workload. Primary intent of this test is to obtain as much data as possible prior to installing system at demonstration site. The following evaluations shall be made during system testing at outside weather conditions.

(a) Complete records of weather data (solar radiation, ambient temperature, wind speed and direction, relative humidity, and cloud cover). (Weather measurements vs. time of day)

(b) Total energy collected by solar system per day (BTU vs. time in hours)

(c) Total energy supplied to hot water load per day (BTU vs. time of day)

(d) Power required to operate system per day (watts vs. time of day)

(e) System control functions (manual observations)

5.2.2.1 Procedure for System Test at Outside Weather Conditions

(a) With prototype system M/N 2 configured on test breadboard (simulating actual installation as best practical), apply power to system and allow system to operate in accordance with system control functions (actual intended operation). Allow system to operate under No Load demand for a minimum of 24 hours.

(b) Following completion of step (a), impose the following daily hot water load demand on system M/N 2.

Time ± 30 Minutes	Amount ± 10%	Rate ± 10%
0800 hrs.	4 gal.	2 GPM for 2 minutes
0900 hrs.	8 gal.	2 GPM for 4 minutes
1100 hrs.	30 gal.	2 GPM for 15 minutes
1200 hrs.	5 gal.	2 GPM for 2.5 minutes
1800 hrs.	8 gal.	2 GPM for 4 minutes
2100 hrs.	20 gal.	2 GPM for 10 minutes

(c) The load requirements of step (b) shall be imposed each day for the total duration of system test at outside weather conditions.

(d) Allow system to operate the maximum number of days practical. Duration of testing will be determined by the test conductor with direction from MSFC SIMS contract COR or his designated representative.

(e) The following data measurements shall be made and recorded during system testing:

Measurement	Parameter
- Solar radiation	Btu/hour/ft.^{2} vs. time of day
- Ambient temperature	°F vs. time of day
- Wind speed/direction	mph/direction vs. time of day
- Relative humidity	% vs. time of day
- Cloud cover	cloud cover vs. time of day
- Collector inlet temperature	°F vs. time of day in hours
- Collector outlet temperature	°F vs. time of day in hours
- Collector absorber temperature	°F vs. time of day in hours
- Collector delta temperature	°F vs. time of day in hours
- Heat exchanger inlet temperature (water)	°F vs. time of day in hours
- Heat exchanger outlet temperature (water)	°F vs. time of day in hours
- Heat exchanger delta temperature (water)	°F vs. time of day in hours
- City water supply temperature	°F vs. time of day in hours
- Hot water system outlet temperature (to load)	°F vs. time of day in hours
- System temporary shelter temperature	°F vs. time of day in hours
- Oil flow thru collectors	GPM vs. time of day in hours
- Heat exchanger flow (water)	GPM vs. time of day in hours
- Hot water flow to load	GPM vs. time of day in hours
- Collector pump power	Watts vs. time of day in hrs
- Preheat tank pump power	Watts vs. time of day in hrs
- Domestic hot water heating element power	Watts vs. time of day in hrs

- Solar pump outlet pressure — PSI vs. time of day in hours
- Collector outlet pressure — PSI vs. time of day in hours
- Heat exchanger outlet pressure (oil side) — PSI vs. time of day in hours

(f) Test data taken from the measurements identified in step (e) shall be provided in plot form.

NOTE: Instrumentation locations for measurements identified in step (e) will be supplied in test setup schematics for prototype system 2 verification test procedure.

5.3 System Development Verifiation Hardware - System development verification analysis will be performed on the total system design. System development verification testing will be conducted on the total system with the exception of system piping and data acquisition system. System piping and insulation will simulate actual installation as best practical.

System development verification testing will be conducted utilizing the following system configured hardware and subsystems:

DCN-1

- Libbey Owen Ford M/N 1112 (5 collectors)
- Heat exchanger
- System pump (oil)
- System pump (water)
- Preheat tank (120 gal.)
- Domestic hot water tank
- System controller
- System cutoff valves
- System sensors
- System pressure/temperature relief valves
- System expansion tank

During system test the above prototype system hardware (excluding solar collectors) shall be housed in a temporary shelter with the shelter ambient temperature maintained between 35° and 100°F. This will prevent the solar system from being exposed to harsh environments and will provide an approximate simulation of the service use environment.

5.4 System Development Verification Test Procedures - Test procedures for conducting prototype system verification testing will be prepared and submitted to MSFC for approval. These procedures will describe the hardware configuration for testing, detailed test methods and procedures, sketches of test setup, test time, limits, data and report requirements, and all other procedural information pertinent to test evaluation program.

5.5 System Design Changes During Development Verification - Any design changes occurring during development verification will be verified by engineering analysis or test evaluation. Ample data will be provided for each design change to verify that the resultant change meets performance criteria requirements and that the resultant change has no adverse effects on the total system performance.

5.6 Development Verification Data - Test data accumulated during the early stages of development testing will be thoroughly evaluated and assessments will be performed on necessary system design changes. This will assure early design maturity of prototype system M/N 2.

5.7 Development Verification Extent/Level - Development verification program will be conducted to the extent necessary to verify that the final prototype system design meets or exceeds the requirements of the system performance specification and the interim performance criteria or that any requirement which has not been met has been properly dispositioned and MSFC approved by a deviation approval request. Any such deviation from the specified requirements will be documented in the final verification report and will become a part of the prototype system performance specification.

5.8 Additional Development Testing - Additional testing and evaluations other than those specified herein may be accomplished. Additional testing and evaluations will be coordinated with MSFC SIMS contracting officer or his designated representative. Additional testing and evaluation will be properly controlled, documented and reported.

