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DOE NASA CONTRACTOR
REPORT

DOE NASA CR-161414

SOLAR PROCESS WATER HEAT FOR THE IRIS IMAGES CUSTOM
COLOR PHOTO LAB - FINAL REPORT

Prepared by

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117 Park Place
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Under DOE Contract EX-76-C-01-2381

Monitored by

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812
For the U. S. Department of Energy

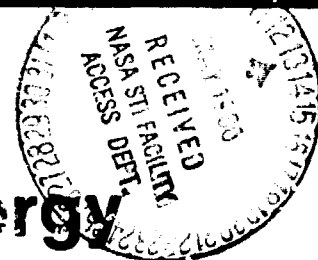
(NASA-CR-161414) SOLAR PROCESS WATER HEAT
FOR THE IRIS IMAGES CUSTOM COLOR PHOTO LAB
Final Report (Interactive Resources, Inc.)
126 p HC A07/MF A01 CSCL 10B

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U.S. Department of Energy



Solar Energy

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I.
FOREWORD

I. FOREWORD

The Iris Images, Inc., film processing lab was the first commercial solar application in its geographic area. It was one of the first solar systems completed under the national solar demonstration program and was among the first systems completely instrumented and monitored under the national solar data network.

The film processing laboratory served as a prototype not only for solar utilization but for the interaction of government and the private sector in the development of the demonstration program and, to some extent, the solar industry.

The reader should be cautioned not to consider the design as the state-of-the-art. It is important to note the sections on lessons learned and to keep in mind the time frame of the installation and the subsequent rapid growth of the solar industry.

John Cofrin, the owner of the film processing lab, must be commended for his pioneering spirit and commitment toward solar utilization. The solar installation was planned with or without government support.

Other key participants in the project included Interactive Resources, Inc., Point Richmond, California, who provided architecture, engineering and construction management services as well as the contracting for the installation of the solar system. NASA's solar demonstration office in Huntsville, Alabama, provided project management for the government under ERDA/DOE, and IBM, Huntsville, was responsible for the instrumentation program, also under contract to DOE.

II.

EXECUTIVE SUMMARY

II. EXECUTIVE SUMMARY

The following is a brief summary of the Iris Images, Inc., solar installation. Major features of this system include:

- Collector type: Site-fabricated, flat plate, liquid
- Freeze protection: Circulation, draindown (Changed to draindown scheme after freeze.)
- Application: Photographic process water heating
- Storage type: Glass-lined steel tank
- New or retrofit: New

The solar energy is used to heat photographic process water in a commercial photo processing laboratory located in Mill Valley, California. The solar system was installed in the new building during the spring of 1976.

Two collector banks are mounted on the flat roof of the building with a total aperture area of 640 square feet. Both banks were site fabricated. The absorber plates for one bank are aluminum, as manufactured by Sunburst Solar Energy, Inc. The other absorber plates are copper and were manufactured by Solar Development, Inc. Copper tubing is used for the fluid passages in both collectors.

Both banks are connected in parallel with rigid copper connections to the risers. Water is pumped between the collectors and three 120-gallon insulated storage tanks (one hour's load) located on the floor of the mechanical room. All ancillary equipment and controls are also located in the mechanical room near the storage tanks.

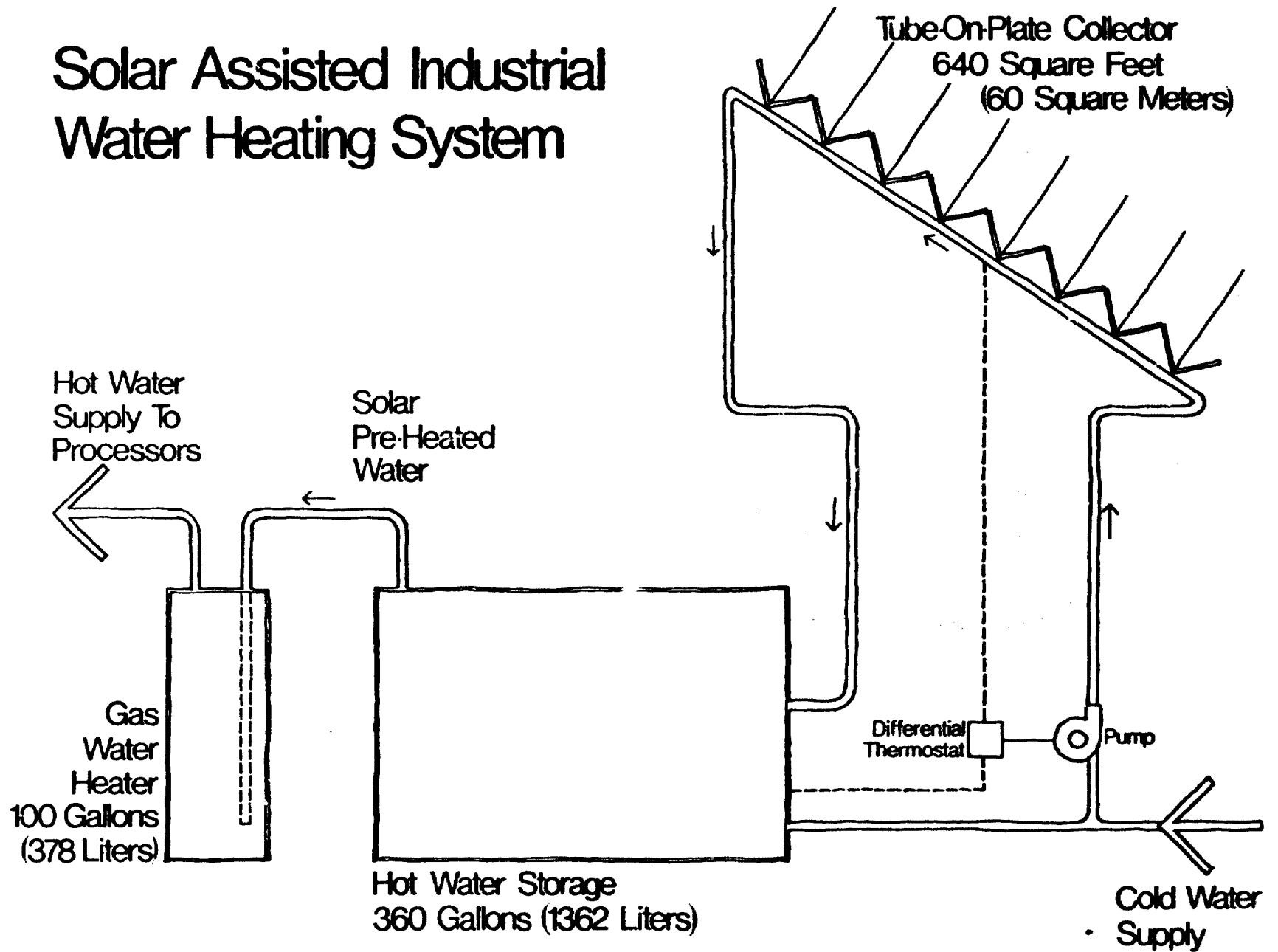
Filtered cold water is first preheated in the solar storage tanks and then flows to the auxiliary heater. Auxiliary heating of the process water is provided by a gas-fired storage-type water heater.

A low-temperature (under 120°F) industrial process such as a film processing laboratory is perhaps the ideal application for solar utilization. With a constant year round daytime load, storage requirements are minimized and solar utilization is maximized. High collector efficiencies can be expected with the low operating temperature.

The most unique aspect of this project is the use of low-cost site-fabricated collectors--an ideal solution where low-cost, skilled labor is available.

The major lesson learned was the importance of fail-safe freeze protection. Relying on pumped circulation in this mild climate did not work when the electric power (to the pump) failed during a freeze. Subsequently, the system was modified to drain down in the event of a power failure.

Solar Assisted Industrial Water Heating System



III.

SITE AND BUILDING DESCRIPTION

III. SITE AND BUILDING DESCRIPTION

A. Site Description

The slightly sloping site is located in Mill Valley, California, close to the San Francisco Bay, at 38°N. latitude. The climate is mild with 3,077 annual heating and 280 annual cooling degree days. (See Figure III.2 for Mean Daily Temperatures; Figure III.3 for Mean Daily Insolation; and Figure III.4 for Water Temperature Data.)

B. Building Description (See Figure III.1)

The Iris Images, Inc., Film Processing Laboratory is a simple, 3,900-square-foot, one-story, industrial building designed for maximum flexibility--no internal load-bearing walls. Clean air and no light were important requirements and therefore minimal windows were used (only on the front).

Walls. The walls are of standard wood frame construction with fiberglass batt insulation, stucco and wood exterior, and gypsum wall board interiors.

Roof. The flat, built-up roof is supported by plywood and truss joists spanning from the east to west walls. The trusses are deep enough to allow for access between the ceiling and roof. This "attic" space is insulated with fiberglass batt insulation and ventilated. Board walkways were installed around the collector support sheds to protect the roofing from foot traffic.

Floor. The floor is generally a painted concrete slab with carpeting in the gallery and office areas.

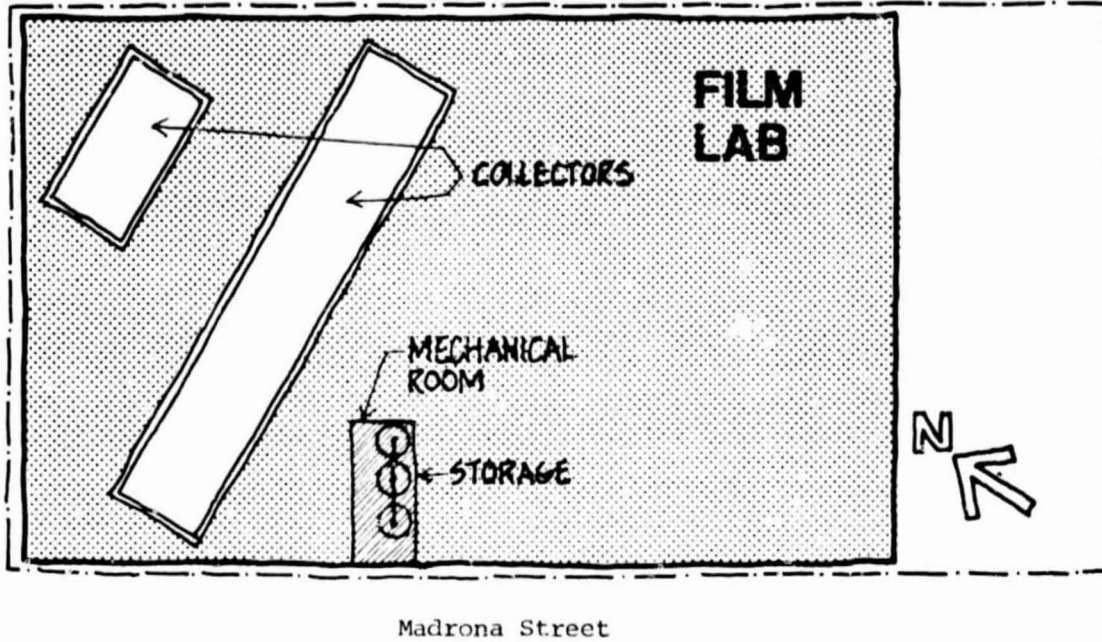
C. Space and Water Heating Systems

Space heating is provided by two gas-fired hot air furnaces (two zones). Each furnace is coupled to an electronic air cleaner and cooling coil. Considering the mild climate and substantial internal heat, the space heating requirements are minimal. A major process water heating load of 6 GPM (1/2 peak) for eight hours per day at 100°F is ideally suited for solar utilization.

Backup water heating is provided by a conventional tank-type gas water heater. Mixing/temperature control valves are utilized at each processor and sink for accurate temperature control.

Figure III.1

Site Plan



Madrona Street

Figure III.2

Mean Daily Temperatures*

	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug</u>	<u>Sept</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>
Max.	55.2	60.2	64.6	69.4	74.2	79.6	83.4	82.1	82.1	74.6	64.9	57.3
Min.	38.3	39.2	38.9	42.7	45.0	47.9	48.3	47.7	47.6	44.9	40.3	37.6

*The project site is within five miles of Kentfield, California, from which this data was derived.

Figure III.3

Average Horizontal Insolation*

<u>Month</u>	<u>BTU/Sq. Ft.</u>
January	722.872
February	969.146
March	1,565.65
April	2,051.55
May	2,250.91
June	2,416.27
July	2,313.82
August	2,105.45
September	1,729.25
October	1,340.01
November	1,014.34
December	767.539

*Mean daily insolation for a 10-year period (1957-67) on a horizontal surface. Data was collected at the University of California, Richmond Field Station Salt Water Conversion Laboratory, 10 miles from the project site.

Figure III.4

Water Temperature Data*

<u>Month</u>	<u>Incoming Water Temperature (°F)</u>
January	55.5
February	53.5
March	54.6
April	57
May	64
June	68
July	68
August	70
September	68
October	66
November	58
December	56.5

*Marin Municipal Water District data (average 1974).

IV.

SOLAR SYSTEM DESCRIPTION

IV. SOLAR SYSTEM DESCRIPTION

A. General Overview

The solar heating and cooling demonstration system used at Iris Images, Inc., is represented in Figures IV.1 and IV.2. The major components in the solar energy system include 640 square feet of site fabricated collectors, three 120-gallon storage tanks and a conventional gas-fired auxiliary water heater.

Subsequent sections describe the collector, storage, energy to load and control subsystems.

B. Collector Subsystem (See Figure IV.3)

1. General Description

The collector array faces due south and is tilted 36° from the horizontal. The array has one bank of 12 collector panels and another bank of four collector panels, each 4' x 10'. Each collector bank consists of a different collector type. The first bank has an aluminum absorber plate that is mechanically bonded to copper tubing. The second bank has a copper absorber plate that is soldered to copper tubing. Both absorber plates are coated with flat black paint. A single glazing of tedlar-coated, fiberglass reinforced panel covers the collectors. The collectors are supported by 2 x 6's and are insulated by 1½" of isocyanurate insulation. The collector backing is 3/8" plywood. All collectors were fabricated at the site.

Two freeze protection systems are used. A pumped freeze protection system circulates warm water through the collector array whenever the temperature on either collector bank absorber plate is below 36°F. The water stops circulating when the absorber plate temperature is above 37.5°F. In the event of a power failure, a solenoid valve will turn off make-up water and depressurize the solar system. A second solenoid valve will open a valve in the collector piping and drain the collectors and exterior piping.

2. Collector Support (See Figure IV.4)

A support structure was built on the flat roof facing exactly south (actual, not magnetic) at a 36° tilt from the horizontal for optimum year round collector performance. Normal 2 x 4 stud framing was used with redwood plywood siding. The two support structures measure 11.5' x 50' and 11.5' x 18' on the tilted plane. The collector is trimmed out with redwood and duct boards were constructed to allow for inspection without damaging the built-up roof.

Figure IV.1

Legend












- | | | | |
|---|-------------------------------|---|-----------------|
|  | Gate valve (open for solar) |  | Relief valve |
|  | Gate valve (closed for solar) |  | Vacuum breaker |
|  | Automatic valve (solenoid) |  | Relief valve |
|  | Check valve |  | Pump |
|  | Automatic air vent |  | Balancing valve |
|  | Thermometer | | |

Figure IV.2

Overall System Schematic

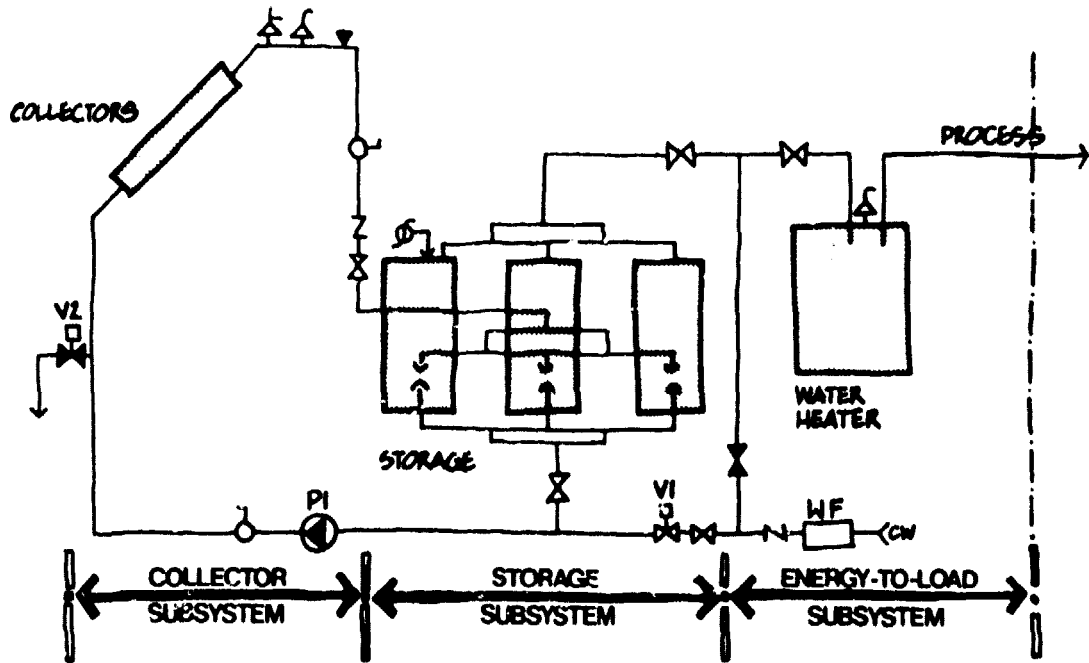


Figure IV.3

Collector Subsystem

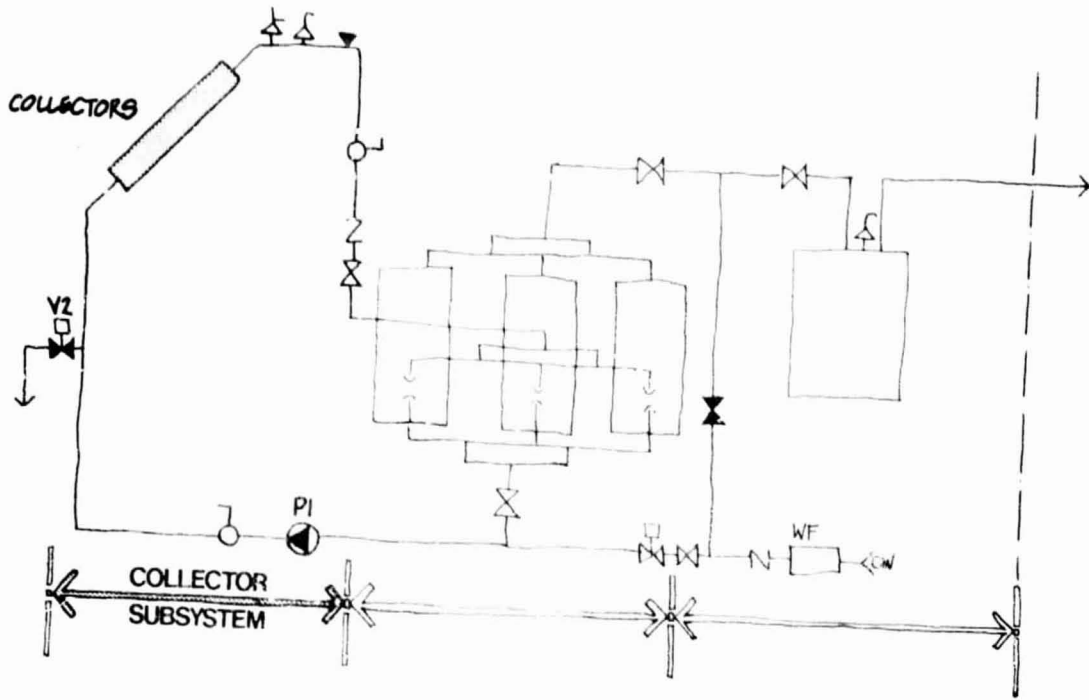
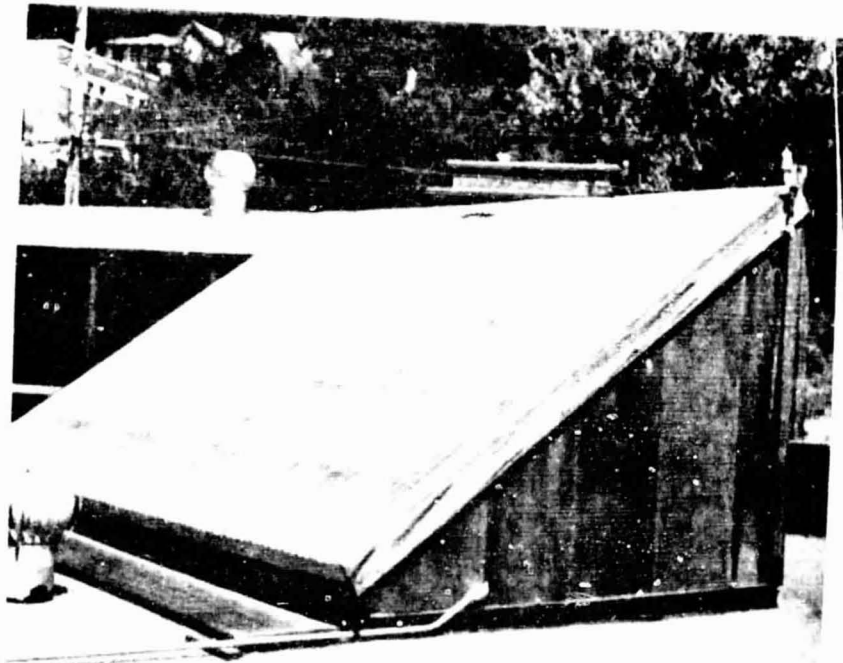


Figure IV.4

Collector Shed/Support



The support system was designed for good architectural integration and low fabrication cost, utilizing conventional materials and construction techniques. It was installed by the general contractor (union). It is important to note that the roof structure (truss joists) was designed for the additional loads (primarily wind) of the collector arrays. If this had not been the case, substantial additional costs would have been made for carrying the loads out to the bearing walls. In other retrofit flat roof projects, the collector support costs have been equal to or greater than the collectors themselves. Another successful detail was the use of roof curbs integrated into the roof during its installation. All penetrations through the roof membrane are therefore made several inches above the roof level, ensuring a water-tight, trouble-free installation. Again, roof penetration details on existing flat roof solar projects are a major source of high costs and/or potential problems.

In summary, planning ahead for solar with an adequately structured roof and the integration of curbs (built into the roof) combined with a support design utilizing conventional wood frame construction, has yielded a most satisfactory, low cost, aesthetically pleasing, and trouble free collector support system.

For detailed construction drawings, see the collector construction section and the as-built drawings. For cost information, see the cost breakdown.

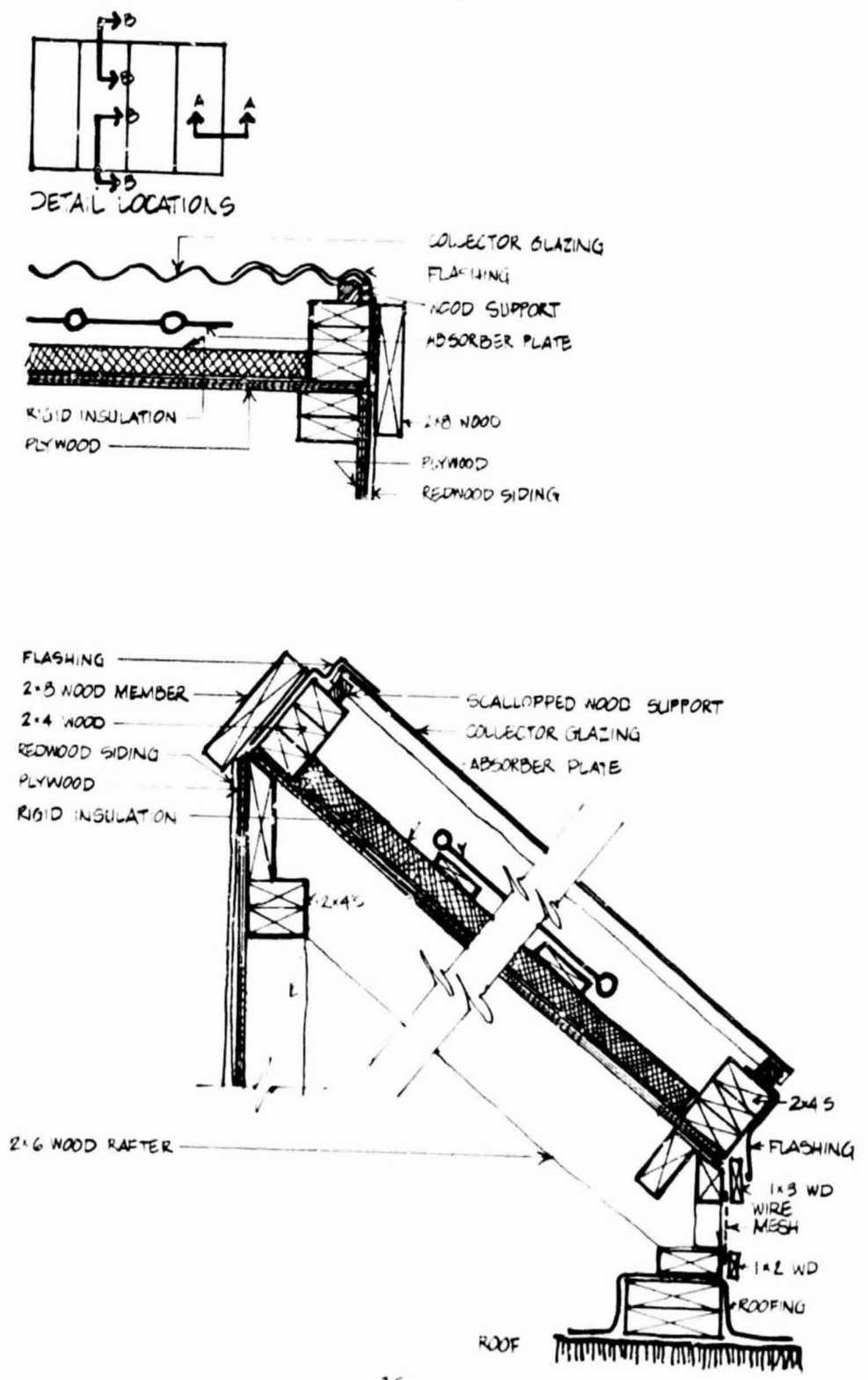
3. Collector Construction (See Figures IV.5 through IV.13)

The collector consists of a blackened metal plate that absorbs the sunlight, converts it to heat, and transfers the heat to the water circulating through tubes that are connected to the plate. The heat is trapped in the collector by glazing on top that is transparent to the incoming light, but opaque to heat, and by insulation under the collector plate preventing heat loss from the back.

a. Site Fabrication. The unusual aspect of the collector construction at the Iris Images Film Lab is that they were site fabricated. The support structure (described earlier) was constructed as a shed with an inclining plywood deck. This deck also serves as the collector back. A rigid insulation, suitable for solar collectors yet commonly used on roofs, was nailed directly to the plywood. Wooden runners were installed to mount the absorber plates and provide a reflective air space (the insulation was foil-faced). Additional runners were mounted atop the absorber plates to receive the glazing. See drawings and photographs for details. The manifolding of the absorber plates was done within the collector, where they were painted black, therefore adding to the actual absorber area.

Site fabrication offers a number of distinct advantages as well as some potential problems. Among them are:

Figure IV.5
Collector Details



- More efficiency: No line losses associated with external manifolds; an actual increase in absorber area. Less edge losses due to a substantial decrease in perimeter length (no edges between collector absorber plates).
- Less materials: No insulation for the manifolds. Less frame wall and edge insulation (none required between absorber plates).
- Less handling: Insulation, absorber plates, and glazing delivered directly to the site; no manufacturer (middleman).
- Less labor: Resulting from less materials and handling.
- Less space: Absorber plates can be mounted side by side with no frame walls, insulation, or space for manifolding.