6. QUALIFICATION VERIFICATION REQUIREMENTS/PROCEDURE

6.1 Qualification Verification Requirements - Requirements for qualification verification are as follows:

- Verification that the prototype system meets or exceeds the requirements of system performance specification. These requirements are:

  Interim Performance Criteria Requirements
  Government Directed Requirements
  System Identification Requirement
  Site Identification Requirement
  Auxiliary Energy Requirement
  Hot Water Requirement
  Operating Requirements
  System Physical Requirements (Design Life, Weight, Dimensions)

6.2 Qualification Verification Procedures - Procedures for verification of each qualification verification requirement are contained in the following subparagraphs.

6.2.1 Interim Performance Criteria Requirement - An analysis will be conducted on prototype system M/N 2 to satisfy this requirement. Each interim performance criteria requirement will be analyzed individually and recorded on an interim performance criteria certification form. This form will indicate compliance or noncompliance to the requirement and will identify the evaluation method utilized to satisfy the requirement. A sample copy of the interim performance criteria certification form is contained in Appendix I of this document. The certification form when completed will become a part of the final verification report.

6.2.2 Government Directed Requirements - This requirement will be satisfied by an analysis of the directed requirement, prototype system and the system performance specification to verify that the directed requirements have been satisfied.

6.2.3 System Identification Requirement - This requirement will be satisfied by review of performance specification and the prototype system to verify that the system is properly identified (type, contractor name, system model no.).

6.2.4 Site Identification Requirement - This requirement will be satisfied by review of performance specification to verify that the site for the prototype system is properly identified and described.

6.2.5 Auxiliary Energy Requirement - This requirement will be satisfied by an analysis of the prototype system load requirements and the prototype system auxiliary energy subsystem design.

6.2.6 Hot Water Requirement - This requirement will be satisfied by an analysis of the prototype system design and the hot water load requirements specified for the prototype system. Test data obtained during system development testing will be utilized to verify the design models for the hot water subsystem.

6.2.7 Operating Requirements - This requirement will be satisfied by an analysis of the prototype system design and the system operating requirements (maximum power to drive system, average yearly electrical power, water requirements). Test data obtained during system development testing will be utilized to verify the design models for the prototype system.

6.2.8 System Physical Requirements - This requirement will be satisfied by an analysis of the prototype system design and the system physical requirements (design life, weight, dimensions).

6.3 Prototype System Qualification

6.3.1 Qualification verification will consist of a critical analysis of the prototype system design at the start of development verification versus the system design at completion of development verification. An assessment of all changes implemented during development verification will be made. All test, analysis, and evaluation data originating prior to and during development verification will be analyzed and evaluated to the requirements of the prototype system performance specification and interim performance criteria.

6.3.2 The prototype system will be considered qualification verified when it is determined that the final system design and hardware has met or exceeded the requirements of the system performance specification and the interim performance criteria or that any requirement which has not been met has been properly dispositioned and MSFC approved by a deviation approval request.

6.3.3 The results of qualification verification will be documented and submitted to MSFC in the prototype system verification report.

7. ACCEPTANCE VERIFICATION REQUIREMENTS/PROCEDURE

7.1 Acceptance verification will be conducted on prototype system M/N 2 to verify that the system meets all specified requirements. Acceptance verification will consist of the following.

- Inspection of system to verify performance specification and workmanship standards
- Inspection of operational test data and evaluations to verify system performance
- Inspection of acceptance data package
- Inspection of shipping list versus hardware to be delivered
- Inspection of shipping instructions and precautions
- Inspection of documentation required for system (installation, operation, maintenance manuals, system drawings and specifications, etc., in accordance with prototype system performance specification and data package requirements).

7.2 The results of acceptance verification will be documented and submitted to MSFC in the prototype system verification report.

8. PROTOTYPE SYSTEM VERIFICATION HARDWARE DISPOSITION

Following the completion of prototype system development, qualification and acceptance verification program, the system hardware shall be removed from the MSFC breadboard facility. The system collectors, expansion tank, heat exchanger, pumps, valves, pre-heat tank, controller, and system sensors shall be prepared for shipment to a designated demonstration site. Shipping instructions shall be in accordance with prototype system M/N 2 shipping instructions.

NOTE: The system components and subsystems shall be thoroughly drained of fluid and all ports shall be sealed and taped to prevent contamination.

Simulated piping, insulation and miscellaneous hardware used during system test will be retained at the MSFC breadboard facility for possible future utilization.

9. PROTOTYPE SYSTEM VERIFICATION DOCUMENTATION

9.1 Prototype System Test Procedure - Prototype system test procedure for prototype system M/N 2 will be generated utilizing the requirements of this document, prototype system performance specification, and drawings. Test procedure will be submitted to MSFC for approval prior to the start of system verification testing. Test procedure shall contain at a minimum the following information.

(a) Identification of hardware/system to be verified (model number, serial number, manufacturer, size, description, etc.)

(b) Test requirements

(c) Development verification test methods/procedures

(d) Instrumentation and data requirements

(e) Location of tests to be conducted

(f) Test limits and tolerances

(g) Test equipment to be utilized

(h) Detailed test setup and system configuration sketches

(i) Test reporting procedures

9.2 Verification Report - A final prototype system verification report will be generated following completion of system verification. Final report will be submitted to MSFC and shall contain at a minimum the following:

(a) Summary - resumè of verification results

(b) Purpose of verification and requirements to be verified

(c) Hardware/system identification (model number, serial number, manufacturer, size, description, etc.)

(d) Summary of verification procedures

(e) Results of development verification

(f) Results of qualification verification

(g) Results of acceptance verification

(h) Definition of analysis conducted

(i) Definition of inspections conducted

(j) Definition of tests conducted

(k) Photographs and/or detailed sketches of test setups

(l) Test data (data sheets, charts, graphs, plots, etc.)

(m) Equipment and facilities used for test

(n) Conclusions and recommendations

10. VERIFICATION MATRIX

Cross reference matrix for prototype system M/N 2 verification is contained in Apprndix II of this document. This matrix is applicable to system selected for physical testing.