With all these advantages it is interesting to note why the designer/builder has not used site fabricated collectors on any other projects in the San Francisco Bay Area. Successful, low-cost site fabrication depends on low-cost, knowledgeable construction workers. The construction crew on the Iris Images Film Lab solar system was comprised of college graduates with construction experience, working for one-fourth the union wage scale with an intimate knowledge of solar utilization and system design. It would be difficult if not impossible to continue working under these circumstances, especially in a highly unionized area. High labor costs are, in fact, pointing solar utilization (active systems) in another direction: towards prefabrication of entire collector arrays and mechanical/control modules. These not only cut down site labor, but minimize uncertainties of quality control.

b. Insulation. R-13 (new), 1½" foil face isocyanurate foam, manufactured by U. S. Gypsum. This insulation system, besides being extremely efficient as an insulator, is moisture-resistant and capable of withstanding the stagnation temperatures encountered in this solar collector when the sun is shining but the water is not circulating (estimated at 250°F). It was a standard, readily available product commonly used for roof insulation.

c. Absorber Plate - Bank A (12 of the 16 plates). Half-inch, O.D. copper tubes are clamped between two 25 mil. aluminum sheets by a high-pressure riveting system; rivets are on 3" maximum centers. The tubes are spaced at 4.56" in a parallel flow configuration and are silver soldered to ¾" copper headers. The aluminum plate is factory finished with a flat black epoxy coating commonly used on aircraft nose cones. Manufactured by Sunburst. See Figure IV.6, and manufacturer's specifications in the operation and maintenance manual.

This plate was initially selected for its low cost, availability, and compatibility with domestic hot water. To allow for expansion and contraction, the plates are not rigidly fastened, but allowed to float within the enclosure.

Figure IV.6

Collector Bank A Absorber Plate Construction Details

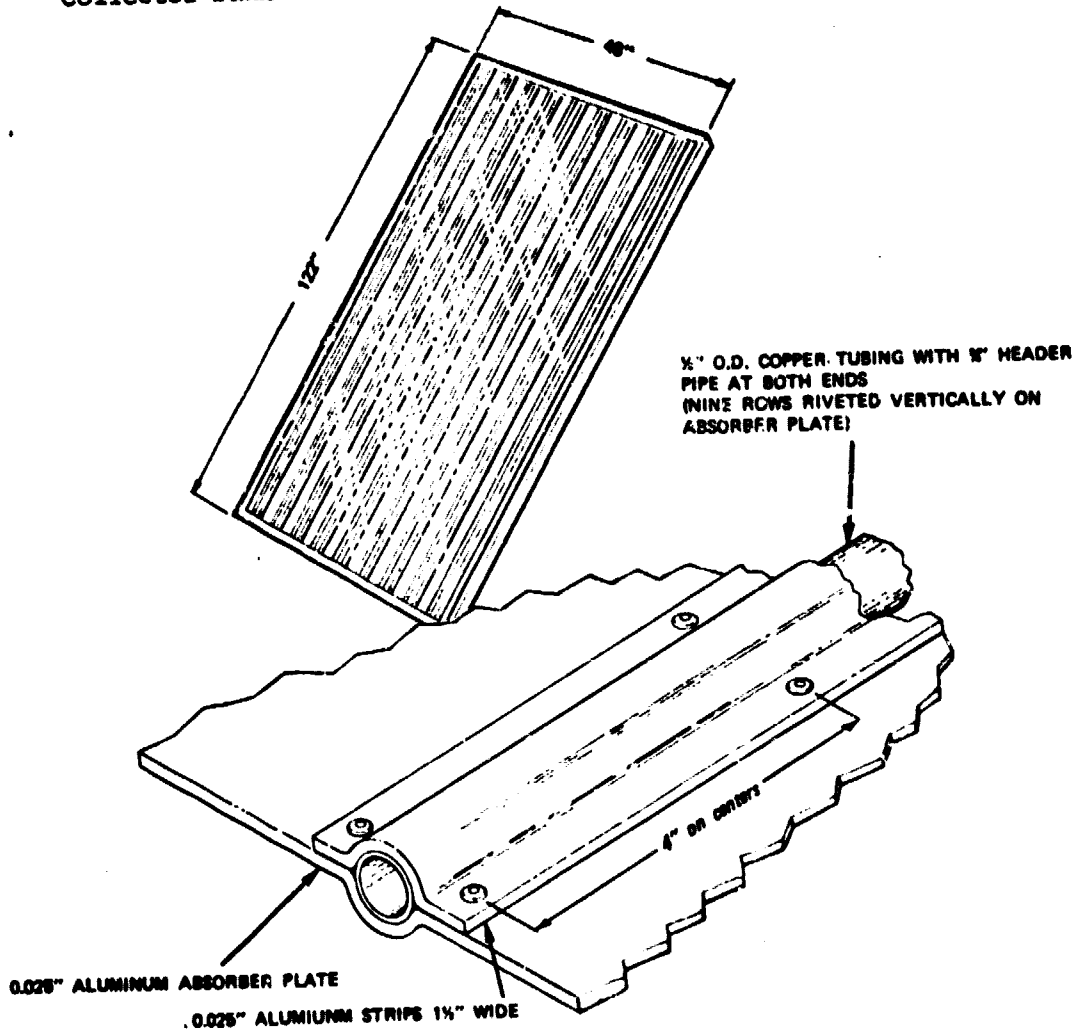
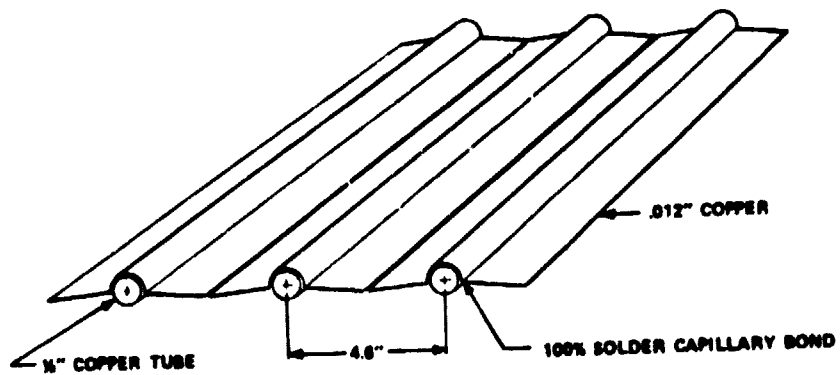


Figure IV.7

Collector Bank B Absorber Plate Construction Details



d. Absorber Plate - Bank B (4 of the 16 plates). Half-inch O.D. copper tubes are set in .012" grooved copper plates at 4.6" centers and are 100 per cent capillary flow solder bonded. The tubes are brazed to 3/4" copper headers. The plates are finished with a flat black paint (Sherwin Williams P2H40 Super Combo Primer). Manufactured by Solar Development Inc. See Figure IV.7, and manufacturer's specifications in the operation and maintenance manual.

Construction of Bank B is similar to Bank A except that, following the freeze and subsequent removal of four Sunburst panels (as described above), these all-copper units were installed for potential higher long-term performance and the opportunity to monitor and compare the performance of the two plates simultaneously. See Performance Analysis.

e. Glazing. Four-ounce/sq. ft., corrugated tedlar-bonded, fiberglass and nylon-reinforced, acrylic-fortified polyester. Manufactured by Filon Division of Vistron Corp.

This glazing system was selected for the following reasons:

- Low cost relative to glass.
 - Durability (hail and rock resistant).
 - Efficiency - 86 per cent transmittant.
- Note: With the tedlar coating, Filon guarantees the transmittance in greenhouse applications for 20 years. In a solar application, it is probable that its transmissivity can degrade and should be checked every few years for possible replacement or repair.
- Strength and rigidity (along its length).
 - Light weight.
 - Ease of handling; one man per 4 x 12 panel.
 - Ease of installation; flashing and sealing facilitated by standard corrugated roof components.
 - Availability; all accessories available from Filon, including flashing, closures and special gasketed washers and nails for a no leak installation.

See the manufacturer's specifications in the operation and maintenance manual.

The 4' x 12' fiberglass panels are mounted on redwood closure strips and sealed with silicone sealant at all the joints. Aluminum roofing nails with rubber gaskets were used for mounting and additional gasketed washers were used to ensure weatherproofing. One panel was screwed down instead of nailed to facilitate removal for easy inspection and possible addition of sensors. Adjacent panels are pop-riveted together with aluminum rivets with rubber gaskets. Aluminum flashing designed to fit the corrugated pattern was used throughout.

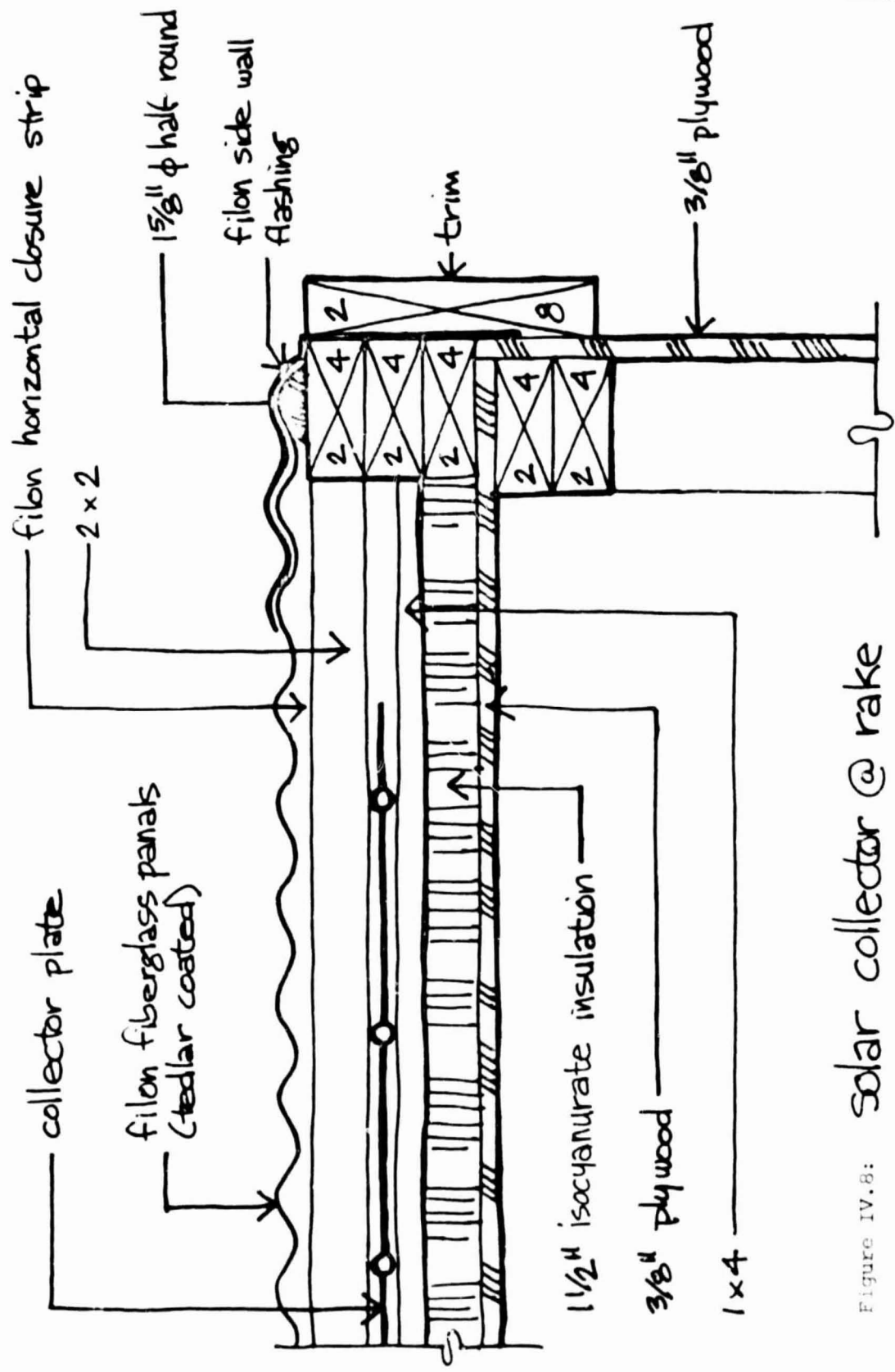


Figure IV.8: solar collector @ rake

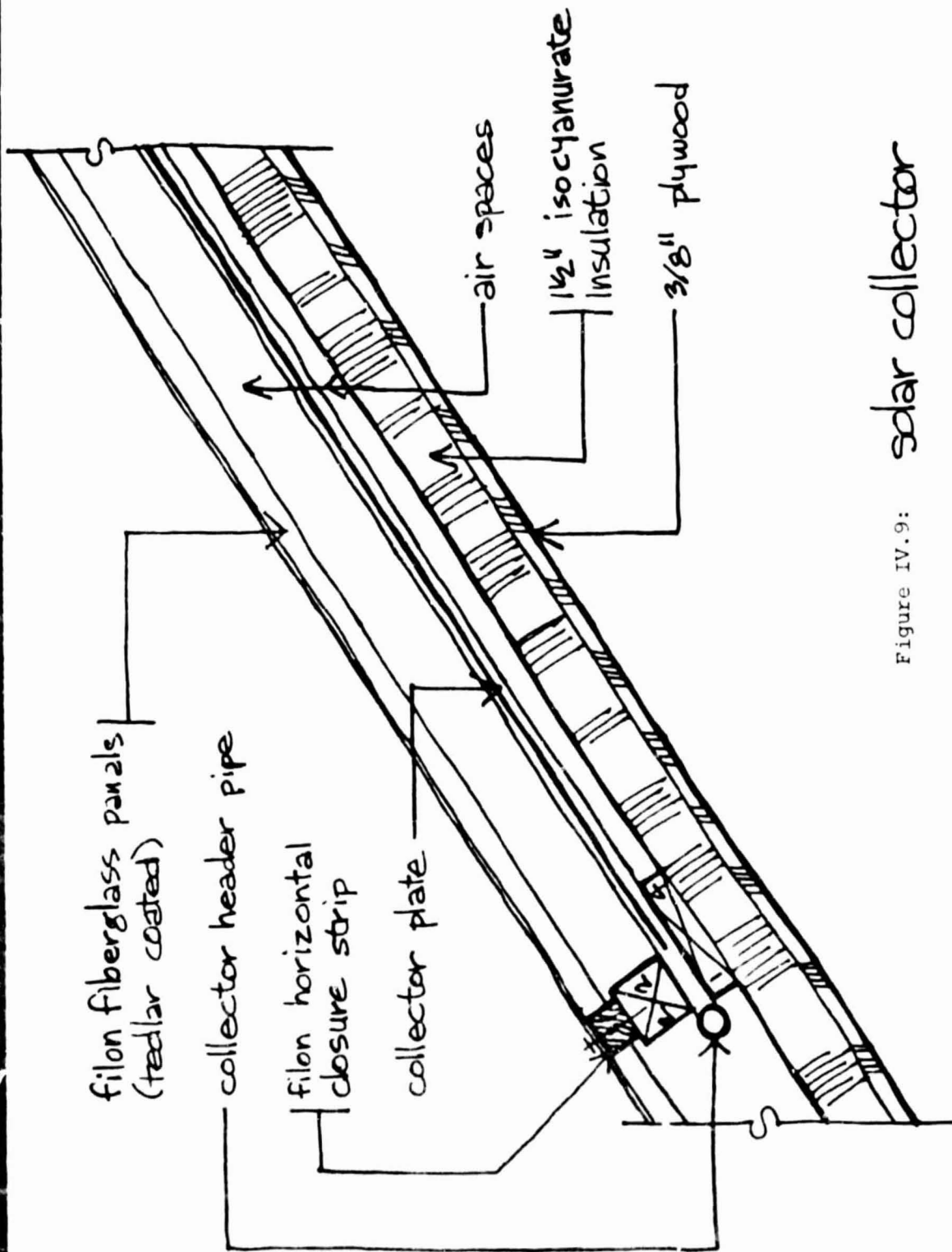


Figure IV.9: solar collector



Figure IV.10

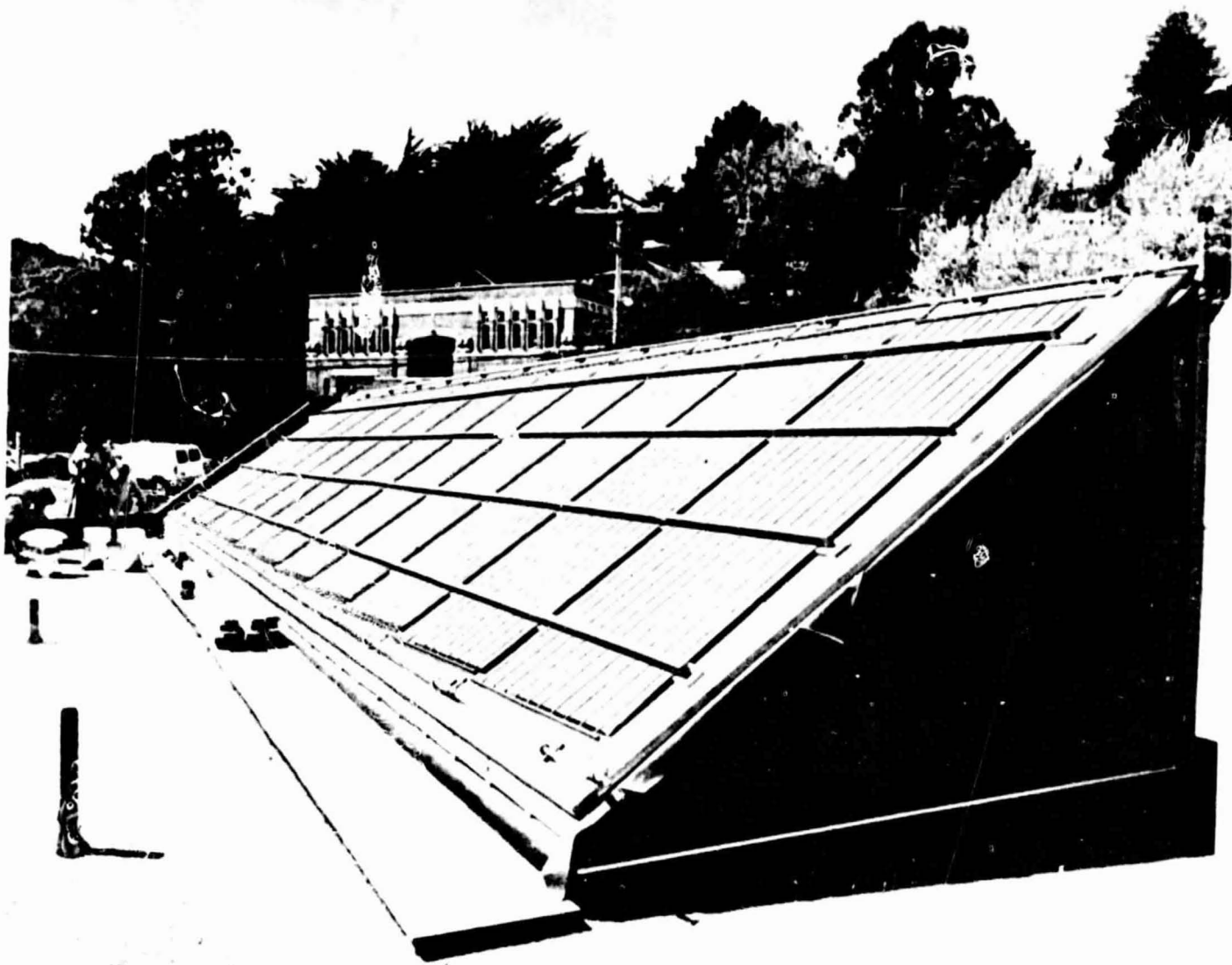


Figure IV.11

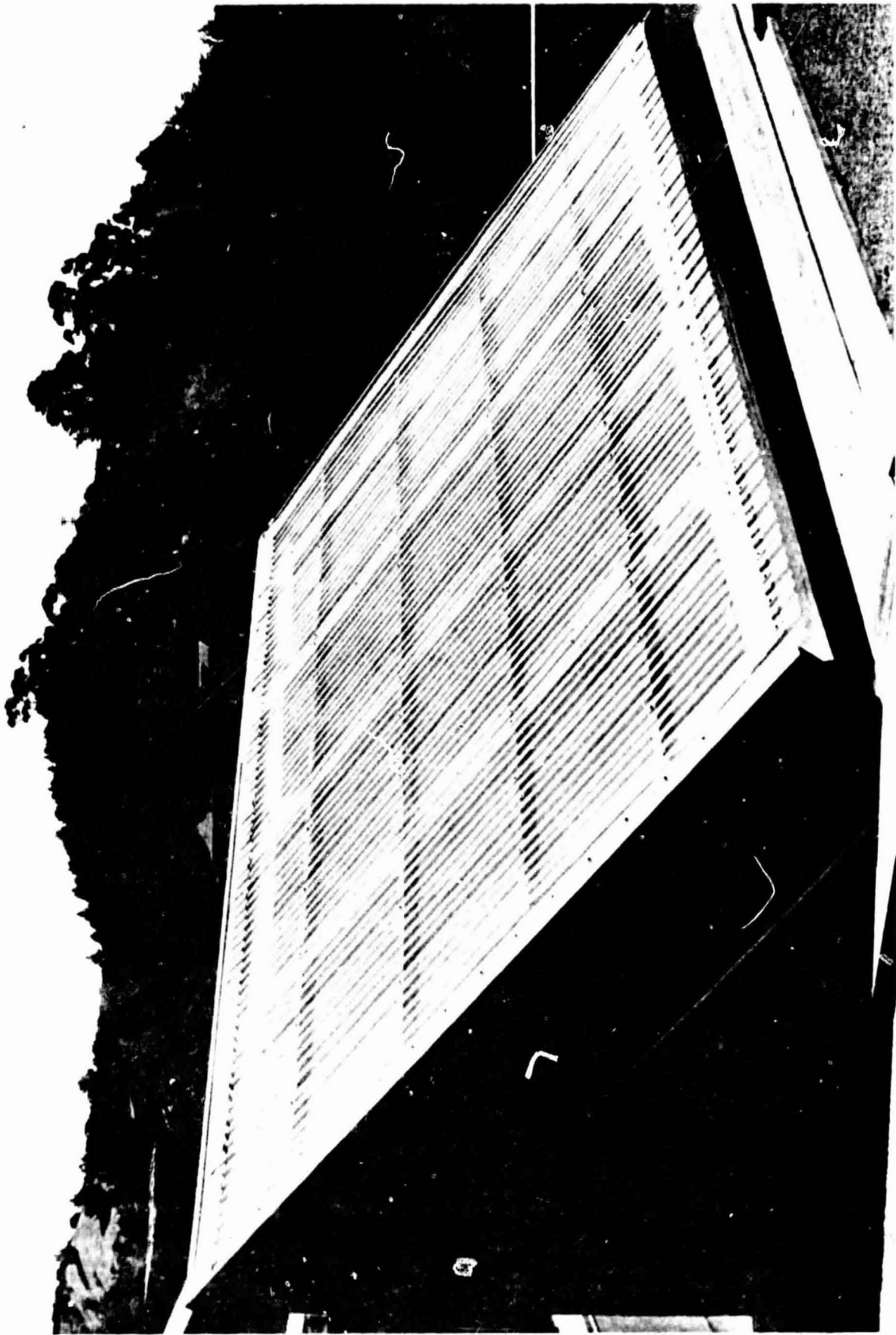


Figure IV.17

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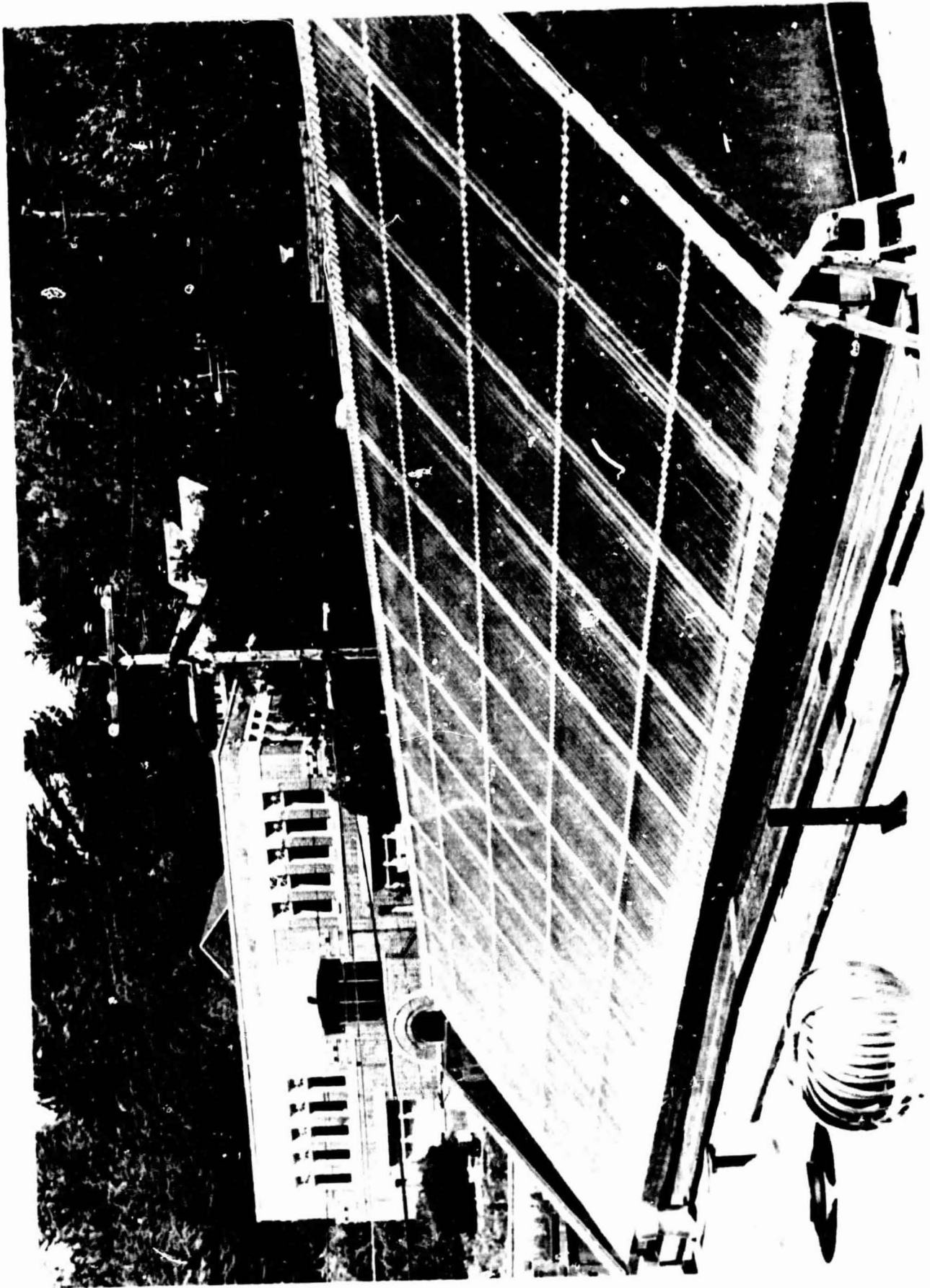


Figure IV.13

4. Collector Plumbing (See Figures IV.14 through IV.16)

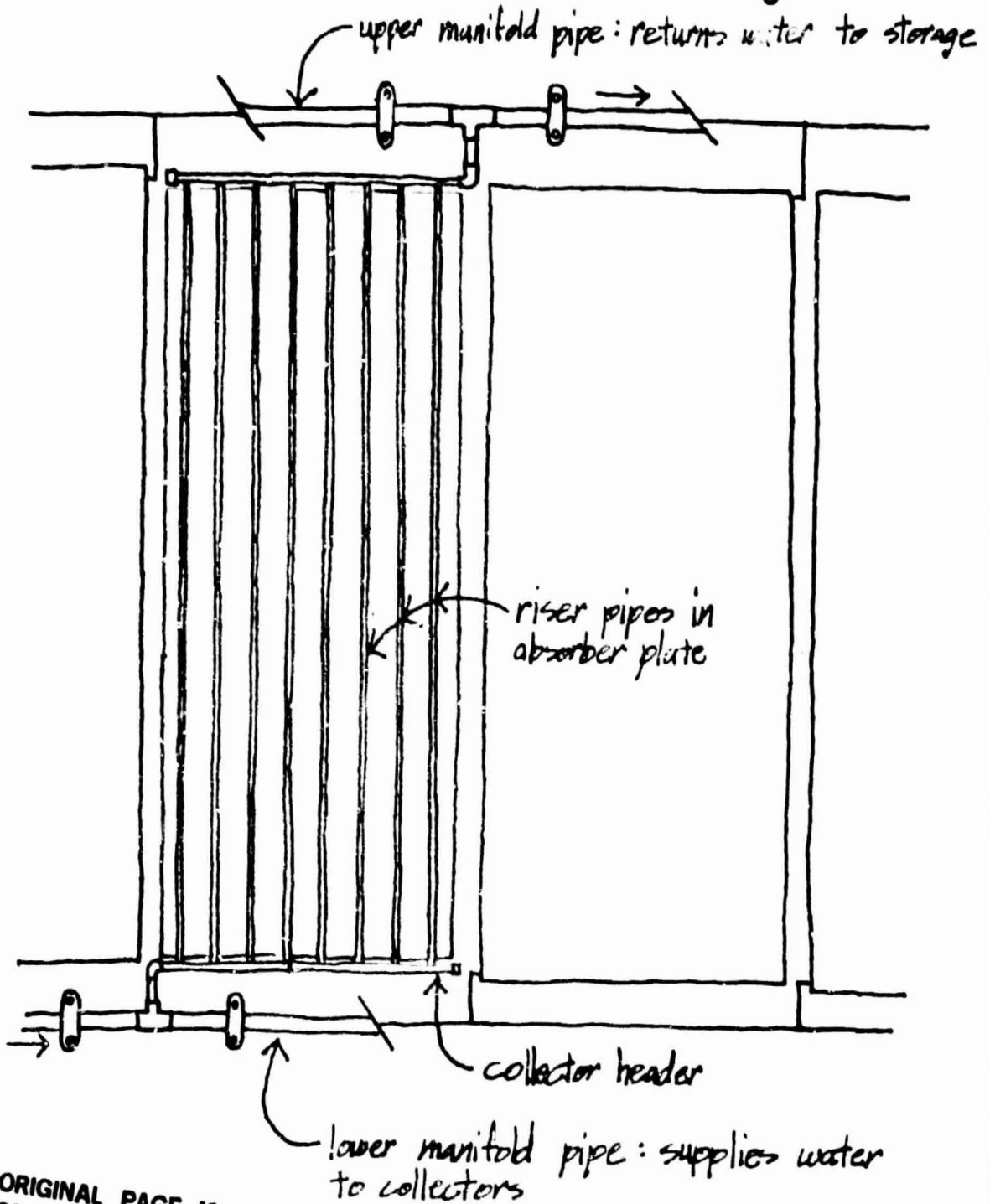
Each 3/4" panel header is manifolded (at opposite and diagonal corners of the panel) to a larger (1" in the small array; 1 1/2" in the larger array) copper header. (See Figure IV.14, Collector Manifolding.) All these joints are sweat-soldered with high temperature 95/5 solder. Only the headers are clamped to the support structure with felt-lined clamps to allow for considerable expansion and contraction within the collector as it heats and cools. To ensure equal flow, the headers are plumbed in a reverse/return configuration. Each collector plate is tilted to allow the escape of any entrained air. Furthermore, the headers are also slanted for air escape and complete draining. All headers are internal (under glazing) and therefore are not insulated.