PROTOTYPE SYSTEM 2
TEST SET UP CONFIGURATION

DCN-1

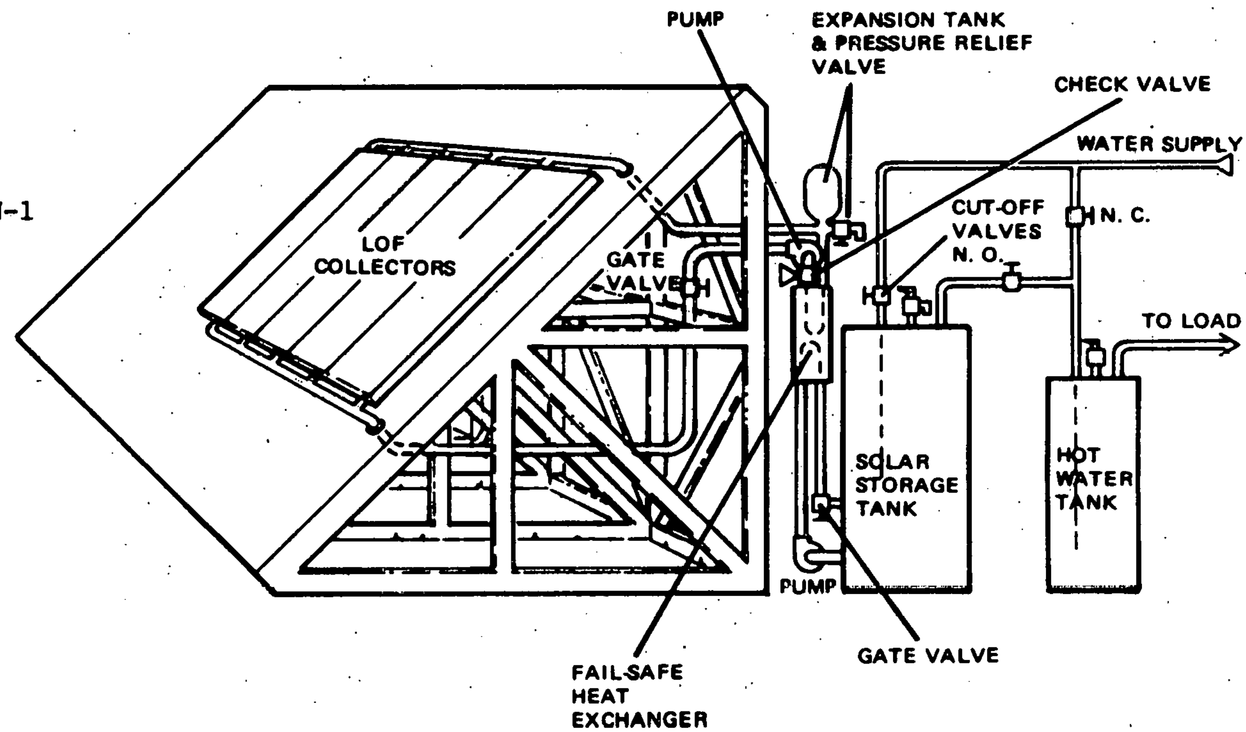

Fig. I

PROTOTYPE SYSTEM MODEL 2 VERIFICATION
APPROACH/FLOW

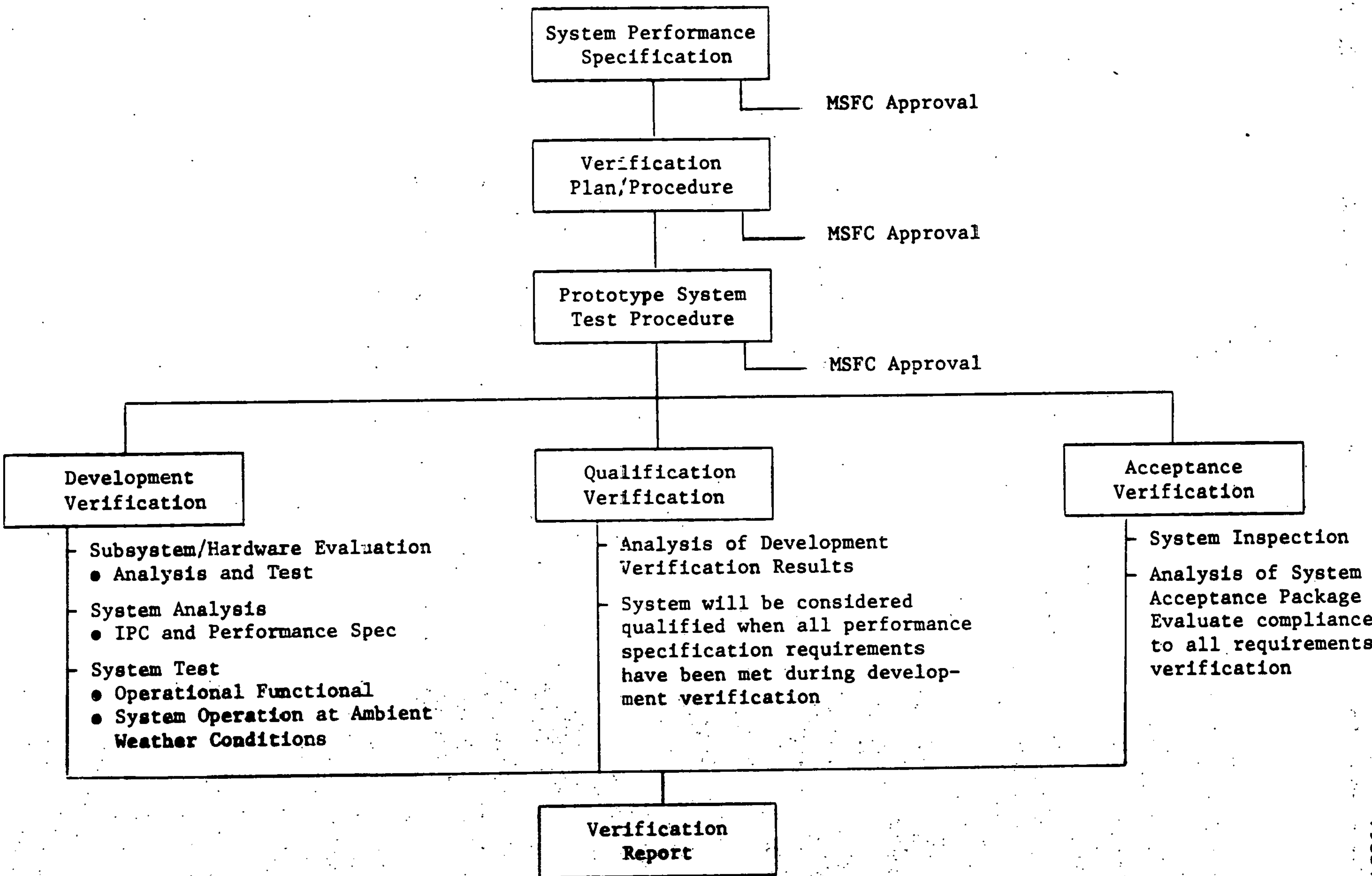

Fig. II

7933448

APPENDIX I

INTERIM PERFORMANCE CRITERIA
CERTIFICATION FORMS

INTERIM PERFORMANCE CRITERIA

CERTIFICATION

System Type ________________________________

System Model No. ____________________________

System Mfg. ________________________________

Certified by ________________________________
Authorized Representative

Date ________________________________

INTERIM PERFORMANCE CRITERIA CERTIFICATION INSTRUCTIONS

I. Evaluate system for each IPC requirement listed on IPC Certification Sheets. All requirements are to be in accordance with HUD Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings. HUD - January 1, 1975.

II. Check each requirement status

Yes - Meets IPC requirement
No - Does not meet IPC requirement
N/A - Requirement not applicable

III. List IPC requirement evaluation method utilized

Analysis
Test
Inspection
Demonstration
Other

IV. All requirements which are not met shall be defined and recorded on IPC Deviation Approval Request (form attached).

IPC REQUIREMENT	IPC NO.	MEETS IPC YES	MEETS IPC NO	N/A	EVALUATION METHOD	COMMENTS
Heating and Heating and Cooling System Performance	1.1					
Hot Water System Subsystem Performance	1.2					
Collector Performance	1.3					
Thermal Storage	1.4					
Habitability of Occupied Space	1.5					
Energy Transport Efficiency	1.6					
Control	1.7					
Auxiliary Energy	1.8					

IPC REQUIREMENT	IPC NO.	MEETS IPC		N/A	EVALUATION METHOD	COMMENTS
		YES	NO			
System Design Conditions	2.1					
Mechanical Stresses	2.2					
Leakage Prevention	2.3					
Collector Adjustment	2.4					
Subsystem Isolation	2.5					
Heat Transfer Fluid Quality	2.6					
Piping Supports	2.7					
Excessive Pressure and Temperature Protection	2.8					

IPC REQUIREMENT	IPC NO.	MEETS IPC		N/A	EVALUATION METHOD	COMMENTS
		YES	NO			
Structural Design Basis	3.1					
Failure Loads and Load Capacity	3.2					
Damage Control	3.3					
Cyclic Loads	3.4					
Cutting of Structural Elements	3.5					
Creep and Residual Deflection	3.6					
Hail Resistance	3.7					
Constraint Loads	3.8					
Ponding Conditions	3.9					

IPC REQUIREMENT	IPC NO.	MEETS IPC		N/A	EVALUATION METHOD	COMMENTS
		YES	NO			
Plumbing and Electrical Installation	4.1					
Fail Safe Controls	4.2					
Fire Safety	4.3					
Toxic and Flammable Fluids	4.4					
Safety	4.5					
Protection of Potable Water and Circulated Air	4.6					
Excessive Surface Temperatures	4.7					
Effects of External Environment	5.1					

IPC REQUIREMENT	IPC NO.	MEETS IPC		N/A	EVALUATION METHOD	COMMENTS
		YES	NO			
Temperature and Pressure Resistance	5.2					
Chemical Compatibility of Components	5.3					
Components Involving Moving Parts	5.4					
Accessibility for Maintenance	6.1					
Installation, Operation and Maintenance Manual	6.2					
Repair and Service Personnel	6.3					
Dwellings/Facility and Site						

IPC REQUIREMENT	IPC NO.	MEETS IPC		N/A	EVALUATION METHOD	COMMENTS
		YES	NO			
Design	7.1					
Adequate Space	7.2					
Functioning of Dwelling/Facility Site	7.3					
Interference with Mechanical Operation	8.1					
Mechanical and Electrical Functioning of Dwelling and Site	8.2					
Mechanical and Electrical Functioning of Connections	8.3					
Structural Integrity	9.1					
Structural Integrity of Dwelling	9.2					

IPC REQUIREMENT	IPC NO.	MEETS IPC YES	MEETS IPC NO	N/A	EVALUATION METHOD	COMMENTS
Structural Connections	9.3					
Safety of Dwellings and Site	10.1					
Durability	11.1					
Durability and Reliability of Dwelling and Site	11.2					
Durability and Reliability of Connections	11.3					
Maintainability of H, HC, HW Systems	12.1					
Maintainability of Dwelling and Site	12.2					
Connections	12.3					
Visual Characteristics	13.1					