At the highest point of each collector array an automatic air vent, vacuum breaker and pressure/temperature relief valve are mounted for safety and efficient operation. A hose bibb was installed for easy rinsing of the collector glazing. This is recommended twice a year.

The collectors are arranged in two banks. One is three times the size of the other. Therefore, the branch lines, to and from the smaller array, were reduced to 1" copper. Balancing valves were placed in the return lines of each array along with a temperature gauge. The flow is adjusted until the temperatures are equivalent. Once this is accomplished, the valve settings can be locked and the handles removed.

Collector transfer fluid (potable water) comes in contact with only code-approved copper pipe. Considering the high water quality at the site, no heat exchanger was warranted so potable water circulates directly through the solar collectors.

Figure IV.14: collector manifolding



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Figure IV.15

Automatic air vent, vacuum breaker, and pressure/temperature relief valve at each array.

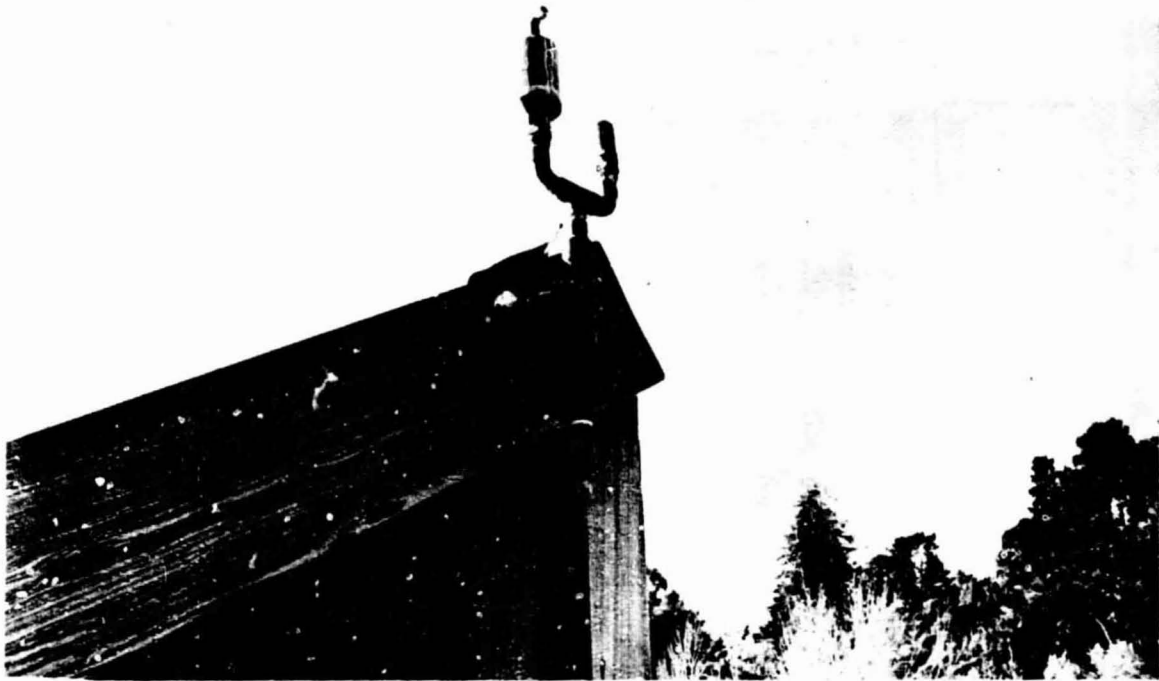
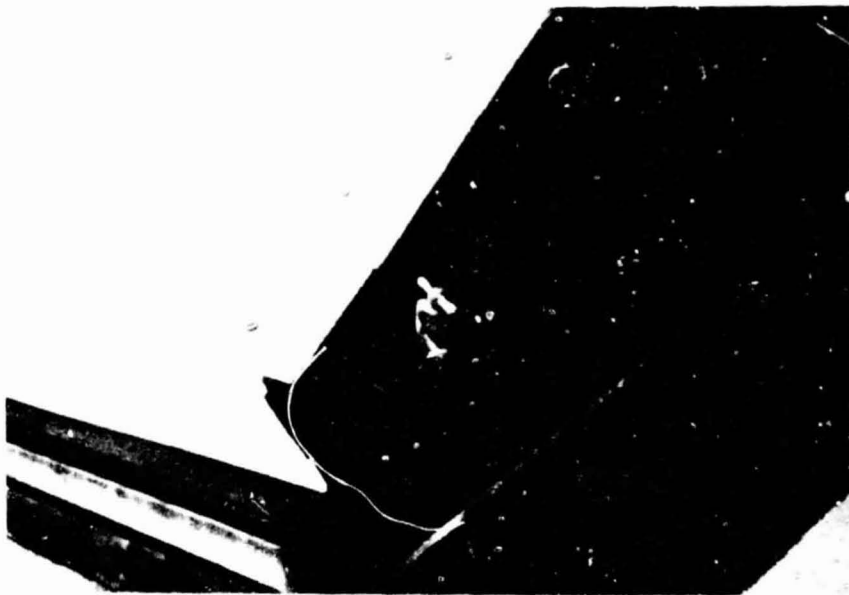


Figure IV.16

Hose bibb for collector cleaning.



5. Collector Transfer Loop (See Figures IV.17 and IV.18)

Although water enters the system in a 1" line, water is circulated through 1½" copper lines to minimize the pressure drop. A balancing valve was installed following the pump to allow for experimentation of flow rates and to isolate the pump if necessary. Normally this valve should remain completely open.

The pipes to and from the collectors are insulated with 1" rigid fiberglass. Gate valves and hose bibbs were installed in the supply and return line to facilitate isolating and draining of the collectors, and to allow for purging of the collectors in the event of excessive scale accumulation (this is not expected with the present water quality).

The bronze circulating pump (March No. 821) is a magnetic drive, 1/20 horse power unit that draws 110 watts (close to a light bulb's energy requirements). The pump is installed with 1½" flanges in a vertical position. Its maximum head is 8.5', and with a 6' head it circulates 12 gallons per minute. The pump operates so quietly that it is difficult to tell when it's on. (See manufacturer's specifications in the operation and maintenance manual.)

Once the pump has stopped circulating, it is possible for warm solar-heated water to rise into the collector where it will cool. To prevent this reverse circulation and heat loss, a check valve was installed in the return line. Temperature gauges were installed in the supply and return lines for quick visual monitoring of the system.

All equipment described above is located in the mechanical room adjacent to the storage tanks. See as-built drawings.

Figure IV.17

Collector Circulating Pump

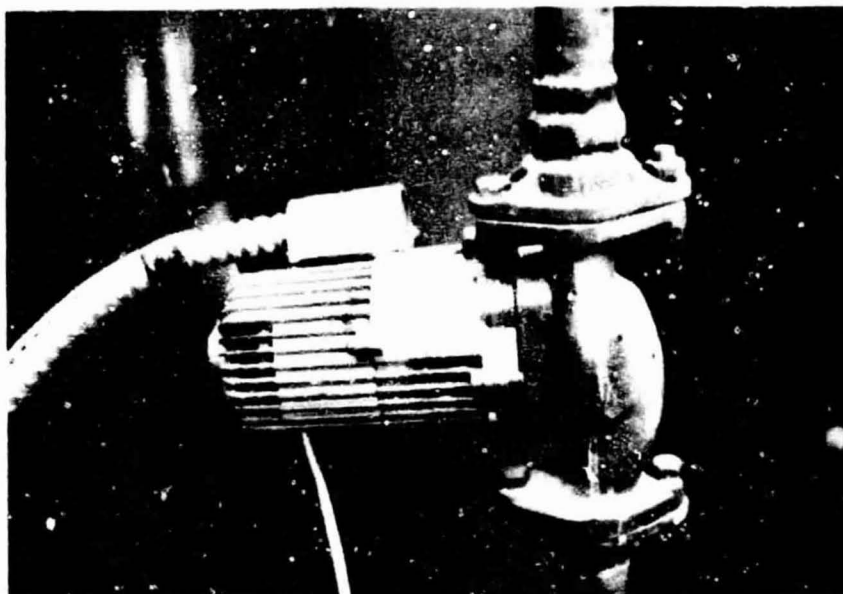
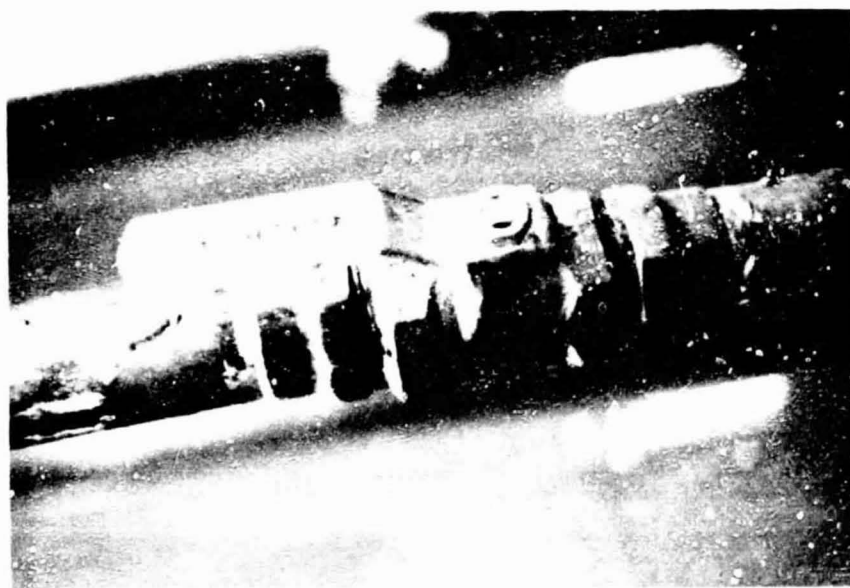


Figure IV.18

Collector Loop Balancing Valve



C. Storage Subsystem (See Figures IV.19 through IV.21)

The storage subsystem is composed of three 120-gallon, glass-lined storage tanks, connected in parallel for a total capacity of 120 gallons. These tanks act as a buffer between solar energy collection and hot water supply, and were not designed for long term storage.

The storage tanks are equipped with magnesium anode rods, hand-hole cleanouts, and hose bibbs at each drain. The tanks are insulated with fiberglass blanket and encased in baked enamel steel jackets. The tanks are connected with 1½" copper manifolds designed to ensure even pressure drop and temperature distribution. (See performance analysis.) At every connection dielectric unions are installed to allow for removal of the manifolds. Additional unions were installed so that the entire manifold sections can be removed, thus allowing for removal and/or replacement of individual storage tanks.

Cold water enters and/or is drawn from the lower-most manifold. Warm water from the collector is returned to the middle manifold, several inches above the supply. The warmest water rises to the top where it is drawn off by the upper manifold. This preheated water enters the cold side of a conventional gas-fired tank-type heater.

The sizing of the storage system was based on one hour of operation to serve as a buffer over slow operational periods such as lunch. It is important to understand that this system was designed to serve only as a preheater to a process need that corresponds to the sun lit hours (a daytime load). Therefore, a minimal storage reservoir was called for.

Pre-insulated and jacketed storage tanks complete with pre-cut copper manifolds, manufactured by American Hydro Power, were chosen for their:

- Low cost.
- Ease of handling.
- Availability (off the shelf).
- Labor savings (pre-insulated and jacketed, and pre-cut manifolds).
- Ability to fit within the mechanical room layout and through the door.
- Proven commercial use with external tankless-type water heaters (now solar collectors).

See the manufacturer's specifications in the owner's operation and maintenance manual.

Figure IV.19
Storage Subsystem

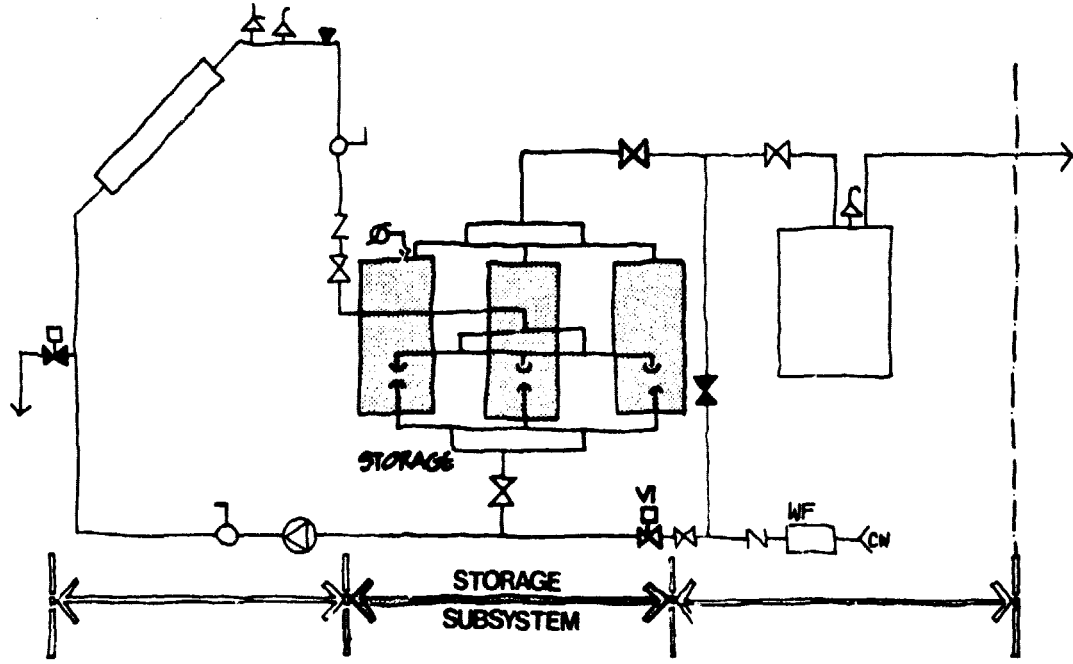


Figure IV.20
Storage Tank Detail

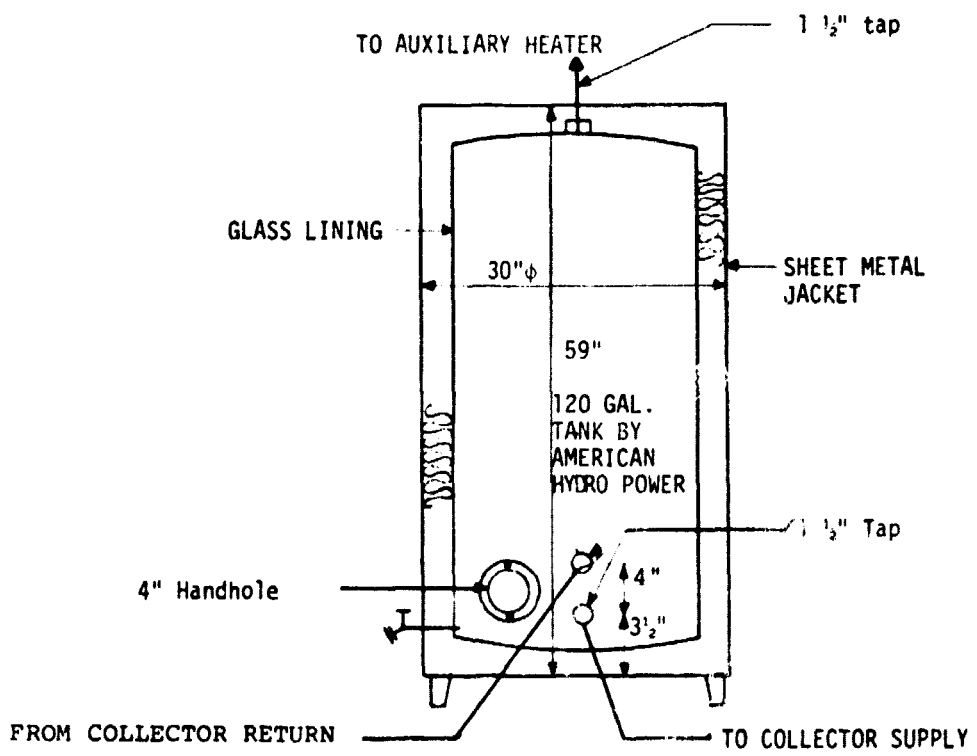
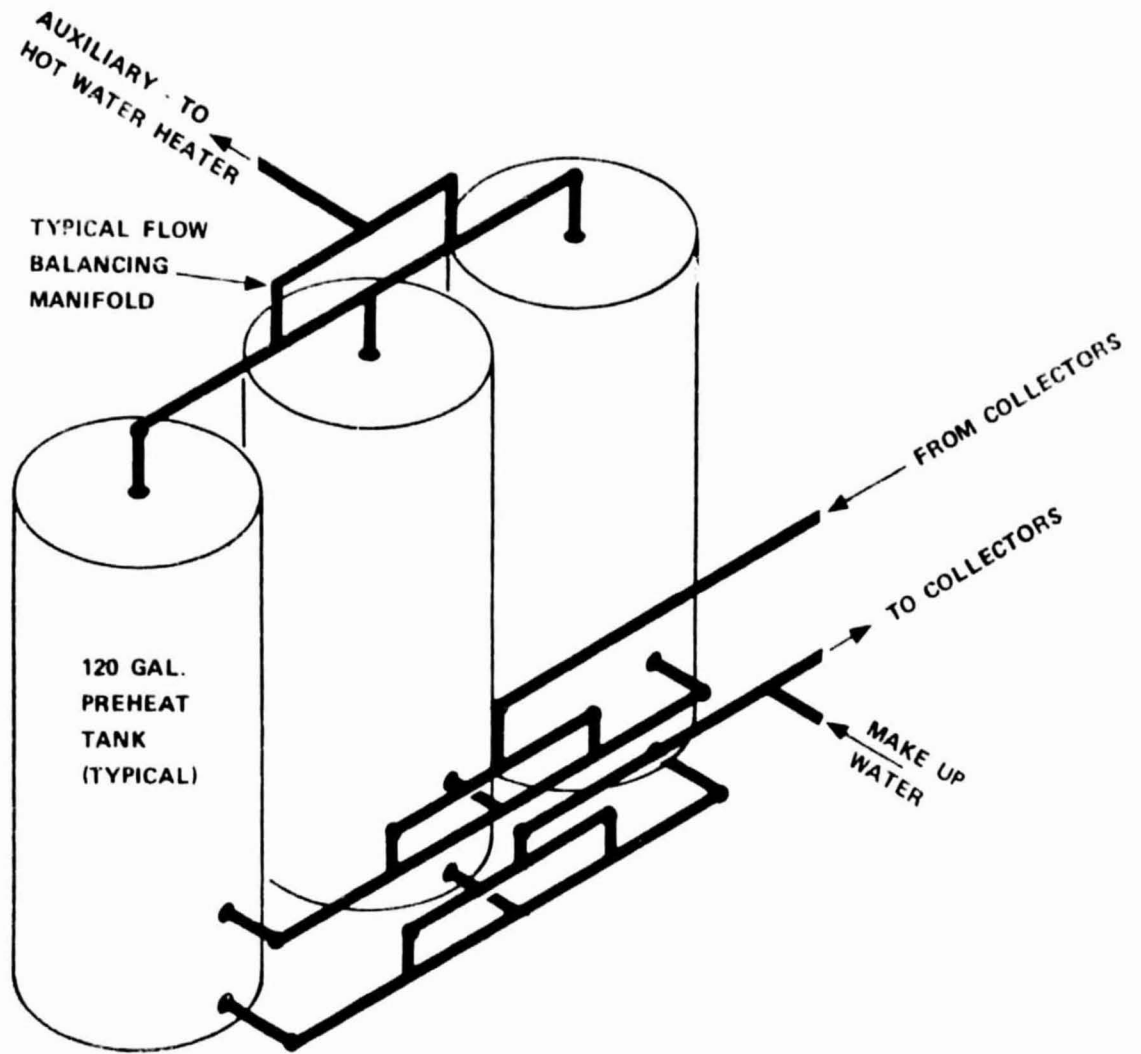


Figure IV.21

Storage Tank Manifold



D. Energy to Load Subsystem (See Figures IV.22 and IV.23)

Water enters the system in a 1" copper line after passing through a sophisticated sand filter. A brass swing check valve prevents hot water from syphoning back into the city lines. The cold water is diverted from entering the cold side of a conventional water heater by a normally-closed 1" brass gate valve.

The water is thus diverted through a normally-open 1" valve to the solar water heating system. Presumably warm water returns from the solar system through a third gate valve normally open and into the "cold" inlet of the water heater.

The auxiliary energy required to heat the film processing water is provided by a 100-gallon, 220,000 BTU/hour, gas-fired domestic water heater, manufactured by American Hydro Power. The solar-heated water from the storage tanks feeds through the auxiliary gas-fired heater, where, if necessary, additional thermal energy is added to raise the water temperature to the desired level of 120°F. The hot water then services the film processors, as well as six sinks and two bathrooms.

The film processors require water varying in temperature from 75°F to 100°F, depending on the type of film that is being developed. The hot water from the auxiliary heater is mixed with cold water to the desired temperature automatically at each unit.

The solar storage tanks were designed only as a buffer between solar energy collection and use. These tanks were not intended to provide long-term storage for peak loads or for periods of inclement weather.

In the event that the solar water heating system must be shut down, the position of the three valves, as described above, are reversed, allowing the system to function normally without solar assistance. That is, cold city water enters the conventional water heater directly and the solar water heating system is isolated.

When the solar water heating system is functioning and collecting solar energy, entering cold water is pumped through the collectors, heated several degrees and returned to the storage tanks. The hottest water in the storage is then drawn from the top and supplies the conventional water heater with pre-heated water, as described above.