INTERIM PERFORMANCE CRITERIA DEVIATION APPROVAL REQUEST

1. Report Number	2. Date	3. Prepared By	4. Organization	5. System Type

6. System Model No.	7. System S/N	8. System Contractor	9. IPC Deviation

10. IPC Number	11. IPC Paragraph	12. Approved By (IBM)	13. Approved By (MSFC)	14. Date Approved (MSFC)

15. Description of Deviation

16. Probable Cause

17. Remarks

18. Deviation Disposition

APPENDIX II

VERIFICATION CROSS REFERENCE MATRIX

CODE 20234

ITEM (Name & Part No.)	VERIFICATION CROSS REFERENCE MATRIX
Prototype System M/N 2	

VERIFICATION METHOD:

1. Similarity
2. Analysis
3. Inspection
4. Test

N/N Not Applicable

PERFORMANCE SPECIFICATION REQUIREMENT	VERIFICATION PHASE			REMARKS
	Development	Qualification	Acceptance	
Interim Performance Criteria	2	2		
Government Directed Requirements	2, 3	2, 3	3	
System Identification Requirements	2, 3	2, 3	3	
Site Identification Requirement			3	
Auxiliary Energy Requirement	2, 4	2		
Hot Water Requirement	2, 4	2		
Operating Requirements	2, 4	2		
System Physical Requirements	2	2	3	

CONTRACT NO. NAS8-32036

VERIFICATION STATUS SUMMARY

FOR

SYSTEM NO. 2

PROTOTYPE SOLAR HOT WATER SYSTEM

FIRST ARTICLE REVIEW DATA PACKAGE
REQUIREMENT PARAGRAPH 4.3.3(a)
APPENDIX B

SEPTEMBER 30, 1977

PREPARED BY M. A. Strickland

APPROVED BY [signature]

1.0 PURPOSE

1.1 The purpose of this document is to present a summary of the verification status for Prototype Solar Energy Hot Water System No. 2.

2.0 SCOPE

2.1 This document provides a summary of Prototype System No. 2 verification which includes verification of performance specification requirements and acceptance verification requirements. Requirements of the performance specification will be satisfied by analysis and test.

3.0 VERIFICATION REQUIREMENTS

3.1 Performance Specification Requirements

Prototype System No. 2 shall be in accordance with the requirements of Performance Specification (IBM Document No. 7933449). All requirements will be verified by test or analysis. Requirements are as follows:

- o Interim Performance Criteria Requirements
- o Government Directed Requirements
- o System Identification Requirement
- o System Hot Water Requirement
- o Operating Requirements
- o System Physical Requirements

3.2 Acceptance Verification Requirements

Prototype System No. 2 shall be in accordance with the acceptance verification requirements paragraph 7.0 of IBM Document No. 7933448. Requirements are as follows:

- Inspection of system to verify performance specification and workmanship standards.

- Inspection of acceptance data package

  - Shipping and handling instructions
  - Warranty and Test Agency Certification
  - "Final Acceptance" and Shipping Form (DD250) including forms for all ship-separate items

4.0 VERIFICATION SUMMARY

4.1 Narrative Abstract - Prototype Solar Energy Hot Water System No. 2 was subjected to a test and analysis verification to verify the requirements of performance specification No. IBM 7933449. Verification was conducted in accordance with the requirements of IBM Document No. 7933448 (Verification Plan/Procedure for Prototype Solar Energy Hot Water System Model No. 2) Acceptance verification will be conducted during final acceptance of Prototype System Model No. 2.

Prototype System No. 2 meets all requirements of Performance Specification No. 7933449 with the exception of seven (7) interim performance criteria deviations on the system collectors. Deviations are identified in Appendix I of this document.

Verification of Prototype System No. 2 will be considered completed with MSFC approval of deviation approval request for system collectors and with the successful completion of acceptance verification to be conducted during final system acceptance.

4.2 Verification Results

4.2.1 Performance Specification Verification

4.2.1.1 Interim Performance Criteria - Prototype System No. 2 meets all interim performance criteria requirements with the exception of collectors. Seven deviations were required for the collectors. A deviation from these requirements is requested by IBM since the subject collectors are Government furnished to IBM. Detailed interim performance criteria evaluation is contained in Appendix I of this document.

4.2.1.2 Government Directed Requirements - These requirements have been satisfied by review of performance specification requirements and system design drawing. System 2 meets requirements.

4.2.1.3 System Identification Requirement - Requirement has been satisfied by identification of system in the performance specification (system type and system model number). System 2 meets requirements.

4.2.1.4 Site Identification Requirement - Requirement has been satisfied by identification of the geographical areas which the design accommodates as listed in the performance specification. System 2 meets requirements.

4.2.1.5 Hot Water Requirement - Requirement has been satisfied by test and analysis of system design. System 2 meets requirements.

4.2.1.6 Operating Requirements - Requirement has been satisfied by test and analysis of system design. System 2 meets requirements.

4.2.1.7 System Physical Requirements - Requirement has been satisfied by analysis of system design. System 2 meets requirements.

4.3 Acceptance Verification Requirements

4.3.1 Inspection of System - This requirement will be satisfied during final acceptance of System 2.

4.3.2 Inspection of Acceptance Data Package - This requirement will be satisfied during final acceptance of System 2.

5.0 VERIFICATION REPORT

5.1 A final verification report for Prototype System 2 will be prepared and submitted to MSFC thirty days following system acceptance. Report will be prepared in accordance with paragraph 9.2 of IBM Document No. 7933448.

APPENDIX I

PROTOTYPE SYSTEM MODEL NO. 2

INTERIM PERFORMANCE CRITERIA EVALUATION

INTERIM PERFORMANCE CRITERIA

CERTIFICATION

System Type Hot Water Only

System Model No. Prototype System 2

System Mfg. IBM

Analysis Conducted by M. A. Strickland

Date September 30, 1977

INTERIM PERFORMANCE CRITERIA CERTIFICATION INSTRUCTIONS

I. Evaluate system for each IPC requirement listed on IPC Certification Sheets. All requirements are to be in accordance with HUD Interim Performance Criteria for Solar Heating and Combined Heating/Cooling Systems and Dwellings. HUD - Januaary 1, 1975.

II. Check each requirement status

Yes - Meets IPC requirement

No - Does not meet IPC requirement

N/A - Requirement not applicable

III. List IPC requirement evaluation method utilized

Analysis
Test
Inspection
Demonstration
Other

IV. All requirements which are not met shall be defined and recorded on IPC Deviation Approval Request (form attached).

IPC REQUIREMENT	IPC NO.	MEETS IPC YES	MEETS IPC NO	N/A	EVALUATION METHOD	COMMENTS
Heating and Heating and Cooling System Performance	1.1			X		
Hot Water System Subsystem Performance	1.2	X			Test & Analysis	
Collector Performance	1.3	X			Test & Analysis	
Thermal Storage	1.4	X			Test & Analysis	
Habitability of Occupied Space	1.5	X			Design Review	
Energy Transport Efficiency	1.6	X			Test & Analysis	
Control	1.7	X			Test & Analysis	
Auxiliary Energy	1.8	X			Analysis	

IPC REQUIREMENT	IPC NO.	MEETS IPC		N/A	EVALUATION METHOD	COMMENTS
		YES	NO			
System Design Conditions	2.1	X			Design Analysis	
Mechanical Stresses	2.2	X			Test	
Leakage Prevention	2.3	X			Test	Applicable portions of system will be pressure tested during system installation
Collector Adjustment	2.4	X			Analysis	
Subsystem Isolation	2.5	X			Design Review	
Heat Transfer Fluid Quality	2.6	X			Test & Analysis	
Piping Supports	2.7	X			Design Review	
Excessive Pressure and Temperature Protection	2.8	X			Test	

IPC REQUIREMENT	IPC NO.	MEETS IPC YES	NO	N/A	EVALUATION METHOD	COMMENTS
Structural Design Basis	3.1					
Service Loads	3.1.2		X		Data Review	No data available to substantiate collector meets requirements
Failure Loads and Load Capacity	3.2					
Ultimate Load Combination	3.2.1 3.2.4		X X		Data Review	No data available to substantiate collector meets requirements
Damage Control	3.3					
Resistance to Damage	3.3.1		X		Data Review	No data available to substantiate collector meets requirements
Glazing Design	3.3.2		X			No data available to substantiate collector meets requirements
Cyclic Loads	3.4	X			Design Review	
Cutting of Structural	3.5			X		
Creep and Residual Deflection	3.6			X		
Hail Resistance	3.7	X			Design Review	
Constraint Loads	3.8	X			Design Review	
Ponding Conditions	3.9	X			Design Review	

IPC REQUIREMENT	IPC NO.	MEETS IPC YES	MEETS IPC NO	N/A	EVALUATION METHOD	COMMENTS
Plumbing and Electrical Installation	4.1	X			Design Review	
Fail Safe Controls	4.2	X			Design Review	
Fire Safety	4.3	X			Design Review	
Toxic and Flammable Fluids	4.4	X			Test	Fluid temperature will not exceed 350°F in the LOF collectors.
Safety	4.5	X			Design Review	
Protection of Potable Water and Circulated Air	4.6	X			Design Review	A double wall heat exchanger is used to seperate the water and silicone fluid.
Excessive Surface Temperatures	4.7	X			Tests	With the specified insulation
Effects of External Environment	5.1					There is no data to substantiate that the collectors meet these requirements.
Solar Degradation	5.1.1		X			

IPC REQUIREMENT	IPC NO.	MEETS IPC YES	MEETS IPC NO	N/A	EVALUATION METHOD	COMMENTS
Temperature and Pressure Resistance	5.2	X			Test & Analysis	
Transmission losses due to outgassing	5.2.1		X			No data available to substantiate collector meets requirements
Chemical compatibility of Components	5.3	X			Design Analysis	
Components involving moving parts	5.4	X			Test & Design Review	
Accessibility for maintenance	6.1	X			Design Review	
Installation, Operation and Maintenance Manual	6.2	X			Design Data Brochure Review	
Repair and Service Personnel	6.3	X			Design Review	
Dwellings/Facility and Site				X		

IPC REQUIREMENT	IPC NO.	MEETS IPC		N/A	EVALUATION METHOD	COMMENTS
		YES	NO			
Design	7.1			X		
Adequate Space	7.2	X			Design Review	
Functioning of Dwelling/Facility Site	7.3			X		
Interference with Mechanical Operation	8.1			X		
Mechanical and Electrical Functioning of Dwelling and Site	8.2			X		
Mechanical and Electrical Functioning of Connectors	8.3			X		
Structural Integrity	9.1			X		
Structural Integrity of Dwelling	9.2			X		

IPC REQUIREMENT	IPC NO.	MEETS IPC		N/A	EVALUATION METHOD	COMMENTS
		YES	NO			
Structural Connections	9.3			X		
Safety of Dwellings	10.1			X		
Durability	11.1			X		
Durability and Reliability of Dwelling and Site	11.2	X			Design Review	
Durability and Reliability of Connections	11.3	X			Design Review	
Maintainability of H, HC, HW Systems	12.1			X		
Maintainability of Dwelling and Site	12.2			X		
Connections	12.3			X		
Visual Characteristics	13.1			X		

INTERIM PERFORMANCE CRITERIA DEVIATION REPORT

1. Report Number	2. Date	3. Prepared By	4. Organization	5. Item Name
	9/29/76	D. Linton		Flat Plate Collector

6. Item Part Number	7. Item S/N	8. Item Mfg. By	9. IPC Deviation
		Libby Owen Ford	Service Loads

10. IPC Number	11. IPC Paragraph	12. Approved By (IBM)	13. Approved By (MSFC)	14. Date Approved (MSFC)
	3.1.2			

15. Description of Deviation

Vendor indicates collector can withstand wind loads of 30 #/ft^2. Per ANSI A58.1 load for severe wind conditions at 30 ft. elevations is 32 #/ft^2.