Figure IV.22

Energy to Load Subsystem

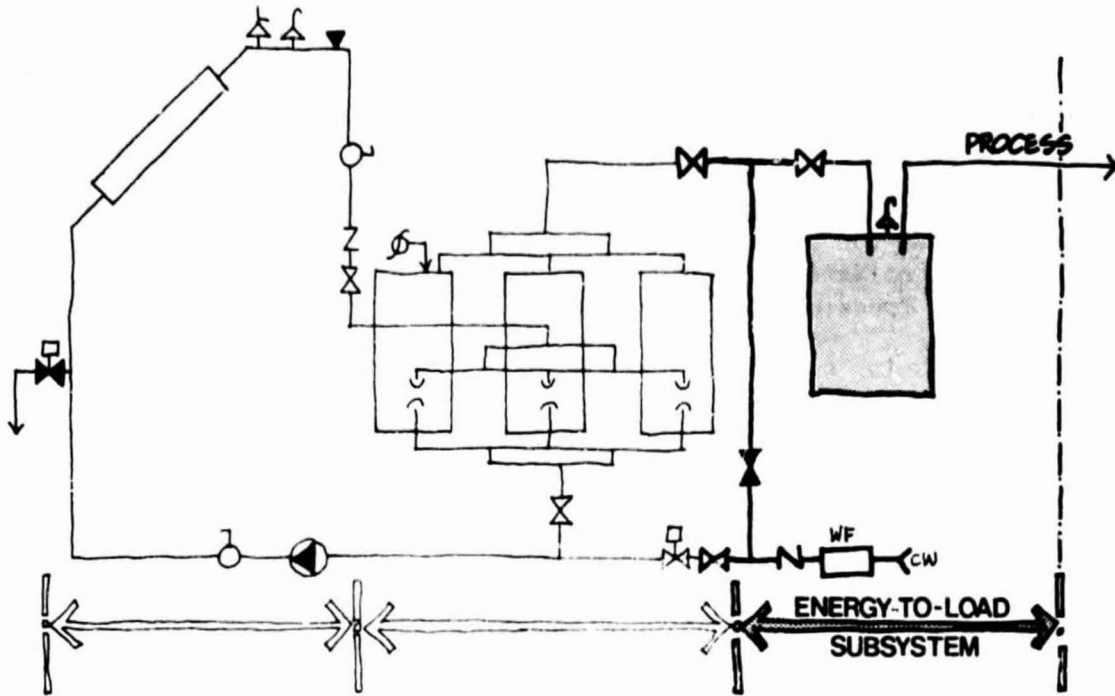
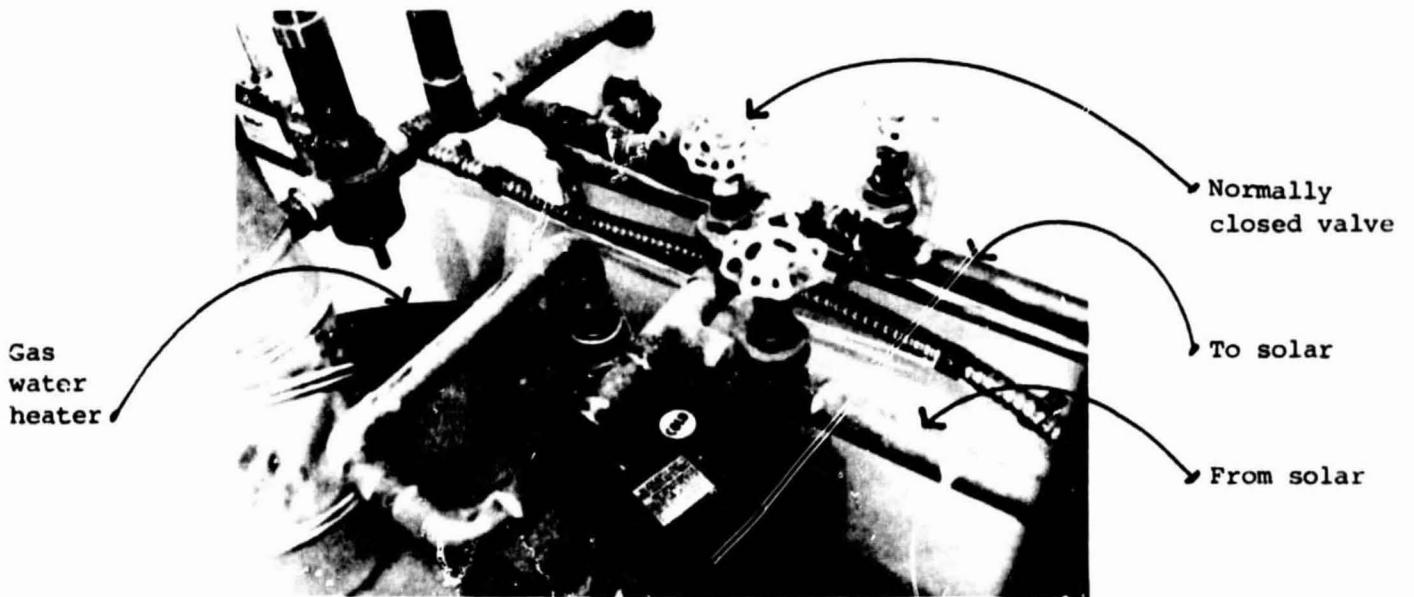


Figure IV.23

Diverting Valves at Solar/Backup Interface



E. Control Subsystem (See Figures IV.24 through IV.27)

Two solid state differential temperature controllers, manufactured by Heliotrope General (Model No. DTT200), DT-A and DT-B, activate and deactivate pump P-1 in the solar collector subsystem. (See Figure IV.24.) Controller DT-A is connected to sensors on collector bank A and the bottom of the storage tank. Controller DT-B is connected to a sensor on collector bank B. These two controllers are mounted in the mechanical room. Pump P-1 performs the dual function of circulating water through the collectors to collect solar energy, and of circulating warm water from the storage tanks to prevent freezing in the collectors.

1. Solar Energy Collection

General description: Controller DT-A compares the temperature differential between the top of collector bank A and the bottom of the storage tank. When the water in the collector is 9°F warmer than the water in the storage tank, pump P-1 is energized. Pump P-1 is de-energized if the collector water is less than 3°F warmer than the storage water.

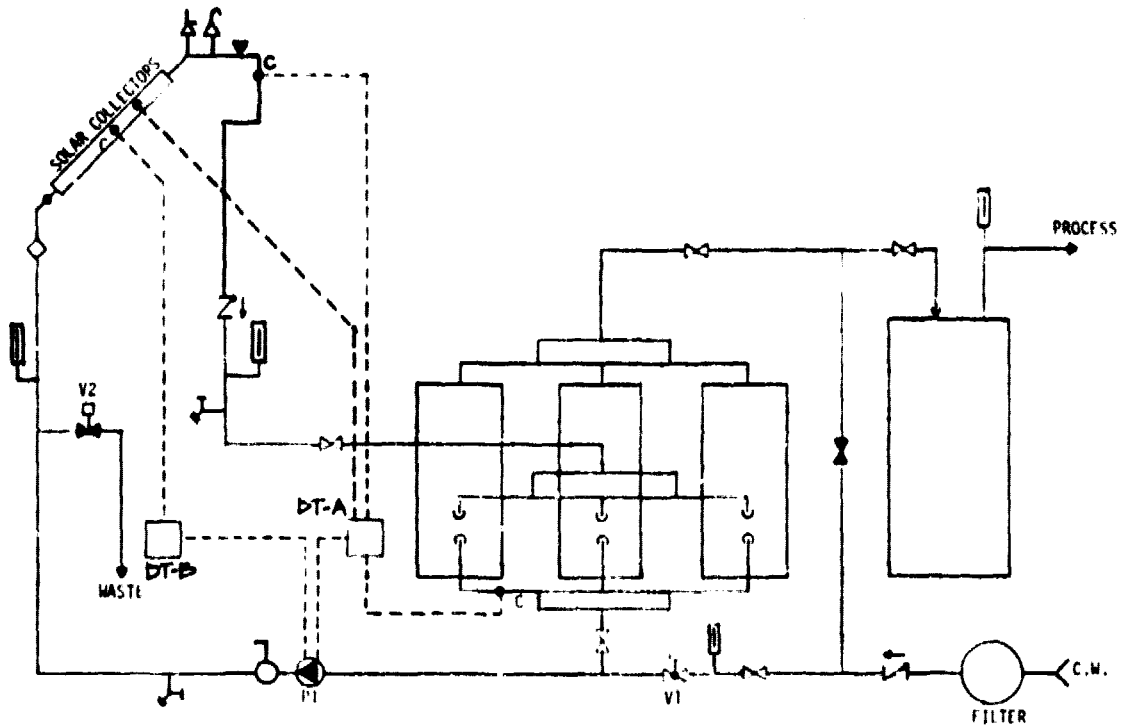
2. Collector Freeze Protection

General description: Two freeze protection systems are used to prevent potential damage to the collectors and exterior piping. In the first system, warm water is circulated through the collectors. A second system operates whenever there is a power failure. Solenoid valves turn off the make-up water, depressurize the solar system and drain the collectors and exterior piping.

Intermittent circulation: Both of the differential temperature controllers, DT-A and DT-B, are equipped with freeze cycles. The sensors for these controllers are mounted on both collector banks. If the water temperature at the collector for either sensor is lower than 36°F, pump P-1 is energized and circulates warm water through the collectors. When the sensor temperature rises above 37.5°F, pump P-1 is de-energized.

Drain down: To guard against freezing during a power failure, a backup system is provided to drain water from the collectors. Solenoid valves, V-1 and V-2, manufactured by Skinner, are respectively "normally" closed and normally open. In the event of a power failure, these valves are de-energized, seeking their "normal" position. Valve V-1 shuts off the water supply to the solar system, and V-2 drains the water from the collector banks into a waste line. Note that the valves' general positions during normal system operation are not their "normal" (no power) position. A manual switch was provided to allow for checking the drain down system. See the manufacturer's specifications for the differential temperature controls as well as the solenoid valves, in the operations and maintenance manual.

Figure IV.24
Control Subsystem



To monitor the operation of the system, several temperature gauges were installed. They were located in the cold and hot water supply lines in the supply and return lines to the collector, and at the bottom and top in one of the storage tanks. These last two had to be removed for IBM/NASA/DOE instrumentation.

Figure IV.25

Solenoid valve used for power-failure freeze protection.

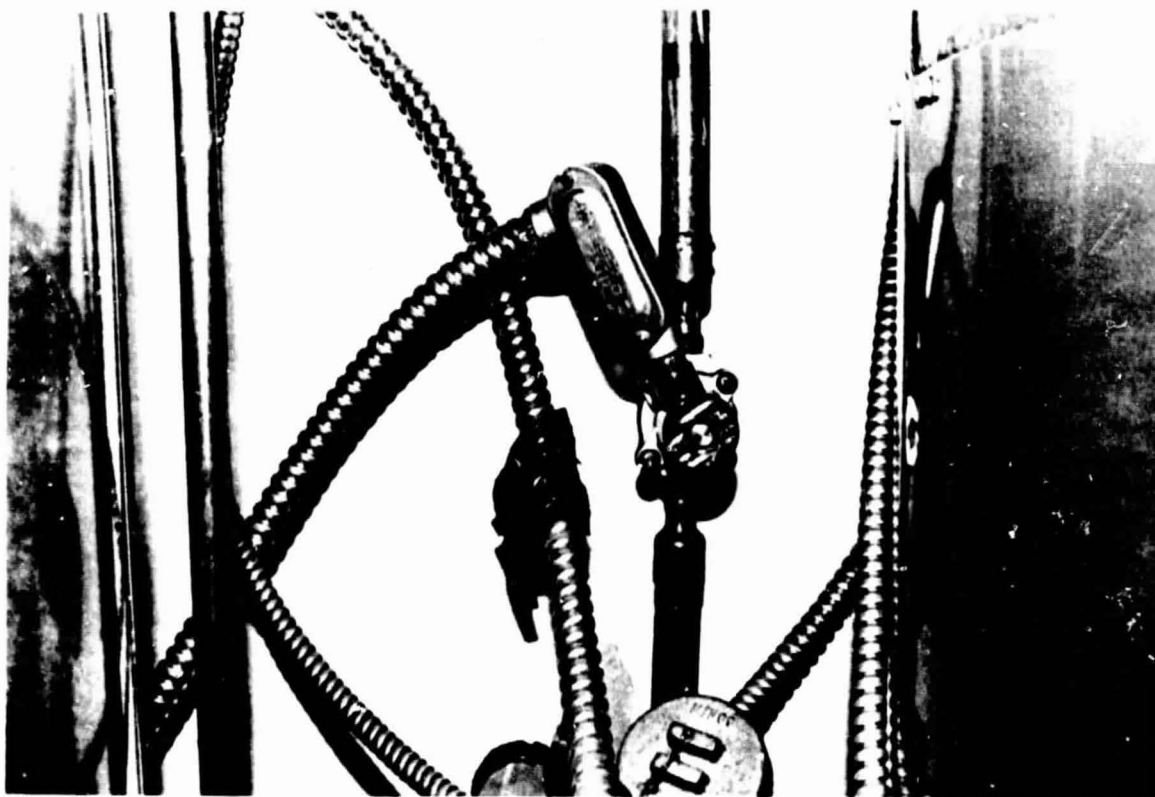


Figure IV.25

Dual Differential Temperature Controllers, DT-A and DT-B

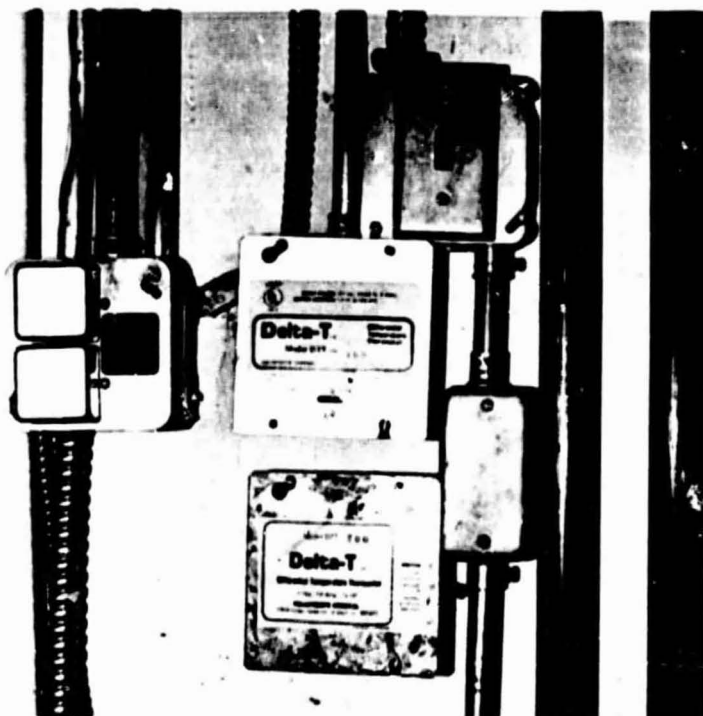
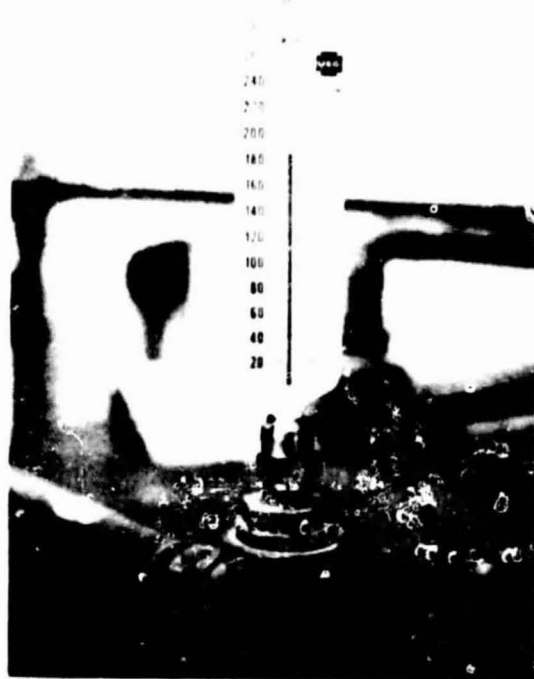


Figure IV.27

Typical Temperature Gauge



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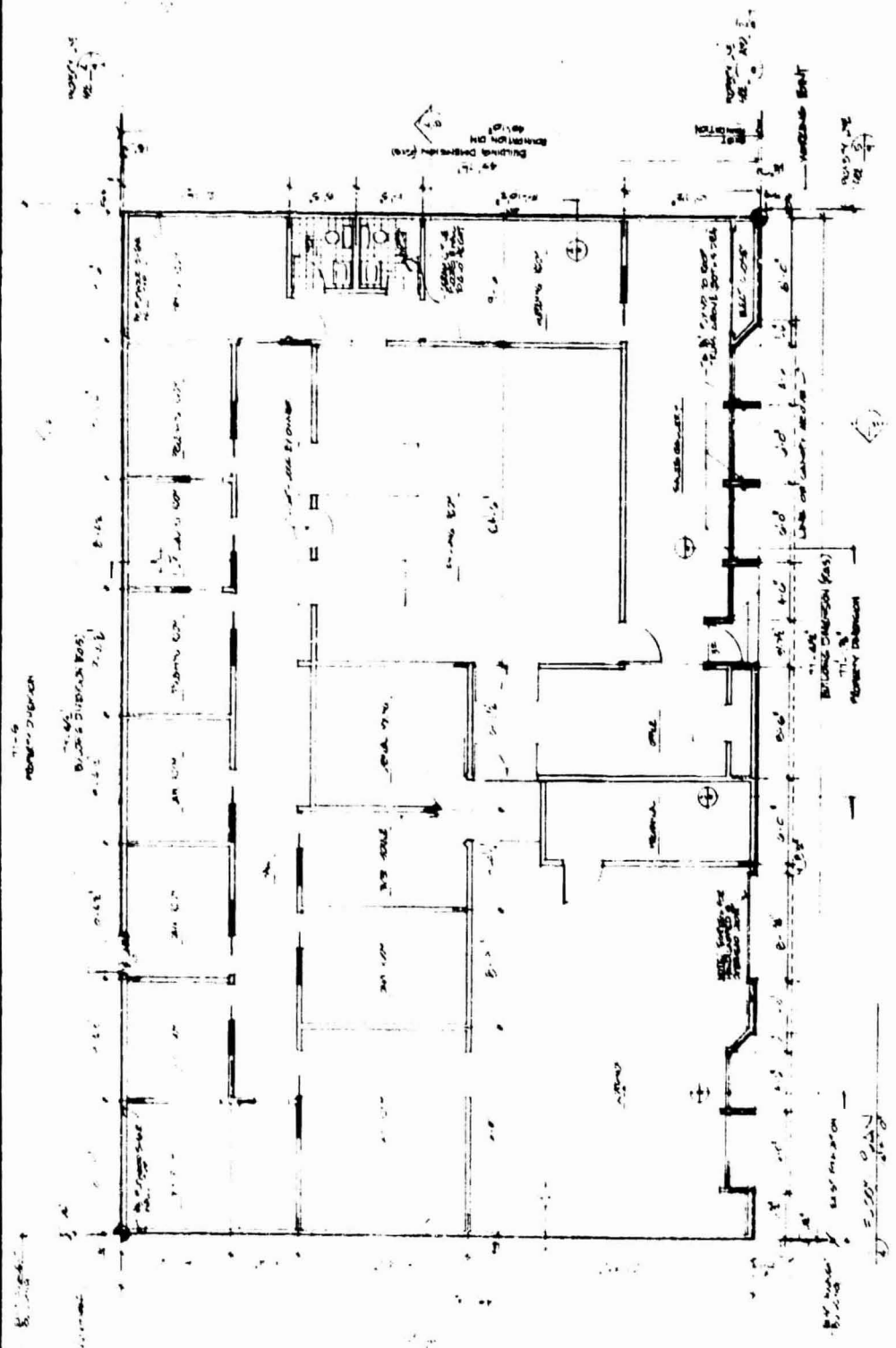
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AS-FULL DRAWINGS



NOTES:
 1. ALL DIMENSIONS ARE TO FACE UNLESS OTHERWISE NOTED.
 2. ALL WALLS ARE 1/2" THICK UNLESS OTHERWISE NOTED.
 3. ALL DOORS ARE 3'0" WIDE UNLESS OTHERWISE NOTED.
 4. ALL WINDOWS ARE 6'0" WIDE UNLESS OTHERWISE NOTED.

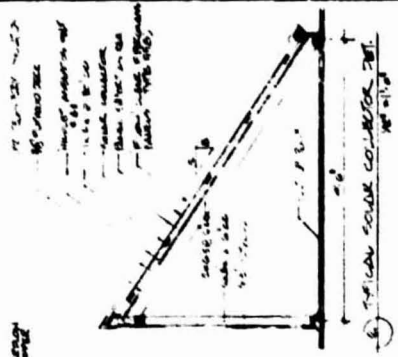
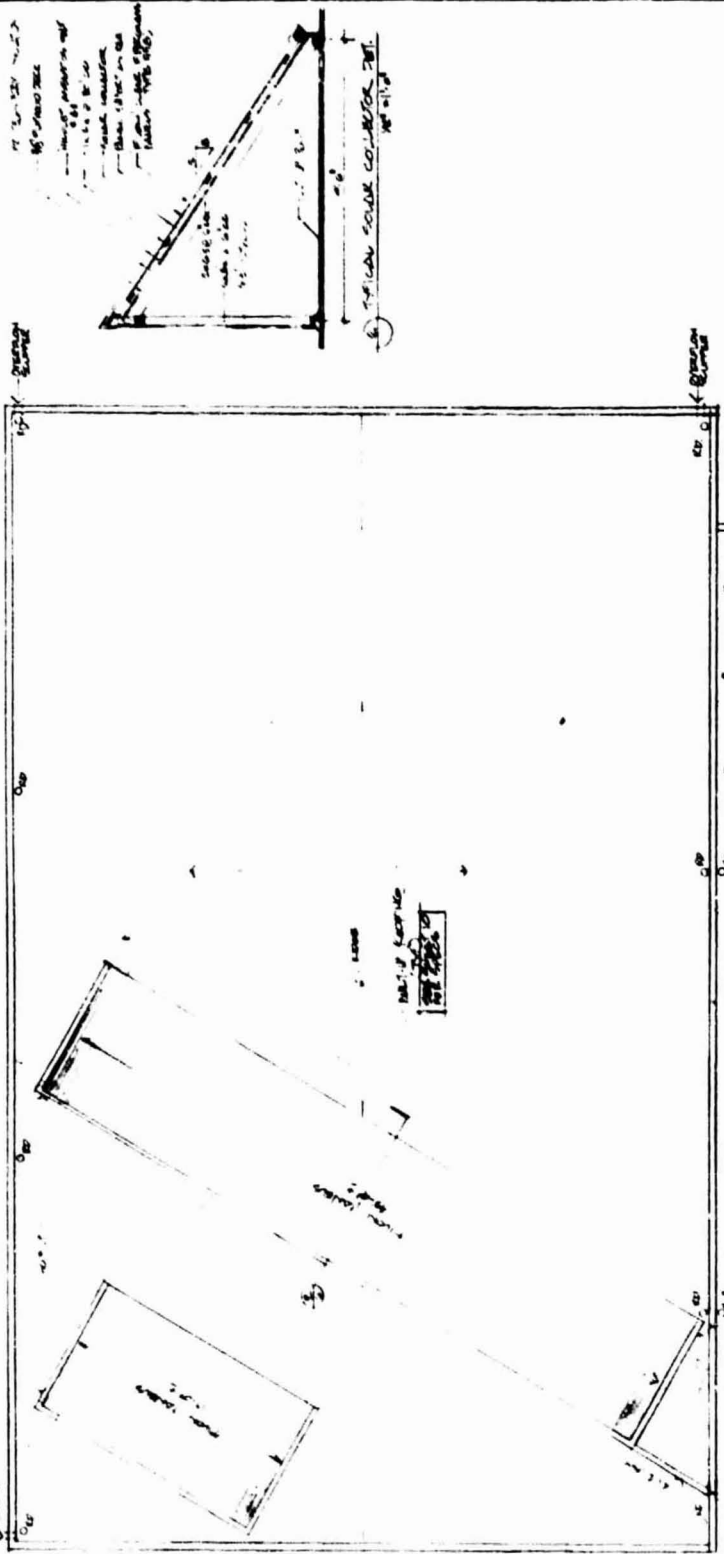
NO.	DESCRIPTION	QTY	UNIT	AMOUNT
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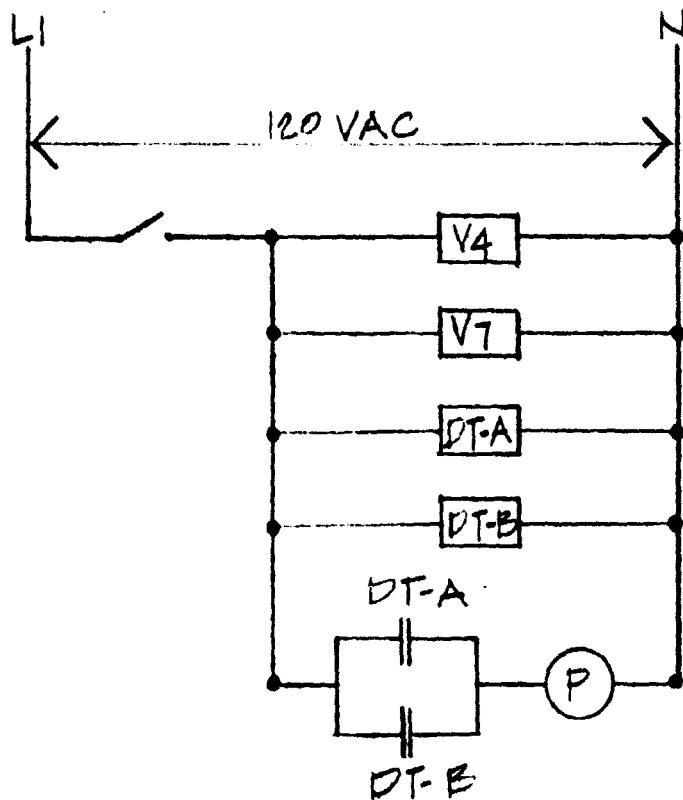
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Working and construction drawings of projects and shall be in compliance with Section 105.01, TAC.

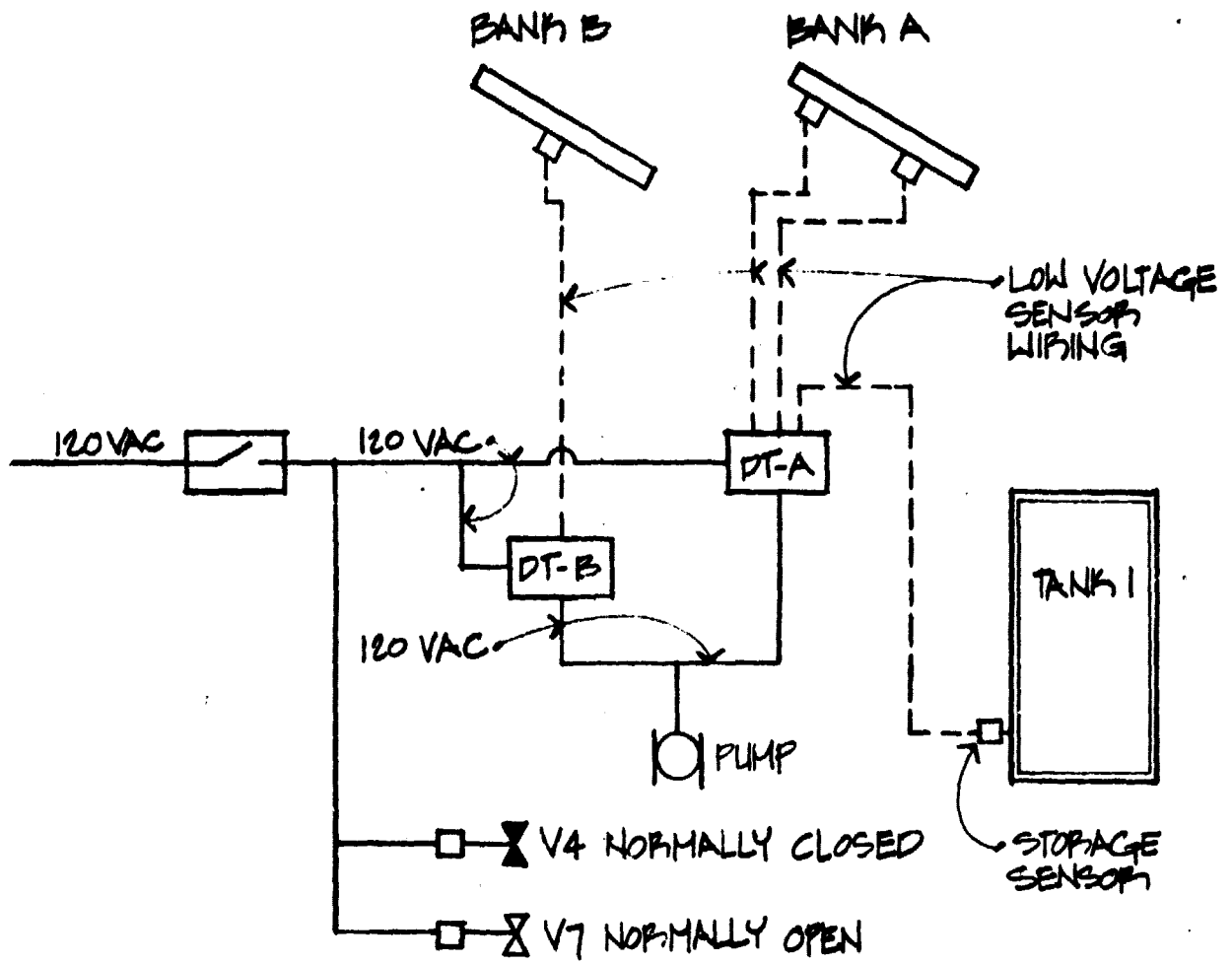
Working drawings and specifications shall be prepared and the contractor shall be responsible for providing all necessary details as provided in Section 105.01, TAC.



CONTROL DIAGRAM

NO SCALE

Interactive Resources, inc. 117 Park Place Point Richmond, CA 94801 (415) 236-7435	rev.	description	date	by	job no.	page no.
					69.4	
					drawn by EJA	
					date 10 SEPT 79	



CONTROL WIRING DIAGRAM

NO SCALE

Interactive Resources, inc. 117 Park Place Point Richmond, CA 94801 (415) 236-7435	rev.	description	date	by	job no.	page no.
					69.4	drawn by EJA date 10 SEPT '79

VI.