16. Probable Cause

17. Remarks

18. Deviation Disposition

IBM07

INTERIM PERFORMANCE CRITERIA DEVIATION REPORT

1. Report Number	2. Date	3. Prepared By	4. Organization	5. Item Name
	9/29/76	D. Linton		Flat Plate Collector

6. Item Part Number	7. Item S/N	8. Item Mfg. By	9. IPC Deviation
		Libby Owen Ford	Ultimate load combinations

10. IPC Number	11. IPC Paragraph	12. Approved By (IBM)	13. Approved By (MSFC)	14. Date Approved (MSFC)
	3.2.1 3.2.4			

15. Description of Deviation

Most of the ultimate load combinations exceed the vendor's stated capability of 30 #/ft ^{2}.

16. Probable Cause

17. Remarks

18. Deviation Disposition

IBM07

INTERIM PERFORMANCE CRITERIA DEVIATION REPORT

1. Report Number	2. Date	3. Prepared By	4. Organization	5. Item Name
		D. Linton		Flat Plate Collector

6. Item Part Number	7. Item S/N	8. Item Mfg. By	9. IPC Deviation
		Libby Owen Ford	Resistance to Damage

10. IPC Number	11. IPC Paragraph	12. Approved By (IBM)	13. Approved By (MSFC)	14. Date Approved (MSFC)
	3.3.1			

15. Description of Deviation

Vendor indicates collector can withstand wind loads of 30 $\#/ft^2$. Ultimate load combinations exceed this load.

16. Probable Cause

17. Remarks

18. Deviation Disposition

IBM07

INTERIM PERFORMANCE CRITERIA DEVIATION REPORT

1. Report Number	2. Date	3. Prepared By	4. Organization	5. Item Name
		D. Linton		Flat Plate Collector

6. Item Part Number	7. Item S/N	8. Item Mfg. By	9. IPC Deviation
		Libby Owen Ford	Glazing design

10. IPC Number	11. IPC Paragraph	12. Approved By (IBM)	13. Approved By (MSFC)	14. Date Approved (MSFC)
	3.3.2			

15. Description of Deviation

Glazing is not permanently marked in accordance with IPC.

16. Probable Cause

100

17. Remarks

18. Deviation Disposition

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INTERIM PERFORMANCE CRITERIA DEVIATION REPORT

1. Report Number	2. Date	3. Prepared By	4. Organization	5. Item Name
	9/29/76	D. Linton		Flat Plate Collector

6. Item Part Number	7. Item S/N	8. Item Mfg. By	9. IPC Deviation
		Libby Owen Ford	Solar and thermal degradation

10. IPC Number	11. IPC Paragraph	12. Approved By (IBM)	13. Approved By (MSFC)	14. Date Approved (MSFC)
	5.1.1 5.2.1			

15. Description of Deviation

The vendor states his collector is capable of sustaining a minimum of 1,000 hours cumulative period of solar exposure with no coolant and full daily solar insulation without damage. It is expected that the collector will be exposed to considerably more than its rated exposure over its service life. There is no data in the data package to substantiate the vendors claim.

16. Probable Cause

17. Remarks

18. Deviation Disposition

IBM07

APPENDIX II

SYSTEM 2 PERFORMANCE ANALYSIS SUMMARY

SYSTEM 2 TEST AND ANALYSIS PERFORMANCE SUMMARY

Initial evaluation of the System 2 design was accomplished using an f-chart simulation model. Three weeks of testing have been completed to date verifying the earlier analysis. To date, the system has worked satisfactorily with no problems. The test report will be submitted 30 days after completion of testing.

The following paragraphs summarize the analysis of the system. The system schematic is shown in Figure 1. The major components are listed below.

- Collectors
  - 98.5 ft^2
  - 45^o tilt angle
  - 0^o azimuth
- Preheat Tank (storage)
  - 120 gal.
  - R-22 insulation
- Heat Exchanger (Double wall)
  - Approximately 50% efficiency
- Circulator Pumps
  - (1) 1/20 HP SS circulator for water
  - (1) 1/12 HP circulator for collector fluid