COST BREAKDOWN AND ECONOMIC ANALYSIS

VI. COST BREAKDOWN AND ECONOMIC ANALYSIS

(See also Appendix D for a complete Solar Project Cost Report prepared by Mueller Associates, Inc.)

A. Cost Summary

	<u>Original Estimate</u>	<u>Actual</u>
Interactive Resources, Inc.		
Materials	\$ 5,880	\$ 5,072
Labor	2,560	2,697
Subtotal	8,440	7,769
Contingency	960	1,567*
Profit and overhead	1,840	1,904
Subtotal (contract amount)	11,240	11,240
Support structure by		
general contractor	3,220	3,220
Electrical	220	220
Construction management fee	1,120	1,120
Total	\$15,800	\$15,800

*Repair and modifications following freeze damage; does not include \$297 for building repair and over \$6,000 in damaged photographic equipment and materials.

B. Cost Breakdown: Interactive Resources, Inc.

1. Initial Construction

Labor		
In-house (250 hours @ \$7)	\$1,750	
Outside (approx. 136 hours)	<u>947</u>	\$2,697
Materials		
Permit	4	
General plumbing	1,129	
Storage tanks	766	
Collector components:		
Absorber plates	1,712	
Glazing and accessories	583	
Insulation	347	
Hardware	145	
Controller	40	
Pump	96	
Tool rental and purchase	<u>250</u>	<u>5,072</u>
Total labor and materials		\$7,769

2. Repair and Modifications to Solar System

Following a freeze and subsequent substantial damage, the solar system was repaired and modified as follows:

- Burst panels in Bank B were replaced with all copper absorbers.
- A second controller was added.
- Automatic valves were installed to drain system in the event of a power failure.

Labor		
In-house (101 hours @ \$7)	\$ 707	
Outside (14 hours)	<u>98</u>	\$ 805
Materials		
Absorber plates	566	
Plumbing	94	
Controller and auto valves	<u>102</u>	<u>762</u>
Total labor and materials		\$1,567

C. Cost Analysis

The installed cost of the Iris Images Photo Lab solar system was approximately \$25 per square foot of collector area. The collector-dependent cost was approximately \$11 per square foot of collector, including support and manifolding.

These costs will seem low, but it is important to realize that besides being inexpensive, the collector is relatively inefficient. A more expensive and efficient model would require less area for the same output. The system cost as a function of area for this collector would be considerably greater since the fixed system cost would be divided by a smaller area. For example, consider a collector system costing \$15 per square foot installed — perhaps similar to the Iris Images collector, but with a slightly better absorber and white water tempered glazing. This collector's performance curve (efficiency vs. temperature difference/input) would probably be parallel but higher than the one used. At normal operating conditions we might expect the Iris Images collector to be 36 per cent efficient (annual predicted average, per IBM System Performance Evaluation) while the higher performance model would be about 50 per cent efficient. Therefore, for the same output the more efficient collector can be 18 per cent smaller. In the case of the photo lab, 461 square feet of this collector would yield the same output as the 640 square feet existing. At \$15 per square foot, it would cost \$6,915 compared to \$7,040 (640 sq. ft. @ \$11). Obviously, the more expensive per square foot collector — \$15 vs. \$11 — would yield a less expensive, more cost-effective system.

The problem of a square foot analysis is compounded when considering system costs. Assuming that the collector-dependent cost for Iris Images was \$7,040, the fixed system cost would be \$8,760 or about \$14 per square foot of collector area. This cost (total) does not change when a smaller, more efficient collector is used, but the square foot unit cost does. In the case of our example, the fixed system cost would be \$19 per square foot of collector area ($\$8,760/461$ sq. ft.). The less expensive, more cost-effective, smaller system with equal output would cost \$34 per square foot compared to our system at \$25.

Clearly, collector or system cost per square foot of collector area is not a good method for evaluation or comparison of collectors or systems.

A cost analysis must be tied to performance — for example, cost per BTU. In this case, IBM predicted the annual delivered output at 97.8 million BTU (see System Performance Evaluation). Assuming the value of the money to install the solar system was 10 per cent per year, the cost of delivered solar heat would be \$16 per million BTU*. This compares favorably with the cost of other solar systems. With the new 10 per cent solar tax credit, the cost drops to \$13 per million BTU, competitive with electricity. With the government sharing 70 per cent of the cost in this demonstration project, the cost to the owner dropped to \$2-\$5 (depending on the tax credit) per million BTU, which is competitive with natural gas.

*This simplified economic analysis assumes that the resale value of the solar system equals its initial cost to the owner plus accumulated costs of maintenance, insurance and taxes and ignores the tax benefits of depreciation.

This analysis does not account for the inevitable increase in gas and electricity costs; however, few businesses will make an investment yielding a negative cash flow when they have other alternatives. They will wait until solar is competitive in year one before considering its use (at least on an economic basis).

VII.
PERFORMANCE ANALYSIS

VII. PERFORMANCE ANALYSIS

(For a description of the on-site instrumentation and the national solar data network, see the IBM Solar Project Description in the Appendix. For the results, see the IBM Solar Energy System Performance Evaluation also in the Appendix.

The System Performance Evaluation predicts that the solar system will operate at an annual collector efficiency of 36 per cent and will provide 97.8 million BTU for a savings of 139.8 million BTU in natural gas (assuming a 70 per cent conversion efficiency). This relates to 36 per cent of the estimated load (demand).

A. Comparison of Collector Banks A and B

Following a freeze which damaged collectors located in Bank B, the opportunity was taken to install absorber plates of a different design to allow for simultaneous testing and evaluation. The new absorber plates were of all-copper construction while the others, in Bank A, were copper tubes mechanically fastened to aluminum sheets (see Solar System Description and operations and maintenance manual, for details). It was anticipated that the new all-copper panels would perform better than the copper/aluminum combination. The glazing and insulation remained the same. Much to our surprise, test data as presented in the System Performance Evaluation Report, indicated Bank A's performance six percentage points higher with the same performance curve slope (1.1).

Although part of the reason may be that collector bank B has more edge losses (four panels compared with 12 in Bank A), and slightly less absorber area per panel, we believe the major reason for poorer performance is reduced ground reflection. Only one pyronometer was installed (in the plane of Bank A) so the magnitude of the reflective component cannot be determined; however, a large expanse of gravelled roof lies in front of Bank A while the roof in front of Bank B is shaded by Bank A.

It seems reflection of light from the ground on to a collector can have a significant impact on its performance. A sawtooth collector array cannot take full advantage of this potential.

B. Storage System Flow Distribution

Considerable effort was made to monitor the performance of the storage tank system -- to the degree that all on-site monitoring (thermometers) had to be removed to accommodate the sensors. Each of the three tanks was equipped with temperature sensors at the top and bottom. The object of the test was to confirm the manufacturer's claim that the manifold system distributed water equally to and from each tank, thus performing as a single unit.

The temperature profiles in the test indicate fairly good distribution. During the period of collector operation, Tank 2 (middle) receives slightly more flow than the other two.

Good tank stratification was also noted even during collection hours when the circulating pump was on. This is probably attributed to the oversizing of the manifold pipes and tank fittings (1½") reducing flow velocities to a minimum, and the location of the collector supply and return ports at and near the bottom of the tank, seven and 11 inches from the floor (above the drain).

C. Anticipated vs. Actual Collector Performance

Based on an analysis of collector performance curves of similarly constructed prefabricated units, we anticipated better performance than indicated in the Performance Evaluation. Specifically, Y intercepts (collector efficiency at inlet temperature equal to ambient) of .56 and .50 for Banks A and B, respectively, seemed low.

All data points were taken at high operating temperatures in a small range of the curve. Therefore, the extrapolated curve's accuracy is highly suspicious.

If the collector performance curves are correct, a large discrepancy seems to exist between single unit test data and actual system performance. Either the components deteriorated rapidly (not indicated by visual inspection) or performance of site-fabricated collectors cannot be predicted based on test results of similarly constructed modules, or actual system operating performance cannot be compared to performance during contrived component tests.

Assuming the performance curve developed by IBM in the System Performance Evaluation was generated from data collected in August, several percentage points could be attributed to dust/dirt accumulation on the glazing. Furthermore, the shading effect of the 1½" wide glazing support runners (four total) would have the effect of reducing absorber area five per cent below that assumed in the calculations.

D. Controller Set Points

Included in the Performance Evaluation was the determination that the controller set points of on at 9°F delta T and off at 3°F delta T were too close. Although we disagree with IBM's conclusion that this was the major cause of the pump cycling (the storage tank sensor was misplaced during instrumentation installation to the collector return rather than supply port) the advantages of adjustable controller set points can certainly be substantiated. (NOTE: IBM believes the control sensor to have been properly installed when the set point conclusions were drawn.)

VIII.

PROBLEMS AND MODIFICATIONS

(LESSONS LEARNED)



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VIII. PROBLEMS AND MODIFICATIONS (LESSONS LEARNED)

1. The biggest problem encountered and lesson learned centers around a freeze coupled to an electrical power failure. In this mild climate in close proximity to the San Francisco Bay, freezes are rare. Therefore, the least expensive automatic freeze control system was chosen, i.e., a controller equipped with a circuit that would turn on the pump in the event of a freeze. This type of system is still widely used and accepted in the Bay Area. The chances of a concurrent freeze and power failure rendering the pump useless is remote; however, it happened in the first year of operation.

When the collector thawed out, water began to leak under city water pressure through large slits in the pipes caused by expansion of water as it turned to ice. It is interesting to note that the leaks occurred in the middle of risers —not at the bottom of the collectors or at the soldered joints. Water leaked through the collector enclosure to the space underneath. Unfortunately, the roof scuppers that were designed were never installed, so the water filled to the top of the curb. The curb height was above the lip of the jackets that surround the supply and return lines as they penetrated the roof membrane. The space between the metal jackets and the pipes were not sealed so that water could leak down to the ceiling and room below.

The doors to each room and between areas are designed to be light tight and are well weatherstripped. As it turned out, they were essentially water tight. Much of the lab was under several inches of water before it began to reach the exterior where someone would notice it. Unfortunately it occurred over a weekend. When the leak was finally discovered, there was so much water in the lab that the fire department had to be called to pump it out. While damage to the solar system was less than \$2,000 and damage to the building just several hundred dollars, damage to photographic equipment and materials amounted to over \$6,000. Water, for example, was found dripping from the bellows of a large room-sized enlarger. Needless to say, the existing freeze control system was deemed inadequate.

Several alternatives were considered and two primary actions were taken:

—An additional controller with a freeze circuit was added and the sensor was placed on the second bank. Therefore, the pump would be activated if either or both controller/sensors indicated a freeze.

—A drain down system was installed to prevent freezing in the event of a power failure. Two solenoid valves were installed. One is normally (no power) closed to isolate the system, the other is normally open to drain the water. Vacuum breakers (two) were added to the collector banks to facilitate rapid and complete draining. The solenoid valves were connected to a switch to allow maintenance personnel to shut off power and check for proper operation.

We would never again design this type of freeze control system. Even with the modifications it is not a fail-safe system. For example, we have visited the site and found the controller turned off. In this case, if no power failure occurred, the collectors would not be protected. Even a normal drain down system that operates whenever the pump is off runs a chance of an automatic valve failure. For these reasons our current designs (1979 vs. 1976) involve drain back systems where the collector loop is separated from the domestic water supply by a heat exchanger and the collector drains by gravity into a sump tank whenever the pump is off. No mechanical/electrical devices are employed.

2. Initially, cold and hot water were mixed twice: first in the mechanical room to prevent scalding, and second at each processor or sink to the desired temperature (75°F to 100°F depending on the process). Each mixing valve requires the hot side to be approximately 20°F warmer than the desired mixed temperature because the cold side cannot be completely shut off.

Therefore, to be mixed twice required the initial water to be heated to about 140°F. This is not ideal for solar utilization where lower temperatures are preferred. Considering that only the bathroom sinks were without their own automatic mixing system, it was decided to eliminate the one in the mechanical room, allowing the back up water heater set temperature to be lowered to 120°F.

3. Several of the initial panels had leaks at the silver soldered joints. Quality control at the factory (in fabrication and testing) was lacking. The leaks were discovered during our pressure test just prior to collector glazing. It was not practical to remove, return, and replace the defective units. Corrective action had to be made at the site. A pipe fitter with special tools and materials was called in to do the necessary repair work.

4. To ensure a water tight insulation, the Filon glazing panels were overlapped two corrugations and sealed with silicone sealant. Once set, the silicone seal is as strong as the fiberglass panels themselves. Therefore, instead of individual panels, there is now one big panel. This was identified as a problem when repair work was required (see collector freeze section) on one bank. Subsequently, sealants are not used and leaking, at least on steep slopes, has not been a problem.

5. On several occasions we have returned to the site to find the controls have been tampered with, i.e., the solar controller is on or off but not in the automatic position, or the backup heater is set at 180°F, etc. This seems to be an unavoidable problem; however, all equipment should be well labeled, key equipment might be locked, and certainly system simplicity is essential. On-site monitors that allow for a quick check of proper system operation are ideal.

6. Butterfly valves (two) were installed on this system for collector balancing. They are not ideal as they seem to move. Ball valves have proven more satisfactory.

7. A potential problem was encountered due to non-union workers being employed on a commercial project. Since our firm was the architect, engineer and construction manager for the entire job, little commotion was raised. But the problem is likely to become more serious. One solution is to design the solar system for retrofit, i.e., have the solar subcontractor come to the site when all other trades have finished. Even this "solution" will not work on larger systems. This is one reason why larger solar systems cost more than smaller systems, contrary to the economy of scale theory.

8. As anticipated, there is considerable expansion and contraction of the headers within the collectors. The felt lining of the clamps has slipped out of place and in recent inspections we have found that the panels have worked the clamps loose and have slipped down in the collector enclosure. It should be noted that the building has been vacant and the collectors have been stagnating every day for about two years. It is possible that some collectors may have slipped to the degree of hampering or preventing proper draining. Once operation is resumed, a thorough inspection and necessary repairs must be made.

9. Initially, no vacuum breakers were installed on the collectors and the relief valves were constantly used for manual venting. With this abnormal use (opening and closing) they began to leak. Manual air vents or vacuum breakers should always be installed.

10. The storage tanks were so-called "off the shelf" products (non-solar); however, they were delivered late and delayed the project several weeks. The fittings supplied by the manufacturer (American Appliance) were copper with no provision for dielectric separation from the steel tanks.

We have found continually that solar specialty products have not been the longest lead items and are not on the critical path. It is helpful for the designers to indicate to the contractor the known long-lead items.

11. Not uncommon with any project, solar or not, there was not enough space in the mechanical room to comfortably house all the equipment. Architects should work with the solar designers early in the design to ensure adequate space.

IX.

INTERIM PERFORMANCE CRITERIA REPORT

Compliance with the Interim Performance Criteria (IPC)

Generally, the design and installation of the solar water heating system at the Iris Images Custom Color Lab followed the intent of the Interim Performance Criteria initially developed by NASA and revised by NBS as NBSIR76-1187. However, several discrepancies or potential discrepancies have been identified and are discussed below; referenced and ordered by IPC paragraph number.

1.3.1	Criterion	<u>Thermal performance of discrete collectors.</u> The solar collectors shall collect or dissipate energy at their design values.
	Evaluation	Engineering review of drawings, calculations, and test data. Solar collector panel performance data shall be generated using the method described in ASHRAE Standard 93-P (in preparation) [19] or any other comparable method demonstrated to have an overall limit of error of less than $\pm 5\%$.
	Commentary	Typical slope intercept curves for flat black and selective coated absorber panels with one and two covers are shown in Figures 1.3-1 and 1.3-2 for air and water heat transfer fluids, respectively. The 93-P test method will provide the efficiency as a function of operating temperature, ambient temperature, and insolation for collectors with a definable aperture or interception area. The collector must have a single heat transfer fluid inlet and outlet and must be separate from the thermal storage device. Collectors with other geometric, optical, or thermal characteristics may require additional or other tests to fully describe their thermal performance for all environmental and operating conditions. Additional information on collector design, performance, and operation is presented in reference [10, 15, 20, 21].

The flat plate collectors installed at the Iris Images Custom Color Lab were site fabricated with all manifolding internal to the collector. Pre-testing this type of collector is not practical. Performance curves of modual collectors with similar cross sections can be used as a guide in sizing and estimating system performance, however an overall limit of error of less than 5% can not be substantiated.

1.7.4	Criterion	<u>Hot water temperature.</u> Potable water storage tanks providing hot domestic water directly to the hot water distribution system shall be equipped with instantaneous automatic temperature controls capable of adjustment from the lowest to the highest acceptable temperature settings for the intended use.
	Evaluation	Review of drawings and specifications.
	Commentary	Location and adjustment of the HW controls can influence the use of auxiliary energy.

Originally a mixing or tempering valve was installed on the hot water distribution system. In addition, each processor and lab sink was individually equiped with automatic temperature controls. Therefore, hot water was tempered twice before use. Although the maximum end use temperature was

only 100°F, this system required hot water temperatures, before mixing, of 130°F to 140°F.

The primary (less expensive and accurate) mixing valve was subsequently removed to increase the solar system's performance by decreasing the minimum temperature requirement. This modification allows untempered hot water to feed the bathroom sinks. If a problem develops, the owner will install additional automatic mixing valves at these sinks.

2.1.6	Criterion	<u>Thermal expansion of fluids.</u> Adequate provisions for the thermal expansion of heat transfer fluids that can occur over the service temperature range shall be incorporated into the system design. Expansion tanks shall be sized in accordance with the recommendations of ASHRAE.
	Evaluation	Review of drawings, specifications, and design calculations.
	Commentary	Water expands about 4% in volume when heated from 40°F to 200°F. Other heat transfer fluids will have different coefficients of volume expansion. Means should be provided in the system design to contain this additional fluid volume without exceeding the operating pressure of the system or resulting in spillage.

Expansion tanks are uncommon in open (flow through) domestic hot water systems where additional pressure caused by fluid expansion normally is relieved through the distribution system. Likewise, no expansion tank was provided in this system. An operational pressure relief valve located in the mechanical room relieves any pressure accumulated over a long period of time with no use (i.e. a weekend) before the pressure reaches that required for release through the system's safety pressure relief valves. Therefore a small spillage can result.

4.2.2	Criterion	<u>Automatic pressure relief devices.</u> Adequately sized and responsive automatic pressure relief devices such as valves and venting systems shall be provided in those parts of the energy transport subsystem containing pressurized fluids. Automatic pressure relief valves shall be set to open at not less than 25 percent in excess of working pressure and at not more than maximum pressure for which the subsystem is designed. Vented non-combustible, potable liquids shall be piped to suitable drains. Non-potable or combustible liquids shall be handled in accordance with Criterion 4.4.1.
		Relief valves shall drain to locations acceptable to the local administrative code authority.
	Evaluation	Review of drawings and specifications and/or determination that methods, devices, and materials to be used are approved by a recognized testing and evaluation agency as being suitable for the proposed use.

Commentary For large systems, special consideration should be given to venting the excessive pressures caused by exposure fires. Guidelines for calculating vent size are contained in NFPA 30 [3].

The pressure relief valves located on each of the two collector arrays are vented above the roof and are not piped to drains. Pressure is not vented from these valves unless the collectors are full and mistakenly isolated from the system. Normally pressure is vented from relief valves suitably piped to the mechanical room drain.

4.3.4 **Criterion** Protection against auto-ignition of combustibles. Combustible solids used in solar equipment shall not be exposed to elevated temperatures which may cause ignition.

Evaluation Review of calculations, drawings, and specifications. Testing to show compliance where necessary.

Commentary Exposure of cellulosic materials as well as other combustible materials over an extended period of time result in the material reaching and surpassing its auto-ignition temperature. The most commonly accepted ignition temperature of wood is 392°F. However, studies have indicated that wood may ignite when exposed to a temperature of 212°F for prolonged periods of time. The ignition temperatures of plastics may be above or below those of cellulosic materials.

With the single glazed flat black collector installed on this project stagnation temperatures are not expected over 250°F, well within the accepted ignition temperature of wood but certainly greater than 212°F. Both Douglas Fir and Redwood were used in the construction of this collector to support the absorber plate and glazing.

Why were the studies in the Commentary not referenced?

CHAPTER 5 - DURABILITY/RELIABILITY

Durability and reliability were not tested prior to construction. Materials in the design were selected with these factors in mind. Whether or not individual components were tested as specified in the I.P.C. is not known. Specifications on each component including some test data can be found in other sections of this report and/or in the operation and maintenance manual.

6.1.1	Criterion	<u>Access for system maintenance.</u> All individual items of equipment and components of the H/C/HW systems which may require periodic examination, adjusting, servicing and/or maintenance shall be accessible for inspection, service, repair, removal or replacement without dismantling of any adjoining major piece of equipment or subsystem. Individual collectors in an array shall be replaceable or repairable without disturbing non-adjacent collectors in the array.
	Evaluation	Review of drawings and specifications.
	Commentary	Accessibility as a function of component life is an important consideration. Some manufactured collector systems and many individually designed systems are done in such a way that sequential installation is necessary. This can make it very difficult to replace an individual collector without disturbing the entire array.

The collectors on the Iris Images Custom Color Lab were site fabricated in two major arrays. A uniform glazing system (corrugated fiberglass) covers each array. Silicone was used to seal laps between the fiberglass panels. Subsequently it was found that individual glazing panels cannot be removed for replacement or repair of themselves or the individual absorber plates below. This design detail is not recommended. A less permanent sealant would have been preferred.

Following the design and construction of the solar DHW system, a large (unanticipated) filtration system (not solar related) was installed in the mechanical room, rendering one of the three 120 gallon solar storage tanks inaccessible. Servicing this tank may require removal of the sand filter or the adjacent storage tank.

6.1.2	Criterion	<u>Access for system monitoring.</u> Appropriate access for sensors shall be provided for inspecting and checking essential system parameters, e.g. temperature, pressure, and critical voltages.
	Evaluation	Review of drawings and specifications for the location of test fittings and electrical contacts.
	Commentary	Adequately located test fittings will permit system monitoring and expedite the maintenance and repair of equipment.

Originally meters were installed to monitor the lower and upper storage tank temperatures. The government's subsequent instrumentation system required the use of all available tank connections. Unfortunately this system does not allow for site readout and therefore monitoring the storage tank temperatures is not possible.

6.2.1	Criterion	<p><u>Installation instructions.</u> The instructions shall include physical, functional, and procedural requirements for H/C/HW subassembly and component installation.</p> <p>These instructions shall describe the interconnection requirements of the various subsystems and components and their interface requirements with the building and site.</p>
	Evaluation	Review of installation instructions.
	Commentary	It is not the intent of this criterion to require the provision of complete, detailed system installation specifications. Such specifications would normally be project specific and part of the procurement process.

Design plans and specifications of the solar DWH system were adequate for building permit approval, however complete installation instructions were not compiled due to the design/build nature of this project. If the design firm was not the builder, more detailed contract documents and/or installation instructions would have been required and prepared.

12.1.1	Criterion	<p><u>Accessibility.</u> The design shall make adequate provision for accessible maintenance.</p>
	Evaluation	Review of site and building drawings.
	Commentary	Solar components should be accessible without trespassing on adjoining property and should not be located unnecessarily under buildings or roads, behind mechanical equipment or in other places which are inaccessible for maintenance without disassembling any major structural or mechanical elements. There should be sufficient room around components to permit their examination, adjusting, servicing, and/or maintenance. Accessibility for repair, maintenance and replacement should reflect the expected life of the component and frequency of routine maintenance required. An element with a shorter maintenance cycle or life expectancy should be more accessible than one that has a longer maintenance cycle or life expectancy.

See discussion regarding IPC - 6.1.1. Access for system maintenance.

APPENDIX A
OPERATION AND MAINTENANCE MANUAL

SOLAR SYSTEMS OPERATIONS AND MAINTENANCE MANUAL .

IRIS IMAGES, INC.
MILL VALLEY, CA

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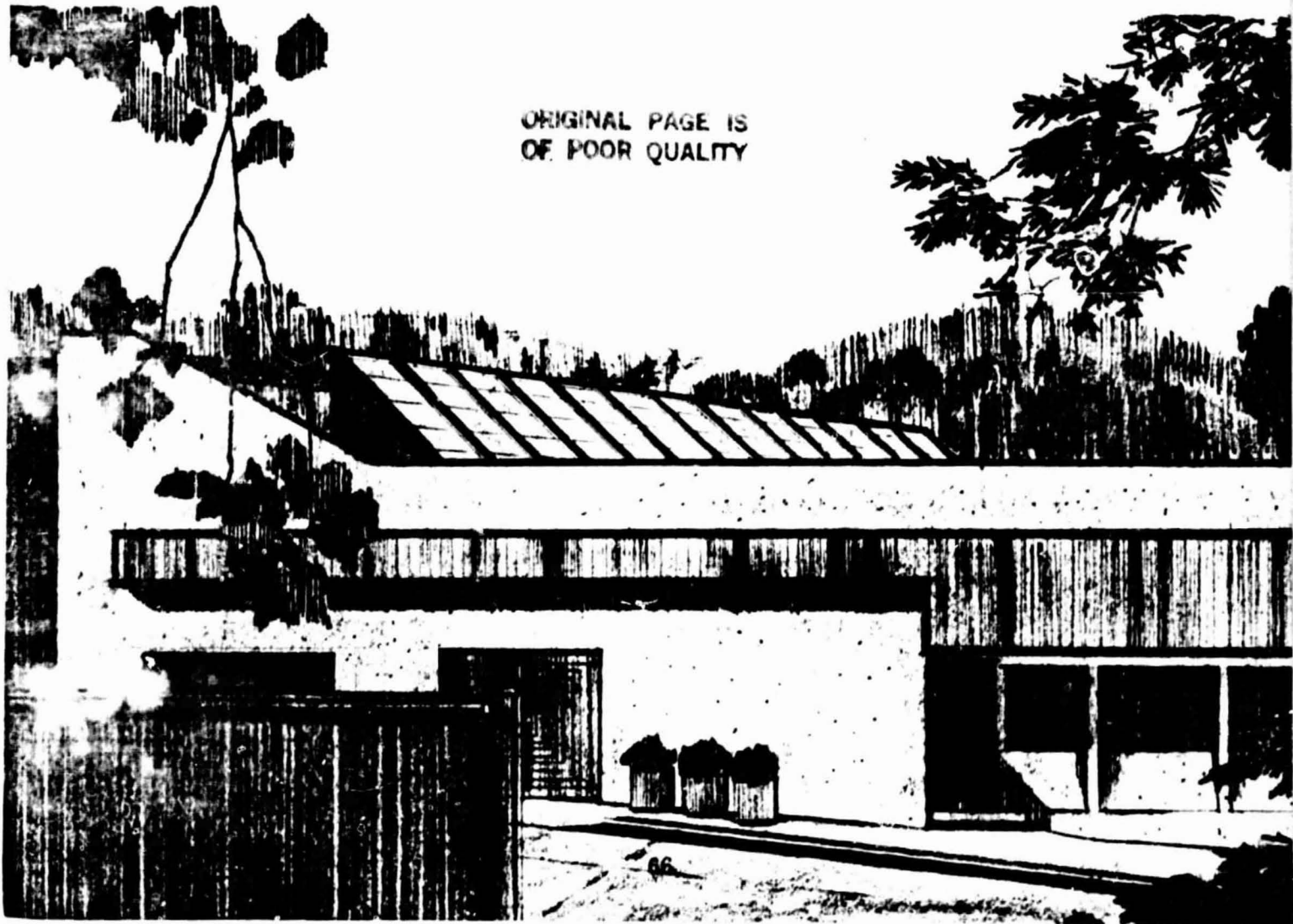


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FIGURES

1. Simplified solar system schematic
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11. Solar collector at rake

SYSTEM OPERATION

I. Summary Description

The Iris Images solar water heating system is designed to provide process hot water for film processing. It is a pre-heat system intended to supply approximately 60 per cent of the annual water heating based on a load of six gallons per minute, nine hours a day, five days a week, at 100°F.

The solar system is designed to meet loads as they occur during the daylight hours on working days, and to meet the average low temperature demands of the system—not to meet peak loads. A simplified system schematic is shown in Figure 1.

Potable water enters the system from the city water main. It may enter the storage tanks or the collectors, depending on the load from the processors and operation of the pump.

A differential temperature controller compares the temperature at the bottom of the storage tanks and at the top of the collectors. When the collectors are warmer, the controller activates the pump and circulates water through the solar collectors, transferring energy in the form of heat to the water storage tanks. The controller will automatically turn the system off when energy is not collected.

The storage tanks in this system are designed only as a buffer between energy collection and use. They are not intended to provide storage for peak loads or over periods of bad weather. The tanks store solar pre-heated water. This water feeds to the backup gas heater, where, if necessary, additional energy is added to bring the water to the desired temperature. From here, hot water is supplied to the film processors as well as six sinks and two bathrooms.

II. Make-up Water Supply

Water to the solar system is supplied from the city water main. Before entering the solar heating system, it passes through a filter located in the mechanical room. This filter is not a part of and is not necessary to the operation of the solar system. The filter was installed to ensure that only very clean water is supplied to the film processors.

A bypass line is provided from the make-up water to the backup heater. The solar system can be completely bypassed, allowing continued lab use while maintenance or repairs are made on the solar system. See Figure 2.

III. Solar Collection Loop

The collection loop transfers heat from the solar collectors to the storage tanks. Potable water is the transfer fluid which flows through the collectors and is the storage medium in the tanks.

A. Control System

To ensure reliability, two differential temperature controllers activate and deactivate the pump in the solar collection loop. The pump performs the dual functions of (1) circulating water through the collectors to collect solar energy, and (2) circulating warm water from the solar storage tanks to prevent water in the collectors from freezing. The two controllers are mounted on the south wall of the mechanical room. See Figure 3.

1. Solar Energy Collection. Remote sensors are located in the top manifold pipe of collector bank A and at the bottom of storage tank 1. Controller A compares the temperature at the two sensors by measuring resistance to a low-voltage electric current. When the collector sensor is 9°F warmer than the storage tank sensor, the controller activates the pump. When the collector sensor is less than 3°F warmer than the storage tank sensor, the controller turns the pump off.
2. Collector Freeze Protection. If the water in the collector freezes, it will expand into ice and burst the pipes. There are two freeze protection systems at Iris Images:
 - a. Pumped Freeze Protection. Both controllers are equipped with freeze protection cycles. Controller A is connected to a freeze sensor on collector bank A and controller B is connected to a freeze sensor on collector bank B. The freeze sensors are located on an absorber plate. If the temperature at either sensor drops below 36°F, the pump is activated and warm water is circulated through the collectors. When both sensors are heated up to 37.5°F, the pump is turned off.
 - b. Drain Down Freeze Protection. The pumped freeze protection does not work during a power failure. To guard against the possibility of a simultaneous freeze and power failure, a system is provided which will drain water from the collectors during a power failure. If a power failure occurs, two solenoid valves will move. One (V4) will close, cutting off make-up water and depressurizing the solar system. Another solenoid valve (V7) will open, allowing water to drain out of the collectors.

For normal solar operation, both temperature differential controllers should be placed in the "automatic operation" position. In this position, the pump will automatically activate and deactivate as required to collect energy and prevent freezing. The pump will activate if either or both controllers so command.

<u>Controller Switch Position</u>	<u>Function</u>
Manual On	Pump will constantly operate regardless of temperature differentials.
Off	Pump will never operate regardless of temperature differentials.
Automatic Operation	Pump will operate in response to temperature differentials as required to collect energy and prevent freezing.

B. Balancing Flow Through Collector Banks

Collector Bank A is equipped with twelve 4' x 10' absorber plates by Sunburst Solar Energy, Inc. Collector Bank B is equipped with four 4' x 10' absorber plates by Solar Development, Inc. The absorber plates in each bank are manifolded to equally distribute flow within each bank. Flow to each bank, however, must be adjusted with a balancing valve to ensure equal flow to all 16 absorber plates. This can be accomplished by adjusting the balancing valves (V8 and V9) and reading the thermometers which are located inside the support structures at the collector outlets.

Balancing can only be accomplished with the pump on. With both valves completely open, the exit temperature from Bank A (T3) will be higher than from Bank B (T4). The balancing valve at Bank A (V8) should be left completely open and the balancing valve at Bank B (V9) should be closed slightly. This will bring the exit temperatures and the flow rates per collector closer together. If Bank A is still warmer, the balancing valve at Bank B should be closed slightly more. If Bank B is warmer, then its balancing valve should be opened slightly. The adjustments should continue until the exit temperatures are the same from each bank. Several minutes should be allowed between each adjustment so the full effect of the change can be registered by the thermometers.

An additional balancing valve is located in the mechanical room in the supply line to the collectors in the event a reduction in the overall flow rate is desired, but for normal operation it should be fully opened. A check valve in the return line from the collectors prevents back-syphoning at night.

C. Collector Temperature and Pressure Relief

If there is no flow through the collectors on a sunny day, the temperature and pressure could go to undesirable highs. To prevent excessive conditions, temperature/pressure relief valves (V10 and V11) are located at the high point of each collector bank.

An additional temperature/pressure relief valve is located on the backup water heater and an additional pressure relief valve is connected in series with the pressure reducer on the cold water supply to the entire building.

IV. Storage

The storage system consists of three 120-gallon pressurized water tanks. They are manifolded to provide equal flow to each tank. Make-up water enters at the bottom of the tank. This is also where water is drawn from the tank to the collectors. Water returns to the tank from the collectors a few inches above the supply. Water is drawn off the top of the tank to feed the bottom of the backup heater.

V. Backup Heater

The natural gas backup heater is a conventional hot water heater. Its minimum temperature should be set at 120°F.

VI. Processors and Sinks

Water is removed from the backup heater by four independently operated film processors. The required temperature varies according to the type of film being processed. Temperature is controlled by tempering valves located at each processor which mix hot water from the solar system with cold water. Required temperatures range from 75°F to 100°F. Bathroom and laboratory sinks are also served with hot water.

VII. Solar System Start-up

To start the solar system, make sure all hose bibbs in the system are closed. Valve V1 should be closed, and valves V2 and V3 open. (See Figure 7.) This will fill the storage tanks and collectors with water and pressurize the system. Automatic air vents, located at the high point of each collector bank, allow air to escape the plumbing system. For normal operation of the solar system, both temperature differential controllers should be switches to "automatic operation." In this position, the pump will automatically activate and deactivate as required to collect energy and prevent freezing.

VIII. Solar System Shut Down

To shut the solar system down and switch to the backup, valve V1 should be open and V2 and V3 closed (see Figure 7). This will unpressurize the storage tanks and collectors, but will allow lab operations to continue with the backup heater. Both temperature differential controllers should be switched to "Off." This position will keep the pump off at all times.

If the system is shut down for more than a few hours— and especially if there is a possibility of freezing temperatures— the solar collectors should be drained. Hose bibbs are located on the supply and return lines between the collectors and storage tanks. A hose can be attached to them to drain the collectors. If it is also necessary to drain the storage tanks, hose bibbs are located at the bottom of them. Vacuum breakers are located at the high point of each collector bank to allow air to enter the system when draining.

PERIODIC MAINTENANCE

I. Summary

The following inspections and maintenance should be done every four months. If properly adhered to, the solar system will perform more efficiently and the components will last much longer. More importantly, some of these tests are absolutely necessary to prevent damage to the system. For instance, if the freeze protection systems are not operating properly, the water in the collectors might freeze, expand and burst the pipes.

These tests take only a few minutes to complete and can greatly extend the life of the system. It is in future years, when fuel prices have greatly escalated, that the solar system will make its biggest economic contribution.

II. Wash Collectors

Every four months the collectors should be inspected for dirt and pollutants on the translucent fiberglass glazing. Dirt on the collector will block sunlight and pollutants will degrade the transparent cover. Rainfall will usually do a satisfactory job of keeping the collectors clean, but when months go by without rain, they should be rinsed off. A hose bibb is located on the roof for this purpose. It is located on the east side of collector bank A near the bottom.

III. Inspect for Leaks

The solar collectors are exposed to extreme temperatures. Excessive expansion and contraction or freezing can cause a pipe to break. If on the roof, a leak might go unnoticed for a long time. It is, therefore, important that the collectors be periodically inspected for leaks.

If a leak is found, the solar system should be immediately shut down, the collectors drained, and the hot water system switched to the natural gas backup system. (See "System Operation" section, Part VIII, "Solar System Shut Down.")

IV. Check Balancing of Collector Banks

A thermometer (T3 and T4) is located inside each collector support structure. It measures the temperature of the water as it leaves each collector bank. The exit temperature from both banks should be the same. (This should only be done when the pump is on and collecting energy.) If they are not the same, then the balancing valve at collector bank B should be adjusted. The balancing valve is located next to the thermometer under the collector support structure.

V. Check Controllers

By looking at the water temperature going to the collectors (T1) and returning to the storage tank (T2), the controller can be checked. When the pump is operating, the returning temperature should never be less than or equal to the supply temperature. These temperatures should be checked periodically in the morning and late afternoon to make sure the pump is activated and deactivated at the proper temperature differentials.

For normal solar operation, both temperature differential controllers should be placed in the "automatic operation" position.

VI. Check Drain Down Freeze Protection System

In the event of a power failure and simultaneous freeze, it becomes absolutely necessary to drain the collectors. A system is provided which will automatically drain the collectors whenever there is a power failure.

The drain down system employs two solenoid valves, V4 and V7. When a power failure occurs, V4 closes, cutting off the water pressure to the hot water system. At the same time, V7 opens, allowing water in the collectors to drain to the floor drain.

During the regular maintenance check, every four months, the proper operation of these solenoid valves should be checked. Above the differential temperature controllers is an electrical switch. Turning this switch to the "off" position will cut off power to the solenoid valves, simulating a power failure. The movement of the solenoid valves and the draining of water can be heard. If in doubt, touch the solenoid valves while someone else turns the switch. You will be able to distinctly feel the movement of valves. After testing, the electrical switch should be returned to the "on" position. For proper operation of this system, V17, located near the floor drain, should always be open.

VII. Oil Pump

Every four months, place a few drops of oil in each of the two ports. Use 20-weight, non-detergent oil. This will greatly increase the life of the pump.

VIII. Drain Sediment Out of Storage Tanks

Every four months the drain valve at the bottom of each storage tank should be opened. The water should be allowed to run until it flows clean. This will keep sediment from building up in the tank bottom.

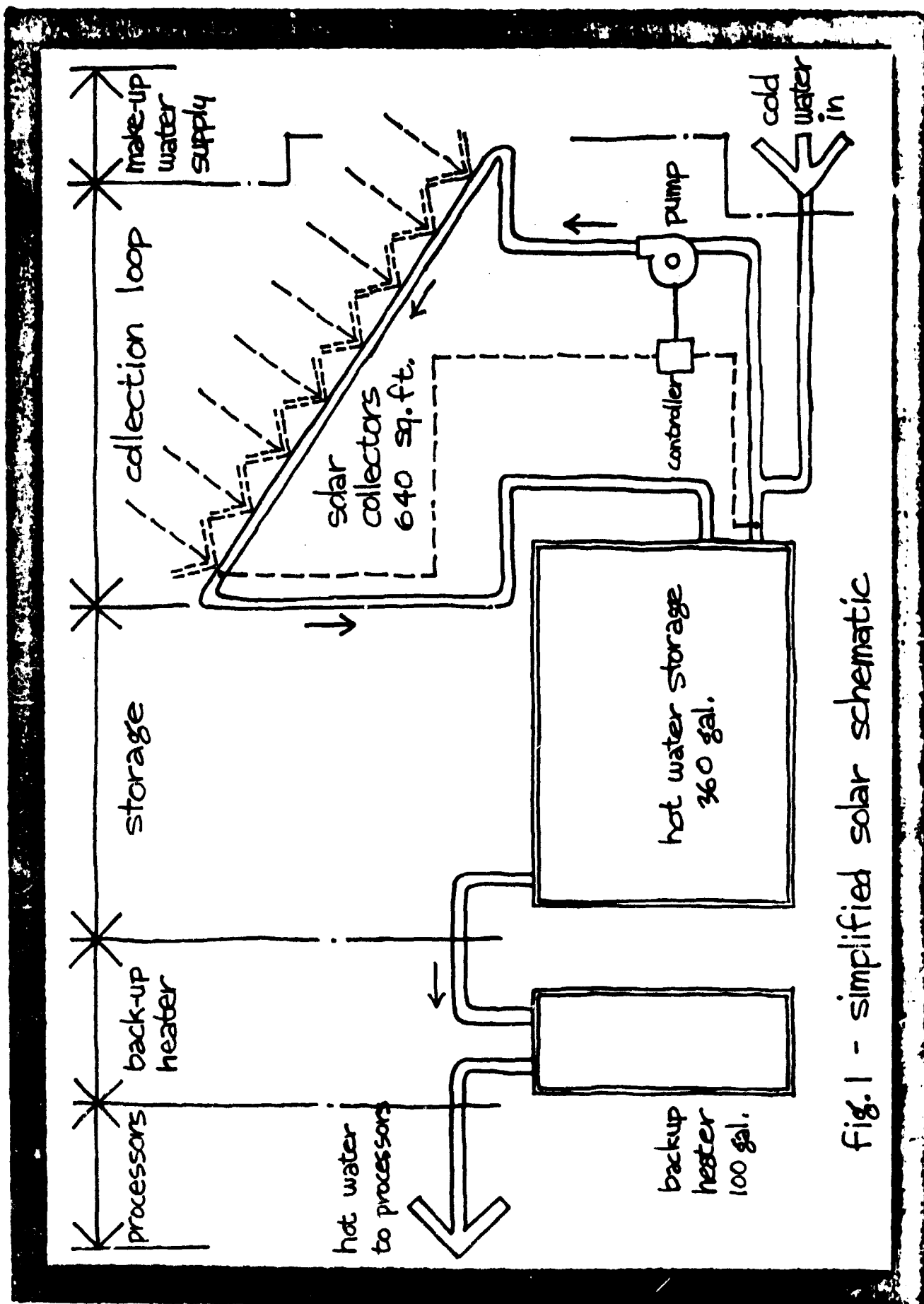
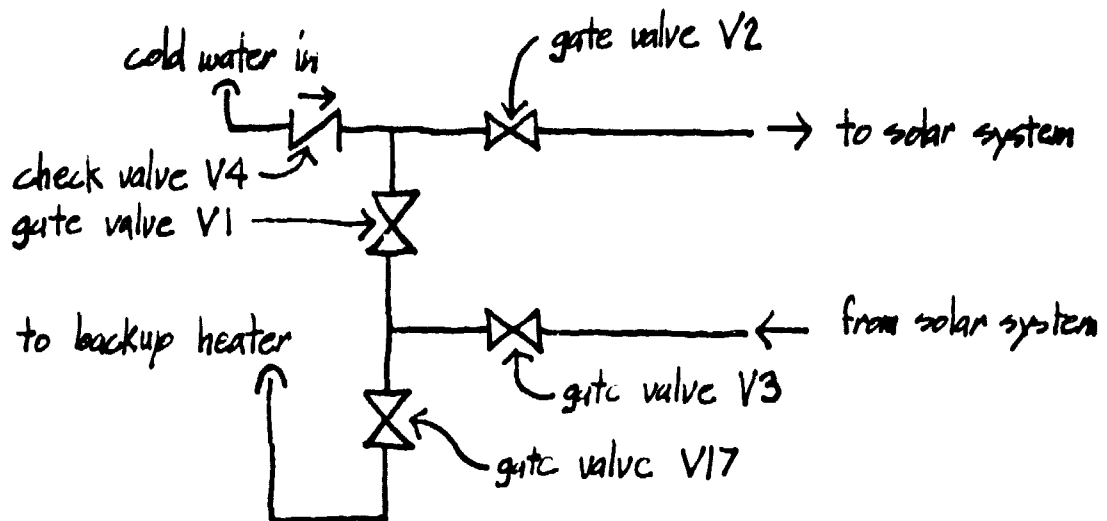


Fig. 1 - simplified solar schematic

fig. 2 · make-up and bypass water supply



	with solar	without solar
V1	closed	open
V2	open	closed
V3	open	closed
V17	open	open

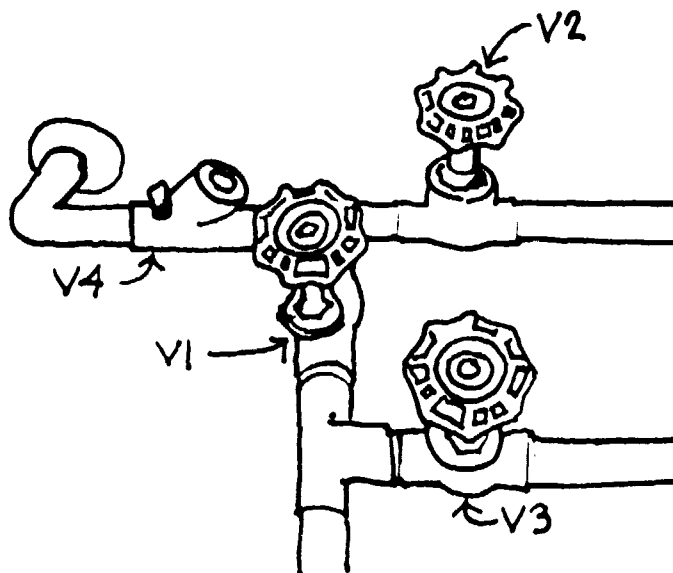
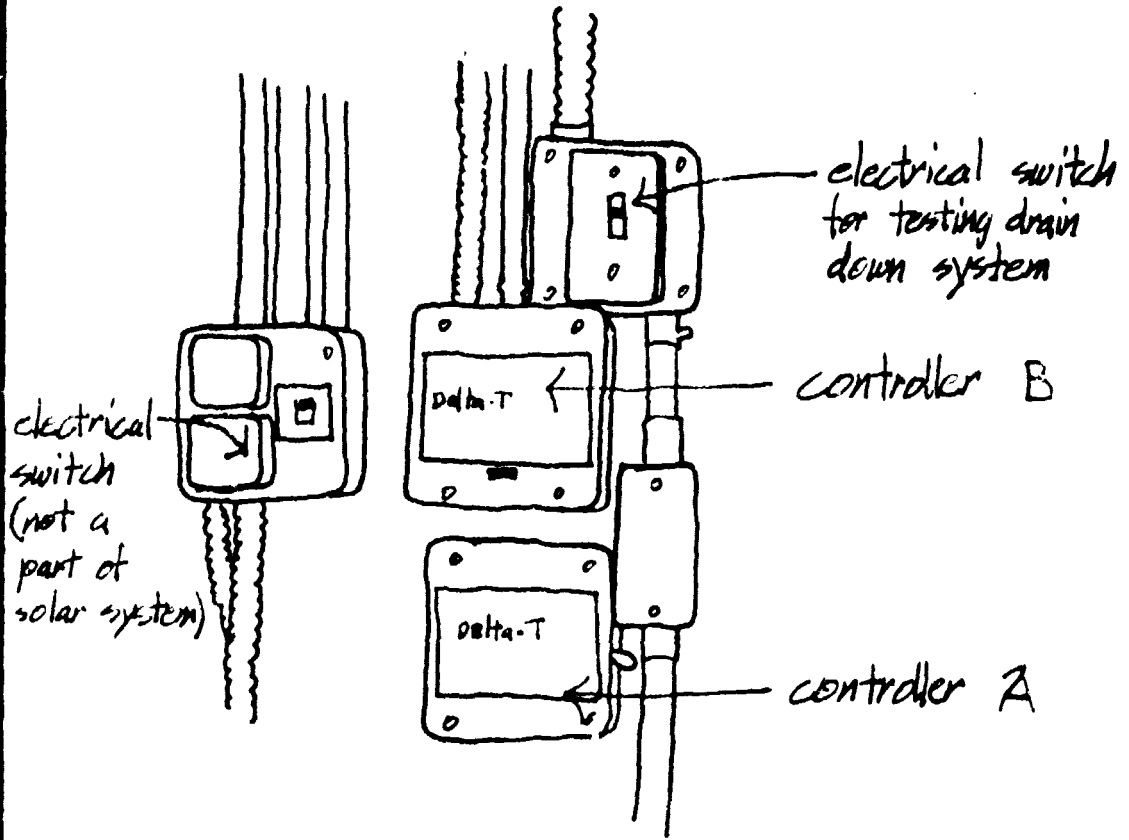
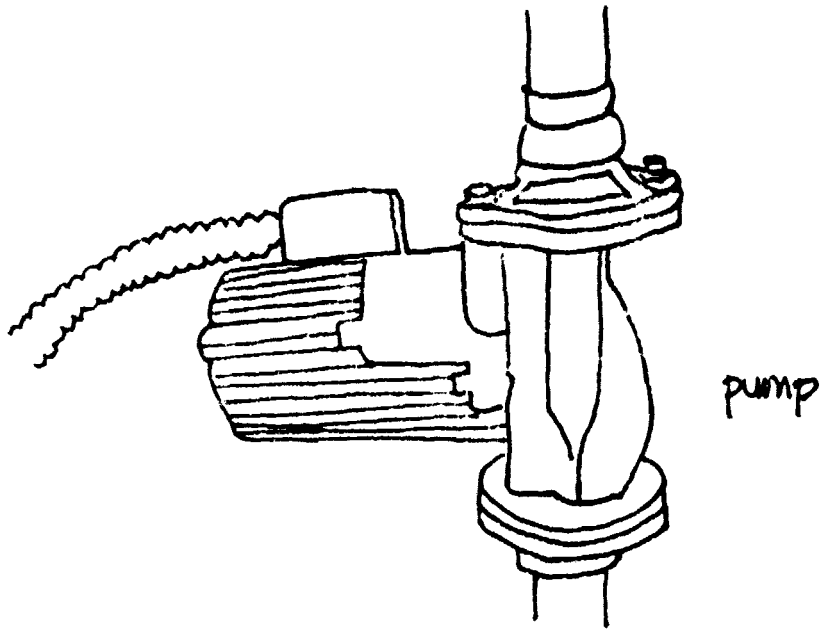
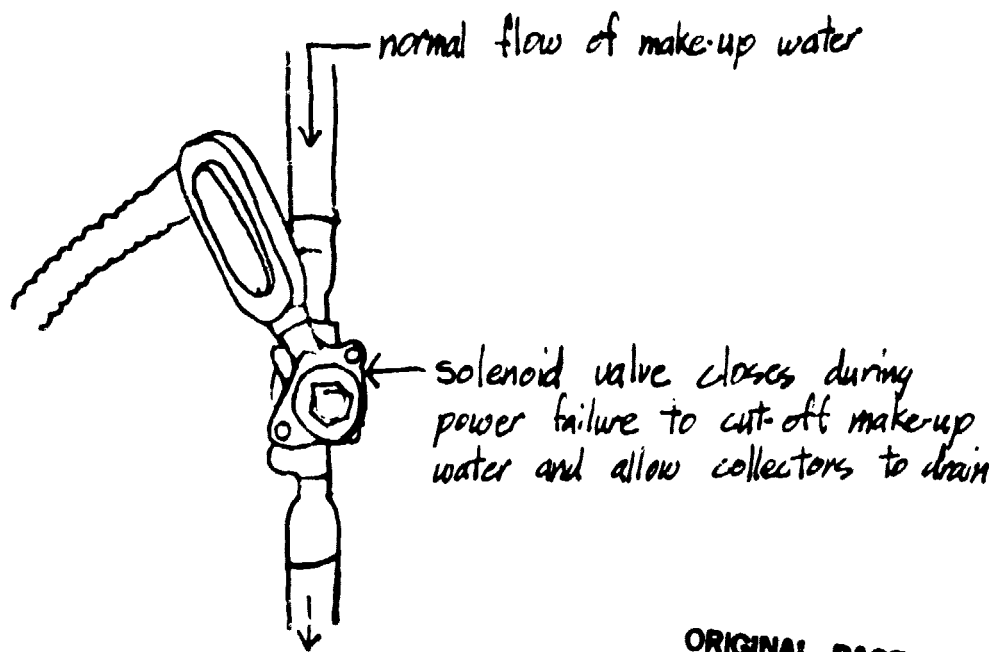
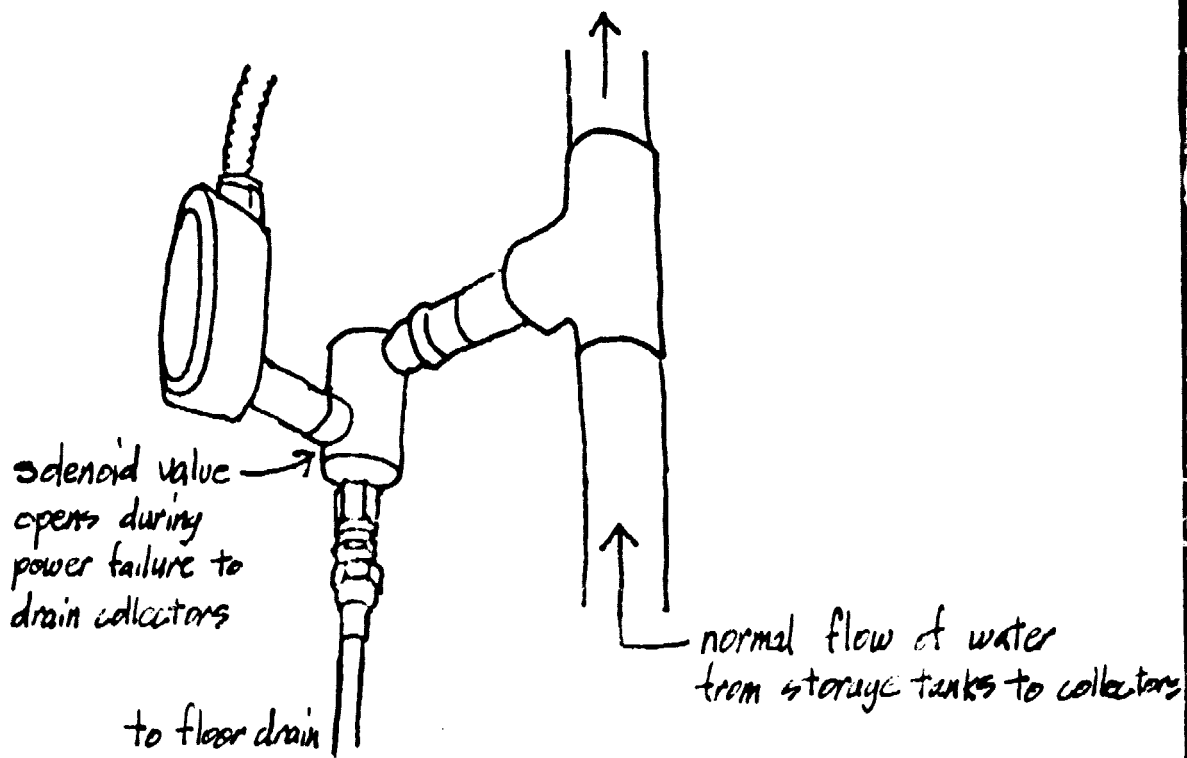