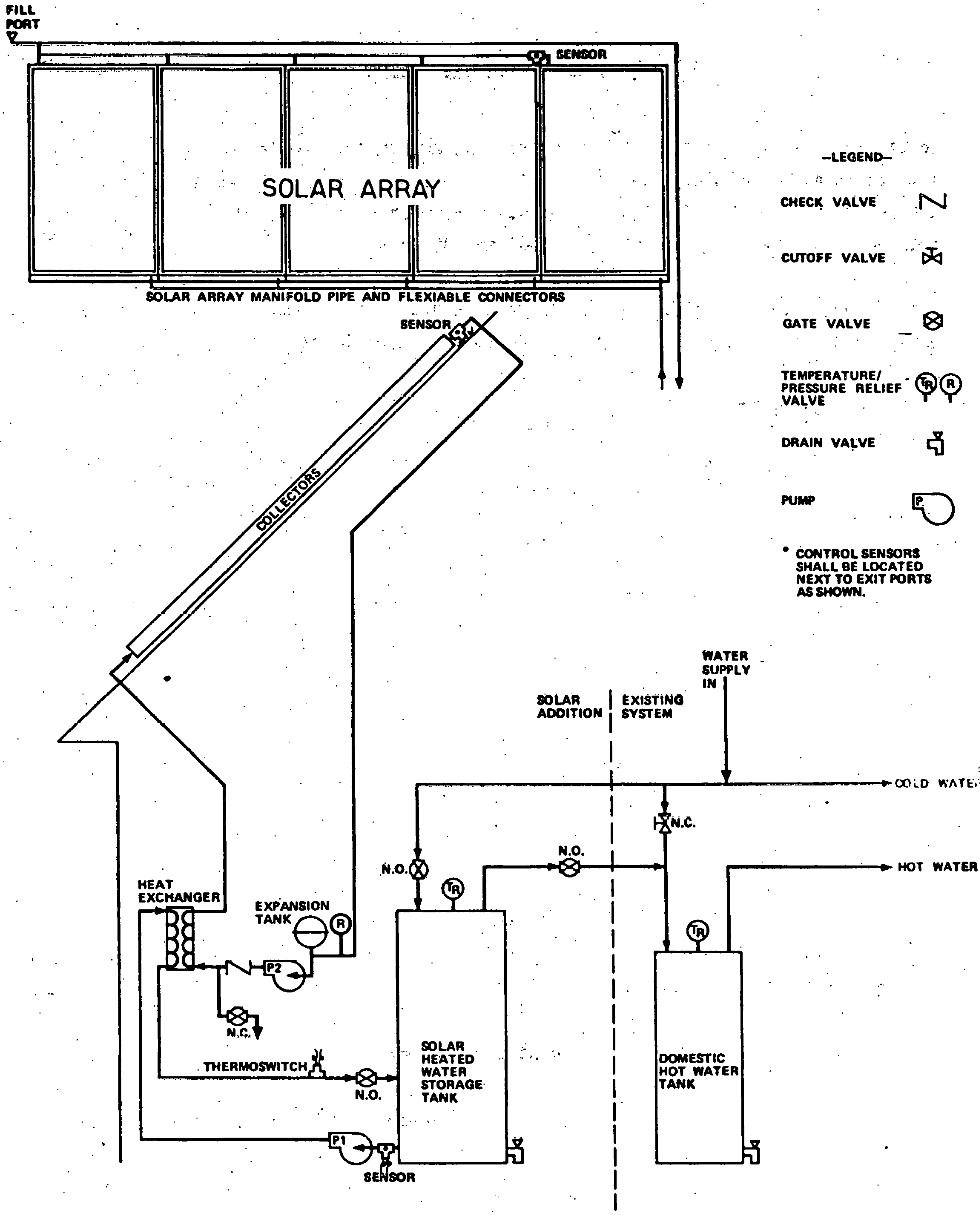

Figure 1. System 2 Functional Schematic

SYSTEM PERFORMANCE

The primary system parameters which determine the overall performance of the System 2 design for any given site/application are the collector unit performance,* collector area and, to a much lesser extent, the preheat storage tank size. The sizes selected for a given application of this design are influenced primarily by the local insolation, the cost of auxiliary fuel, and the hot water load (consumption rate). System 2 was designed for nominal values of these conditions applicable to the most statistically significant portions of the continental United States. It thus represents a design with wide-spread application potential with only slight adjustments necessary in system size. The "nominal" conditions as used herein are defined as:

o	Insolation, mean daily total,	1200-1700 Btu/Ft^2
o	Auxiliary Fuel Cost (Elec.)	0.02-0.04 $/KWH
o	Hot water consumption	50-120 gallons/day

A. Collector

Evaluation has shown that the optimum collector area for this system design is one collector panel (19.7 Ft^2) for each 15 gallons per day of hot water consumption. This approximate relationship holds for the range of nominal conditions and results in a solar contribution of from 45 to 65% of the annual dhw load. For applications where the hot water consumption rate is unknown, a typical single family residence with an automatic washer is sometimes assumed to consume an average of 75 gallons/day, thereby requiring five (5) solar panels.

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* The collector unit performance is fixed since System 2 specifies the LOF collector. Subsequent discussion of system sizes is therefore applicable specifically only to the use of this collector.

B. Storage

The optimum preheat tank size is approximately 24 gallons per collector panel. This is based on producing the highest performance return per initial (tank) cost and assumes the use of a preheat tank of a size common to standard domestic hot water tank manufacturer. Sizes in this category in the general range of interest are typically 80, 100 and 120 gallons. For five (5) collectors, the 120 gallon tank is near optimum.

C. Performance for Bangor Site

The initial site for the System 2 baseline design is a single family residence located near Bangor, Maine. Pertinent system/site parameters including collector area and tank sizes are compiled in Table 1. For the conditions listed in Table 1, System 2 design will supply annually approximately 10.89×10^6 Btu to the total hot water load of 19.44×10^6 Btu. This is a percent solar contribution of 56%.

Table 1. Site and System Parameters

Parameter	Value
o **Site Conditions**	
Location	Togus, Maine
Application	DHW, Single Family Residence
Hot Water Consumption	75 gallons per day*
Delivery Temperature	$140^{o}F$
Supply Water Temperature	$55^{o}F$, mean
Insolation	1300 Btu/Ft^2, mean daily
Auxiliary Fuel Cost	0.0268 $/KWH
o **System Design**	
Number of Collectors	5
Collector Area	98.5 $Ft.^2$
Tilt Angle	45^{o}
Azimuth Angle	0^{o} (due south)
Storage SIze	120 Gallons

* Recommended design value for typical residence with automatic washer per NBS 76-1059 "Intermediate Minimum Property Standards for Solar Heating and Domestic Hot Water Systems".

PROTOTYPE SYSTEM NO. 2 HAZARDS ANALYSIS

A hazards analysis was performed to define potential hazards or undesired events relative to the System 2 design, to identify the safety requirement to eliminate the hazard, and to indicate the means of compliance with each safety requirement. A summary of the hazards analysis results follows.

All potential hazards identified are minor level hazards and no major hazard levels have been found. No residual hazards have been identified and no failure modes have been identified which would contribute to the occurrence of a hazard. The use of standard off-the-shelf hardware minimizes potential hazards.

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