fig. 3 pump and controllers

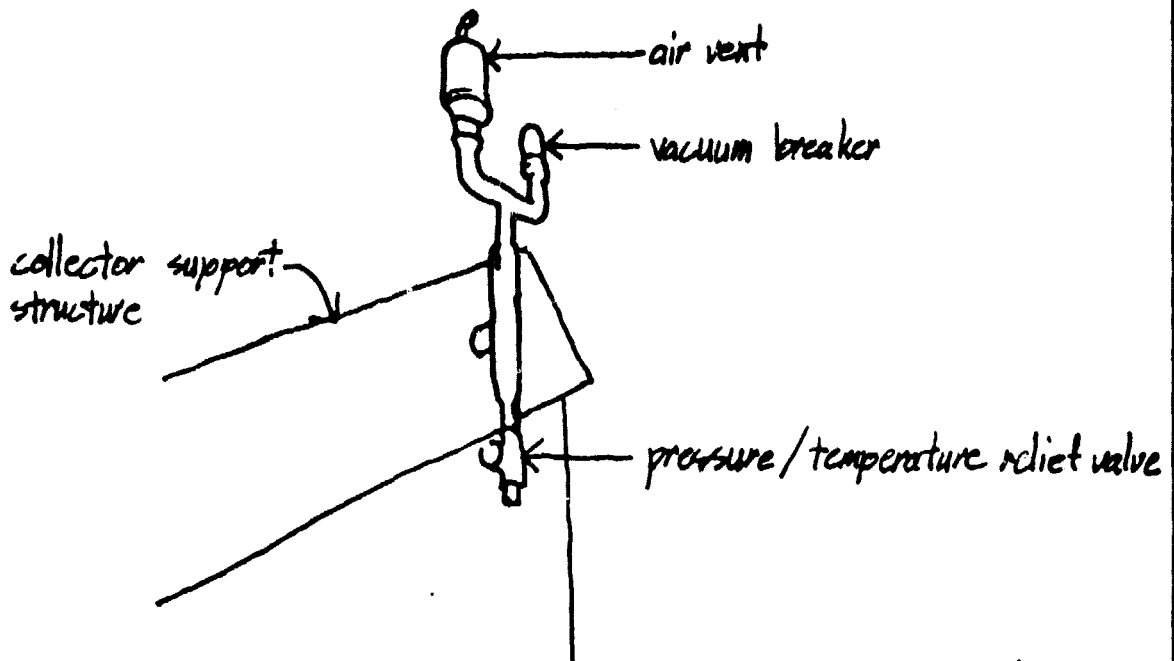




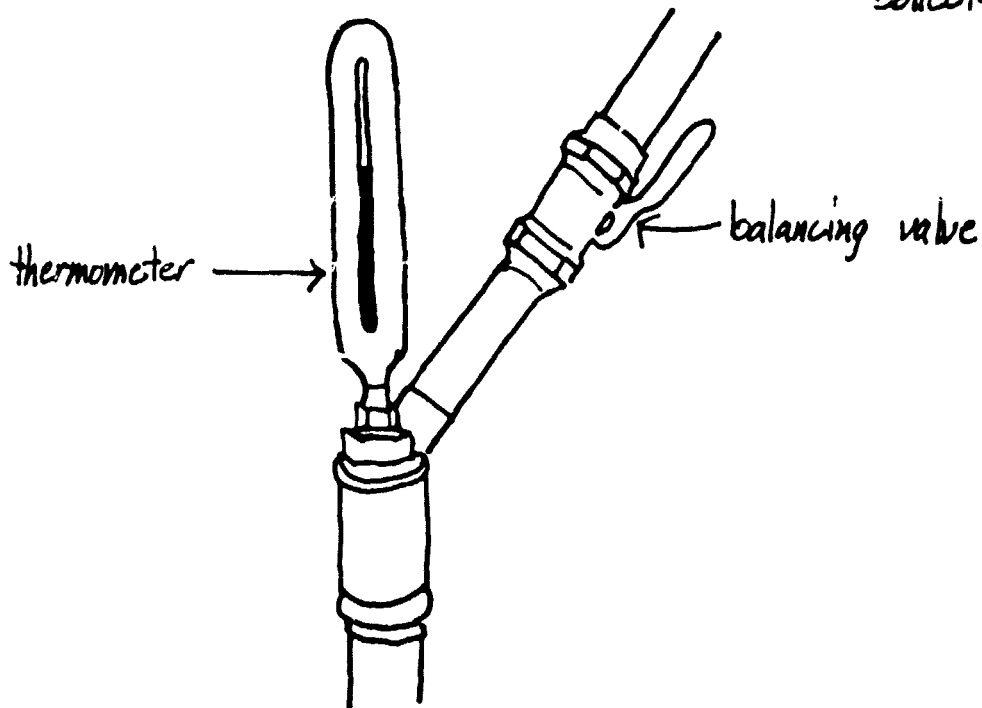
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fig. 4. solenoid valves

fig. 5 collector valves & vents

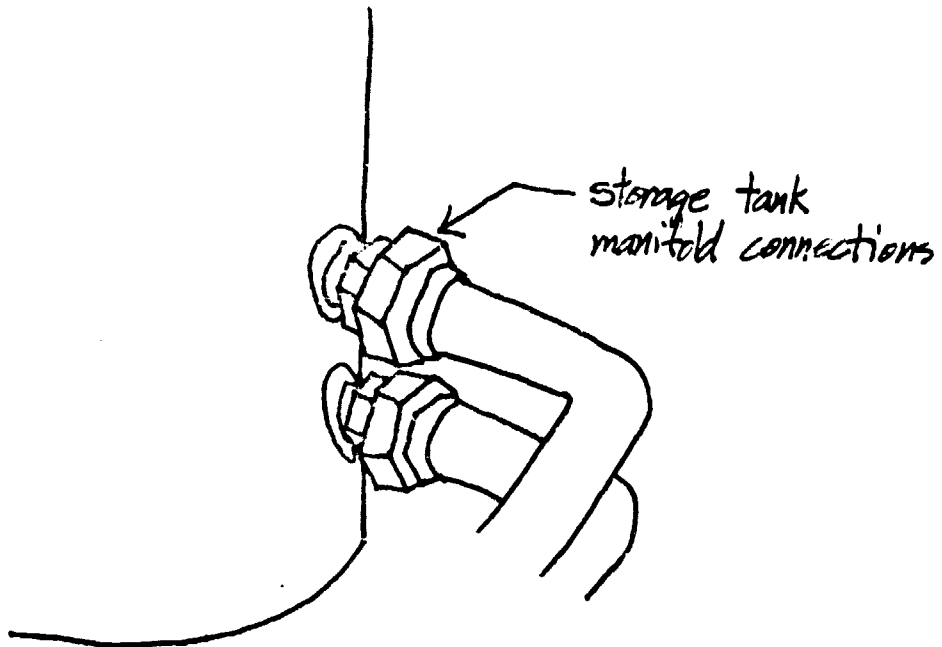


exterior vents & valves located on east side of each collector bank

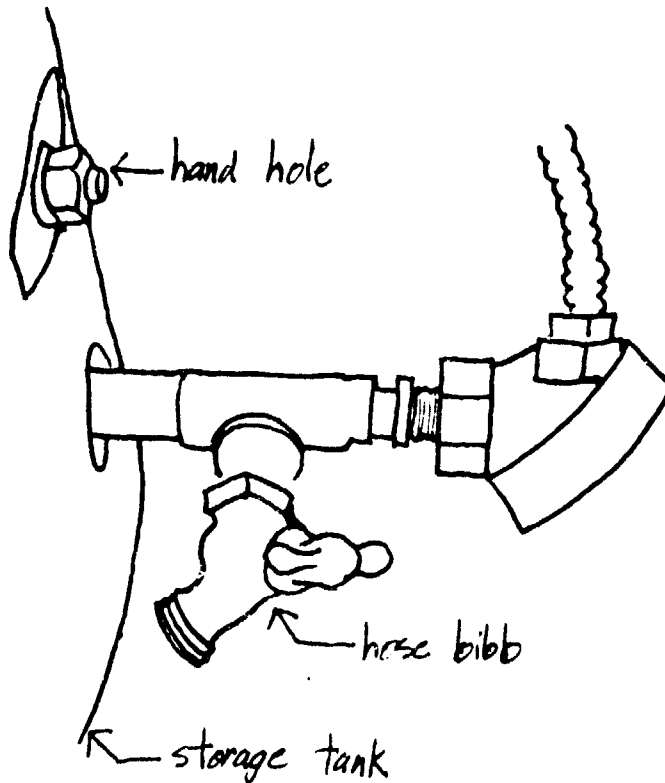


balancing valve located on the inside of each collector support structure

fig. 6 storage tank connections



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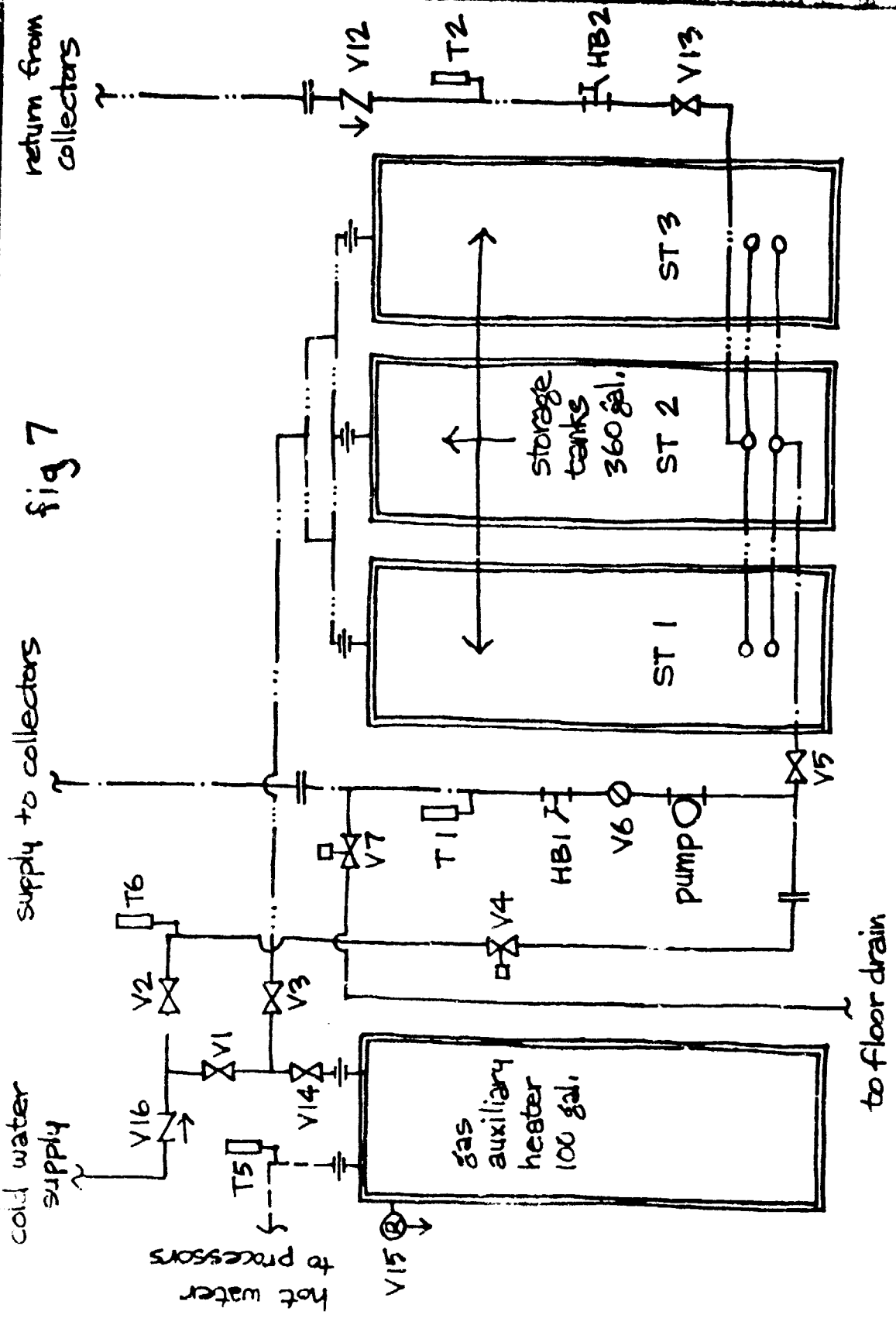


fig 7

fig. 8. roof plan

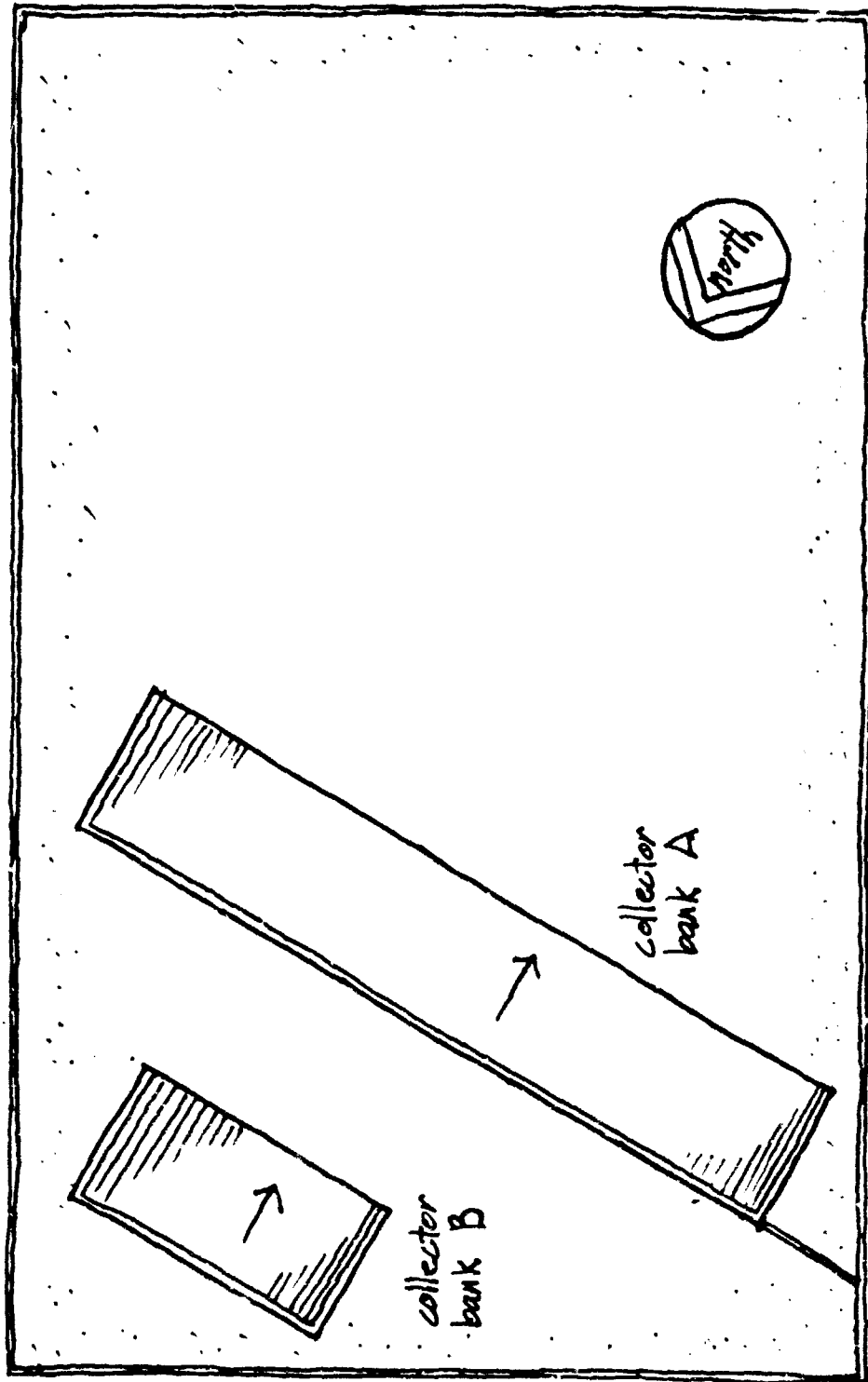
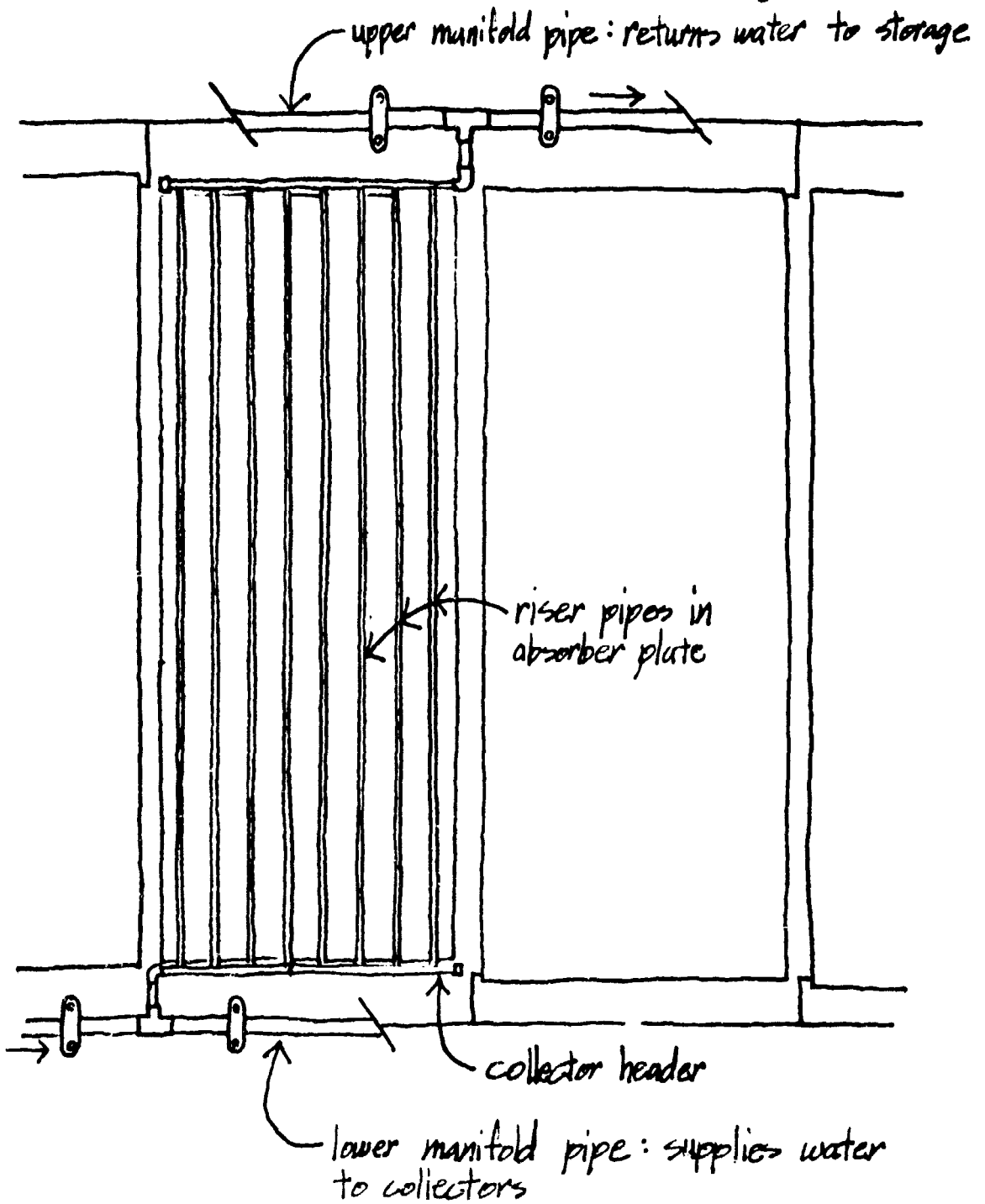
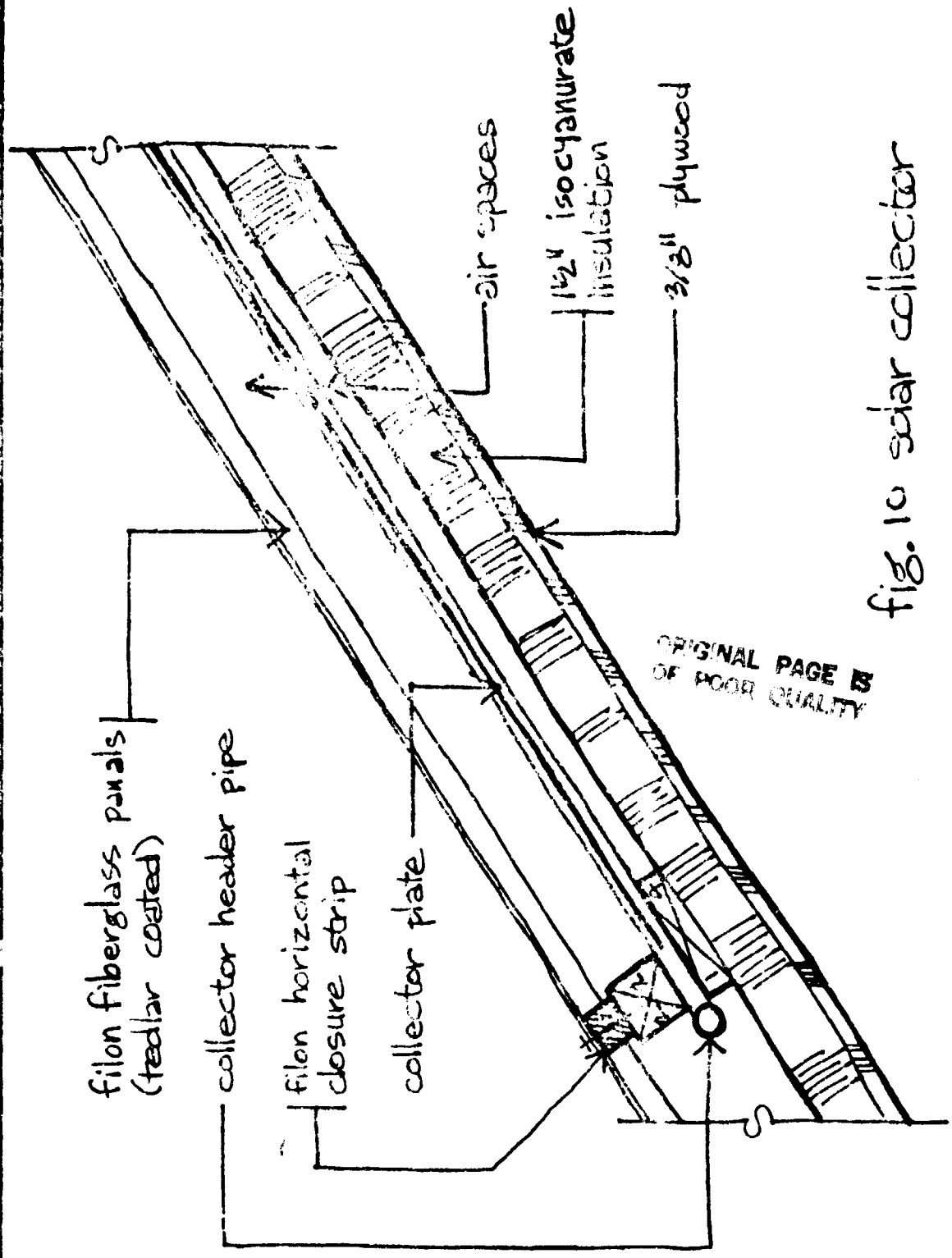


fig. 9 collector manifolding





filon fiberglass panels
(tedlar coated)

collector header pipe

filon horizontal
closure strip

collector plate

air spaces

1 1/2" isocyanurate
insulation

3/8" plywood

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fig. 10 solar collector

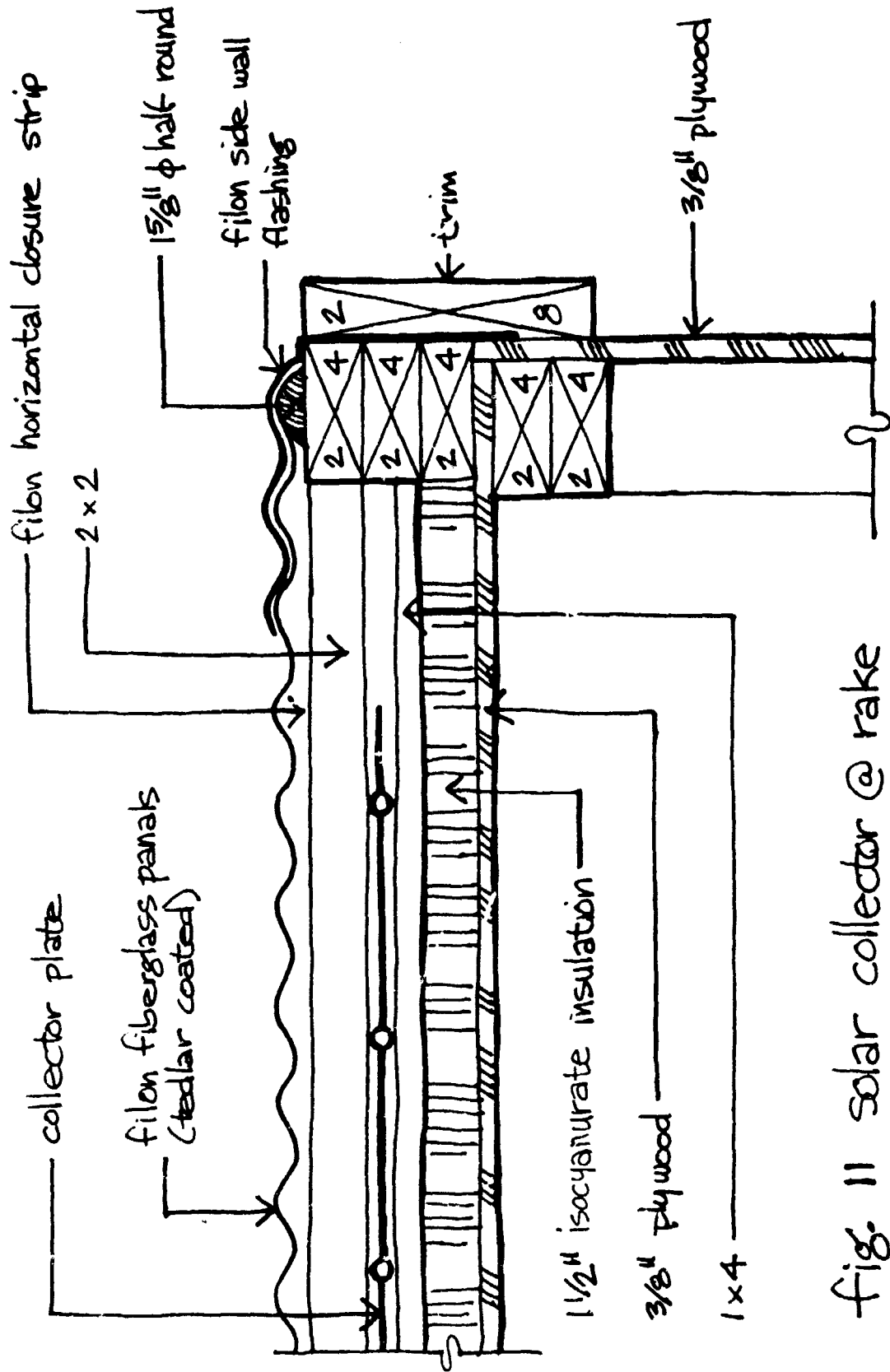
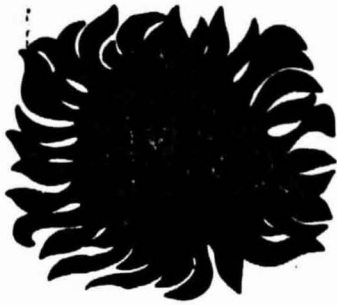


fig. 11 solar collector @ rake

COMPONENT SPECIFICATIONS

<u>Components</u>	<u>Manufacturer</u>
Solar collector absorber plate (Collector Bank A)	Surburst Solar Energy, Inc.
Solar collector absorber plate (Collector Bank B)	Solar Development, Inc.
Solar collector glazing	Filon, Division of Vistron Corp.
Solar collector insulation	U. S. Gypsum
Pump	March Manufacturing Co.
Differential temperature controllers	Helictrope General
Storage tanks	American Appliance Co.
Solenoid valves	Skinner Co.



SUNBURST

Solar Energy, Inc.

SOLAR ENERGY ABSORBER PANELS

METAL ABSORBER PLATE SPECIFICATION SHEET TEXT

Thinking about solar energy?

- ... If you've examined the options and penciled out the economics, you know that modular solar collectors – those boxed, glazed, "ready to connect" units – are expensive.
- ... You know that solar collectors aren't so "ready to connect". Properly insulated connective piping may cost as much as 20% above the price of the collectors; not to mention your labor costs!
- ... You're aware that modular, pre-boxed collectors limit your design options and are difficult to install aesthetically.
- ... And clearly, you don't want to pay the manufacturer's markup on the collector boxing and glazing.

Now there is a low cost, quality manufactured, high efficiency absorber panel available to you. The **SUNBURST SOLAR ENERGY ABSORBER PANEL**.



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The Sunburst Method

Sunburst Solar Energy Panels can be mounted in a unitary array. Several panels are easily headered together and boxed within a single surround. Glazing and framing is done by the installer on the jobsite. The expensive, insulated connection piping is no longer losing heat; the bare pipe painted black within the collector surround acts as additional absorber surface.

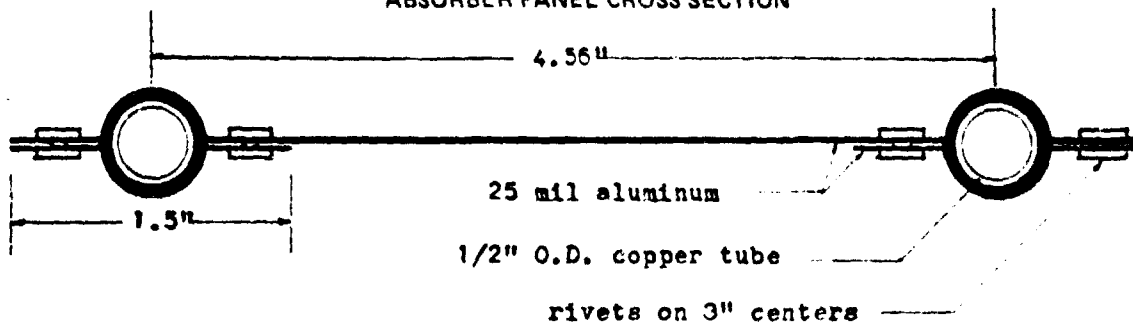
Such a cost-effective installation provides an attractive sales opportunity to your energy conscious client.

Technical Description

The Sunburst Solar Energy Absorber Panel is constructed of long life corrosion resistant copper tubing, clamped between sheets of 25 mil aluminum by a high pressure riveting system. All joints in the copper tubing are silver soldered and have a melting point of 1200°F. The flat black epoxy coating has been used for years as an exterior paint for jet aircraft.

Materials selection for this absorber panel has been based on long life and lowest cost per delivered BTU.

ABSORBER PANEL CROSS SECTION



Applications

Domestic Water Heating

To provide the hot water for an average California family of 5 requires roughly 60 square feet of Sunburst Solar Energy Absorber Panels. They may be installed on a roof, garage, hillside or freestanding. By piping to a storage tank in series with your existing water heater, considerable energy is saved with no danger of insufficient hot water.

Space Heating

The demand for near total energy self-sufficiency is increasing. Solar space heating cuts utility bills up to 80%. Individualized plans are available to aid in the design of your solar project.

Swimming Pool Heating

One of the most attractive uses of Sunburst Solar Energy Absorber Panels is for pool heating. Rising natural gas costs and unavailability of new hookups make solar heating the best available option. The existing pool filtration pump and piping are generally usable for a Sunburst installation. With a single glazing, the Sunburst Panels will provide steady heat year round. Performance is not as subject to ambient weather conditions as are unglazed systems.

* Understanding the subject of solar collector efficiency requires more information than is generally presented. The temperature differential between the incoming water and the collector surface is the "force" by which heat is drawn into the water.

Collector efficiency is defined as
$$\frac{Q_{col}}{Q_{sol}} = \frac{(T_{out} - T_{in}) \times R}{Q_{sol}}$$

where Q_{col} is the heat output of the solar collector (BTU/hour)

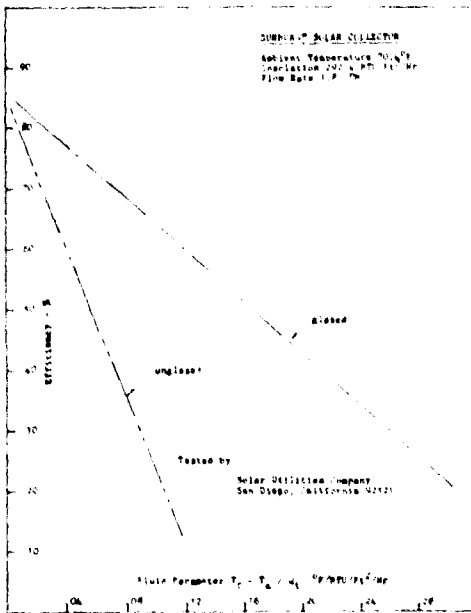
Q_{sol} is the heat available from the sun (BTU/hour)

T_{out} is the temperature of the water leaving the collector ($^{\circ}F$)

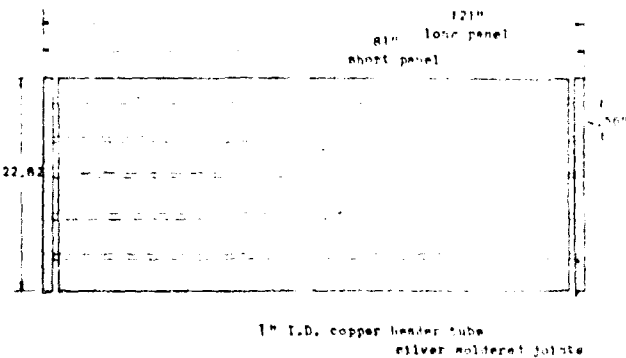
T_{in} is the temperature of the water entering the collector ($^{\circ}F$)

R is the water flow rate (Lbs./hour = GPM \times 60 \times 8.3)

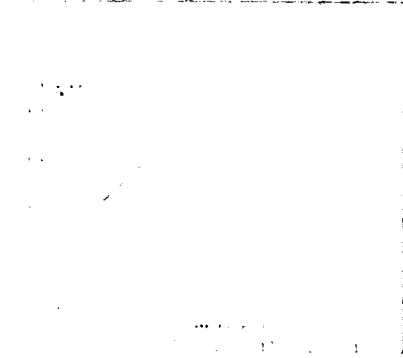
SUNBURST SOLAR COLLECTOR



ABSORBER PANEL DIMENSIONAL DATA



SUNBURST SOLAR COLLECTOR

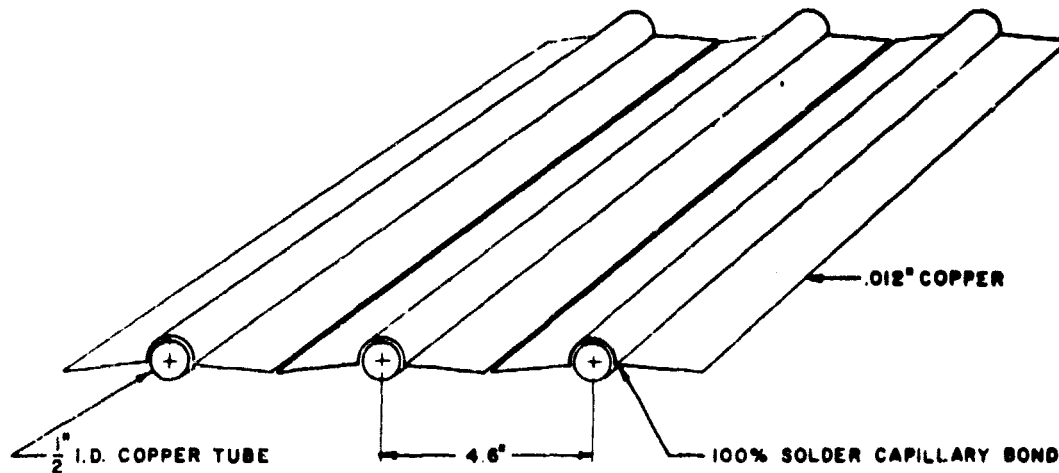


Collector efficiency is also a function of the outside ambient temperature (T_{amb}). A performance curve representing collector efficiency vs. the parameter $\frac{T_{out} - T_{in}}{T_{in} - T_{amb}}$ shows true collector performance and allows comparison of collectors regardless of size, materials, water temperature or test location.

** Wind conditions significantly affect the performance of an unglazed solar collector.

SDI

ALL COPPER SOLAR ABSORBER PLATE



SDI copper absorber plates are normally manufactured in the following configurations:

- 4' x 10' sinusoidal (45 lbs.)
- 4' x 10' parallel with 1/2" headers
- 4' x 10' parallel with 3/4" headers
- 4' x 10' parallel with 1" headers

Other lengths (under 10 ft.) and widths are readily available on special order. Plates are normally supplied unpainted but can be provided with a high quality flat black paint.

SHERWIN WILLIAMS P2140 SUPER COMBO PRIMER

ADVANTAGES

- time proven design
- excellent heat transfer
- low cost
- no thermal warping or stress concentrations;
- plate/tube design not subject to low cycle fatigue failure.

SOLAR DEVELOPMENT, INC.
4180 Westroads Drive
West Palm Beach, Florida 33407
(305) 842-8835

TECHNICAL SERVICES DEPARTMENT • 12333 SO. VAN NESS AVENUE • HAWTHORNE, CALIFORNIA 90250

Solar Energy Bulletin

The following general information and data is presented in response to the many inquiries we have received relating to the use of Filon® Fiberglass Reinforced Panels (FRP) in solar collectors. The attached solar data is based on preliminary tests conducted by Filon and independent laboratories. Additional tests are presently under way. Others are planned to provide more complete and specific information on Filon panels and their useful function as covers for solar collectors. As this information is documented, additional bulletins will be issued.

Justification for the use of Filon panels as covers for flat plate collectors is extremely strong even though a complete and thorough investigation of the use of FRP for this application has not been completed.

Filon panels are manufactured with acrylic fortified polyester resin reinforced with fiberglass. All Filon panels contain UV absorbers to reduce color degradation. Two types of Filon panels are suggested for solar applications. The first has a protective film of DuPont's polyvinyl fluoride Tedlar® on one surface. This gives added U.V. protection plus protection from surface degradation. Tedlar is virtually impervious to erosive and corrosive atmospheric conditions. The second product suggested for covers has Filon's exclusive Filoplated® surface on one side. The Filoplated surface protects against degradation in much the same manner as Tedlar through use of an acrylic modified gel coat. Standard Filon panels are not recommended for long-term efficiency due to the lack of a protective surface.

SPECTRAL

Comparative spectral transmittance graphs for various weights of Filon panels and types of glass are included with this report. This data was compiled by E.I. DuPont Laboratories. Additional spectrophotometer data provided by Pittsburgh Plate Glass Laboratories is also included for comparison purposes. All panel data presented is for the Tedlar-coated quality. Test data on Filoplated and standard types of panels will be available at a later date.

Solar energy transmission of Filon panels in the ultraviolet portion of the spectrum is very low, as indicated by the data. Based on the following academically accepted information, this should not significantly effect the performance of a collector. The percentage of U.V. radiation reaching the earth's surface is gener-

2.

ally less than 7% of the total useful solar energy (0.2 microns to 25.0 microns). The portion of the solar energy received on the ground and effective in solar applications is substantially in the range of 0.29 microns to 3.0 microns.

The following tables give the percent transmission and reflectance in the U.V., visible, and infrared portions of the spectrum for various Tedlar-clad Filon panels. A comparison is also made with clear float glass:

RADIANT ENERGY TRANSMITTANCE

Flat panels Type 748 (approx. 4 oz. psf); Type 558 (approx. 5 oz. psf); Type 568 (approx. 6 oz. psf); Clear Float Glass (approx. 2.45 lbs psf/.188" thick)

<u>Type</u>	<u>U.V.</u>	<u>Visible</u>	<u>Infrared</u>	<u>Total Solar Energy</u>
558	9.4%	89.2%	86.4%	86.2%
568	7.4%	88.7%	85.5%	85.5%
*748	14.0%	86.7%	86.6%	85.3%
Glass	74.0%	89.0%	73.0%	81.0%

RADIANT ENERGY REFLECTANCE

Flat panels Type 748 (approx. 4 oz. psf); Type 558 (approx. 5 oz. psf); Type 568 (approx. 6 oz. psf)

<u>Type</u>	<u>U.V.</u>	<u>Visible</u>	<u>Infrared</u>	<u>Total Solar Energy</u>
558	5.4%	7.6%	6.8%	7.3%
568	5.4%	7.9%	6.0%	7.0%
*748	5.7%	8.4%	7.1%	7.8%

*(Type 748 had one year outdoor weathering exposure prior to test).

Above tests conducted by PPG Industries. Data taken from IBM 526 Datex, Beckman DK2A.

SOLAR and DIFFUSE TRANSMISSION

3.

<u>Filon</u>	<u>Weight</u>	<u>Solar Energy¹ Transmission</u>	<u>Diffuse Light² Transmission</u>
Type 388 Flat	approx. 8 oz. psf	82%	93%
Type 608 Flat	approx. 10 oz. psf	77%	92%
Type 546 2½" corr.	approx. 4 oz. psf	78%	90%
Type 548 2½" corr.	approx. 4 oz. psf	84%	95%
Type 558 2½" corr.	approx. 5 oz. psf	76%	95%

Glass

Single Strength	approx. 1.22 lbs psf	86%	96%
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¹ASTM #E-424 (B)
Desert Sunshine Exposure Tests, Inc.

²ASTM #D-1494
Filon Research Laboratory

HEAT DISTORTION

The heat distortion temperature of Filon panels (ASTM D648) is approximately 220°F @ 264 psi and 319°F @ 66 psi. Therefore, Filon panels should remain structurally sound when used as covers on most flat plate collectors. Prolonged exposure at elevated temperatures in excess of those indicated above will cause some discoloration of the panels and possibly some gradual deformation; however, Filon panels will not collapse.

OPEN AQUEOUS COLLECTORS

Filon panels are not currently recommended as covers for collectors having direct exposure to aqueous fluids. Under these conditions, the panels can develop internal blooming, a condition brought about by absorption of moisture which weakens the glass-resin bond in the panels. The result is a reduction in light transmission and ultimately a weakening of the panel structure. It may be possible to use FRP in this type of application when a non-aqueous fluid is used. To the best of our knowledge, specific data is not available relative to the use of other fluids, and their long-term effect on FRP. However, tests are being conducted on various commercially available products.

FASTENING

Filon FRP, aluminum and steel have similar thermal expansion coefficients. This allows Filon panels to be fastened directly to these materials when proper preparations are made. Due to short lengths normally involved in solar collec-

4.

tors any difference in expansion coefficients can be accommodated by pre-drilling fastener holes $1/32'' - 3/64''$ larger than the diameter of the fastener. Fasteners should be $1/2''$ to $1''$ from the panel edge and approximately $6'' - 8''$ apart. Filon panels predrilled as above may be nailed directly to wood frames using aluminum spiral shank nails.

Silicone adhesives provide an excellent bond to Filon panel surfaces and may prove to be a satisfactory alternate for mechanical fastening techniques. In addition to the silicones several other adhesives have been evaluated for their bonding strength and found to be very effective; however, their use in solar applications has not been evaluated. If additional information is desired for these products, we suggest contacting one of the following manufacturers or a local adhesives distributor:

- A. Dymax - #830 w/#530 primer - Conap Inc., Div. of M.P.B. Corp.,
1405 Buffalo Street, Olean, NY 14760.
Product not recommended for continuous use at temperatures above 260° F.
- B. Versilok - #506 w/#4 primer - Hughson Chemicals, Div. of Lord Co.,
Erie, PA 16512.
Product will perform continuously at elevated temperatures up to 250° F.

CHEMICAL RESISTANCE

Filon FRP products are extremely stable, have high resistance to most chemicals and acids normally found in industrial atmospheres and may be used in the presence of hydrocarbons, alcohols, peroxides, carbonates, and diluted halogens. For specific recommendations in high corrosion atmospheres, consult Technical Services Department.

HAIL

Generally, hail only causes cosmetic damage. Under the impact of most hail stones, a small clouding or "starring" area will appear. This is an internal fracture of the glass fibers and will not significantly reduce light transmission values.

MAINTENANCE RECOMMENDATIONS

Super-smooth surfaces are usually washed clean by rain. During dry periods, hose or wash to remove accumulated dirt.

LOAD and DEFLECTION DATA

Filon panels are unusually resilient and will take deflections well beyond those that would crack glass or deform metal. Filon panels will snap back without damage when the load is removed.

In order to keep load-carrying capacity at a maximum, use a minimum number of fasteners at the mid-span support. Under wind and snow loads, the panel is under its greatest stress at this point. Excess fastening simply perforates and weakens the panel at the maximum stress point (see figure 1). Load-bearing capacity varies with panel configuration and gauge (see figures 2, 3, & 4).

Fig. 1 Effect of fastener frequency

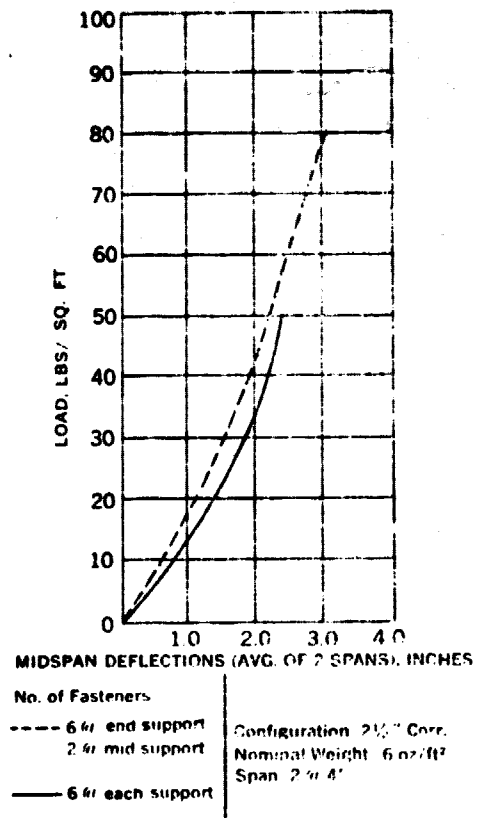


Fig. 2 Effect of panel gauge

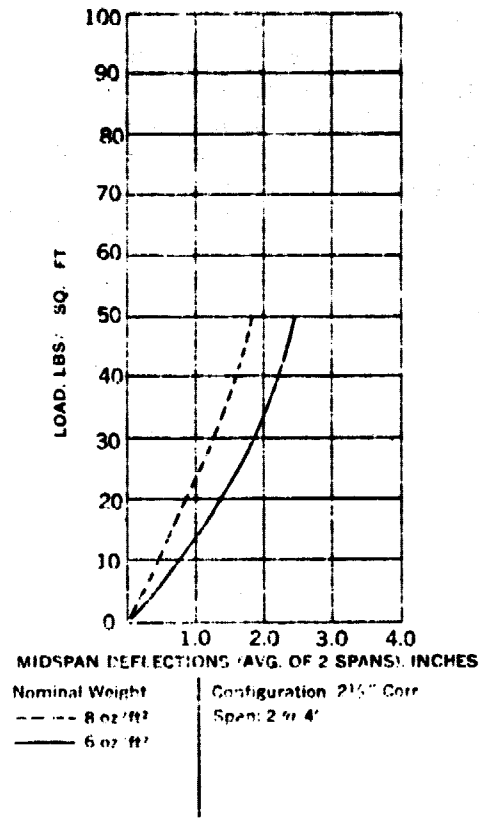


Fig. 3

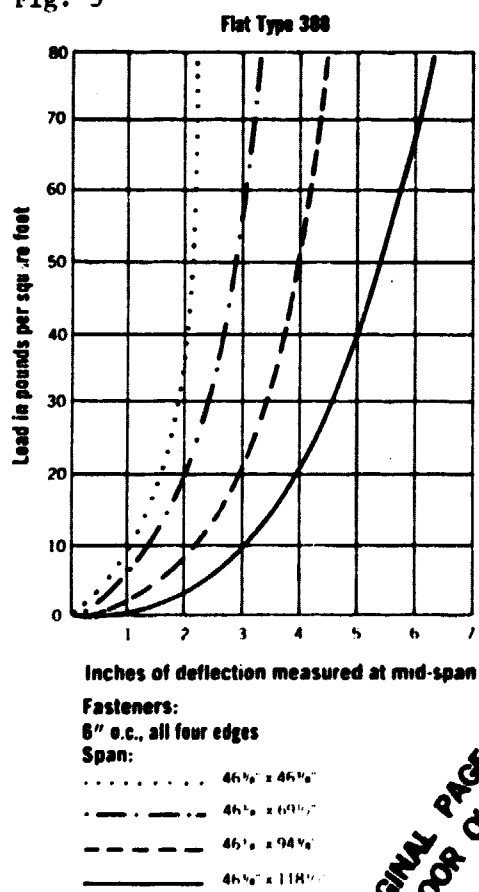
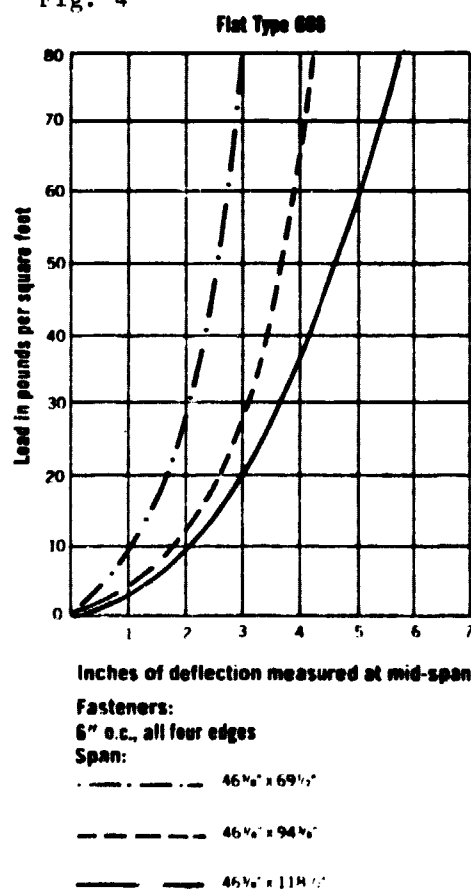


Fig. 4



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WIND LOADS

For wind resistance, a 4' x 8' collector cover should have one cross support in the center. The panel should be fastened to the center cross support 15" - 18" o.c. to prevent rattles. This cross support will normally prevent the panel from touching the black body under heavy wind loads. Flat Filon Type 388 fastened as indicated above (2-46 3/8" x 46 3/8" spans) will support, in a horizontal position, a load of 10 lbs. per square foot with a one-inch deflection at midpoint of each span. (S.P.I. load and deflection test). This 10 lb. load may be translated into a wind load of approximately 55 mph based on the following formula:

$$* MPH = \sqrt{(300.3) (X)} \quad (\text{Where, } X = \text{Load in lbs. psf})$$

The most severe wind load would be on a vertical installation. Therefore, wind loads calculated for this condition should be safe for other angles. For vertical Filon panels installations, to calculate the uniform load on the panels in lbs. per square foot, given the wind velocity in miles per hour, the following formula may be used:

$$* X = \frac{(MPH)^2}{300.3} \quad (X \text{ represents load in lbs. psf})$$

*The formulas presented above are for estimating only. Wind loads must take into consideration many factors including height, shape and size of application, as well as the angles of installation, and other design criteria. Proper engineering sources, as well as building code requirements, should be consulted in order to develop specific design data.

APPROVALS

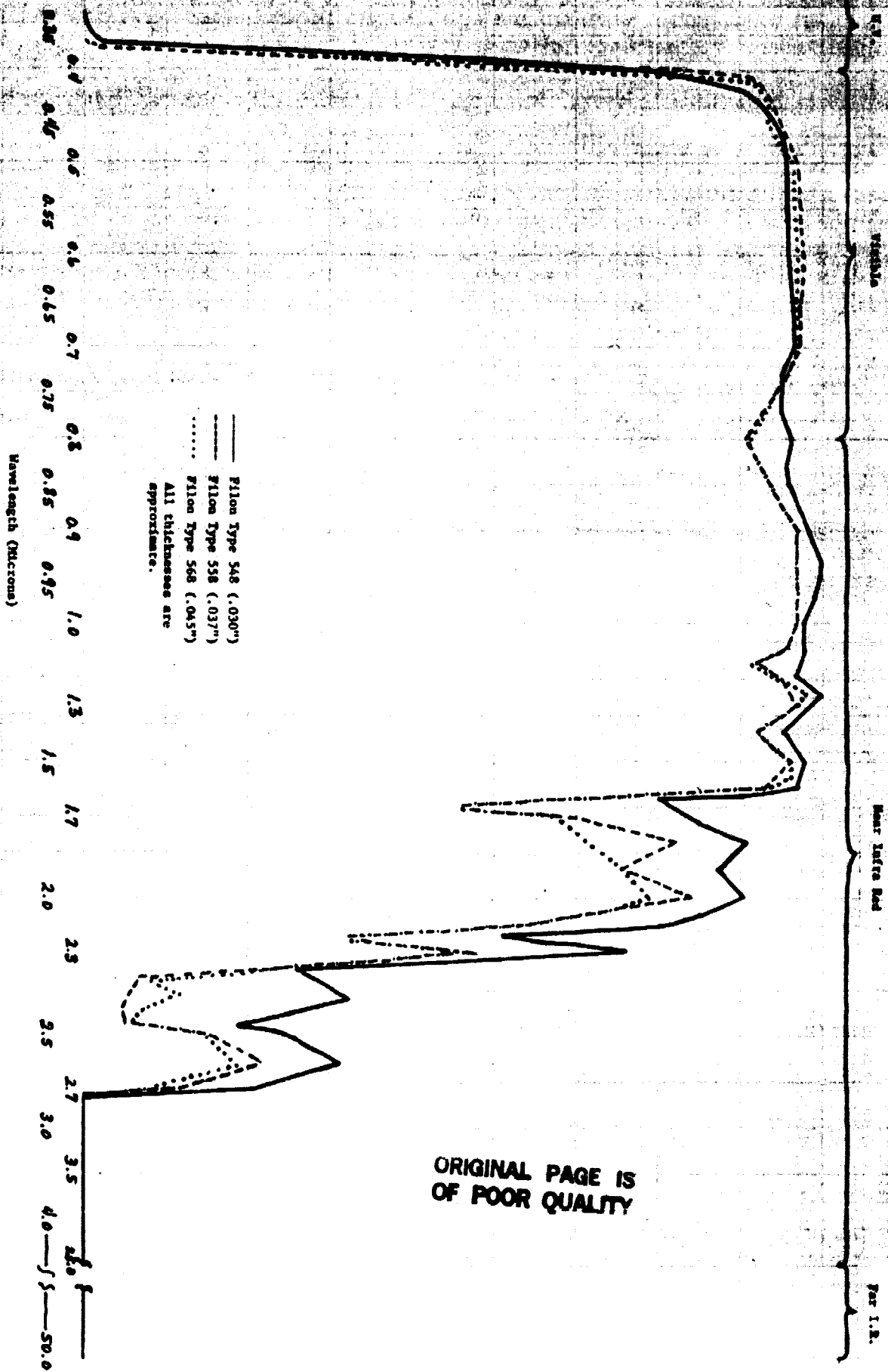
Product Standard: Filon panels exceed applicable specifications of U.S. Dept. of Commerce National Bureau of Standards Product Standard, "Glass-Fiber Reinforced Polyester Structural Plastic Panels," PS 53-72.

Code Approvals: Filon panels meet requirements of the major model building codes and most state, county and municipal building departments, as well as fire underwriters.

Federal Specifications: Filon panels meet Military and Federal Specifications for "Plastic Panels, Corrugated, Translucent, Glazing" (L-P-505C GSA-FSS). Refer to Federal Supply Number 9330-282-8332.

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For information on FILON solar panels, physical properties, contact
FILON, Hawthorne, California 90250.**

Transmittance (Percent)



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Near Infra Red

Visible

U.V.

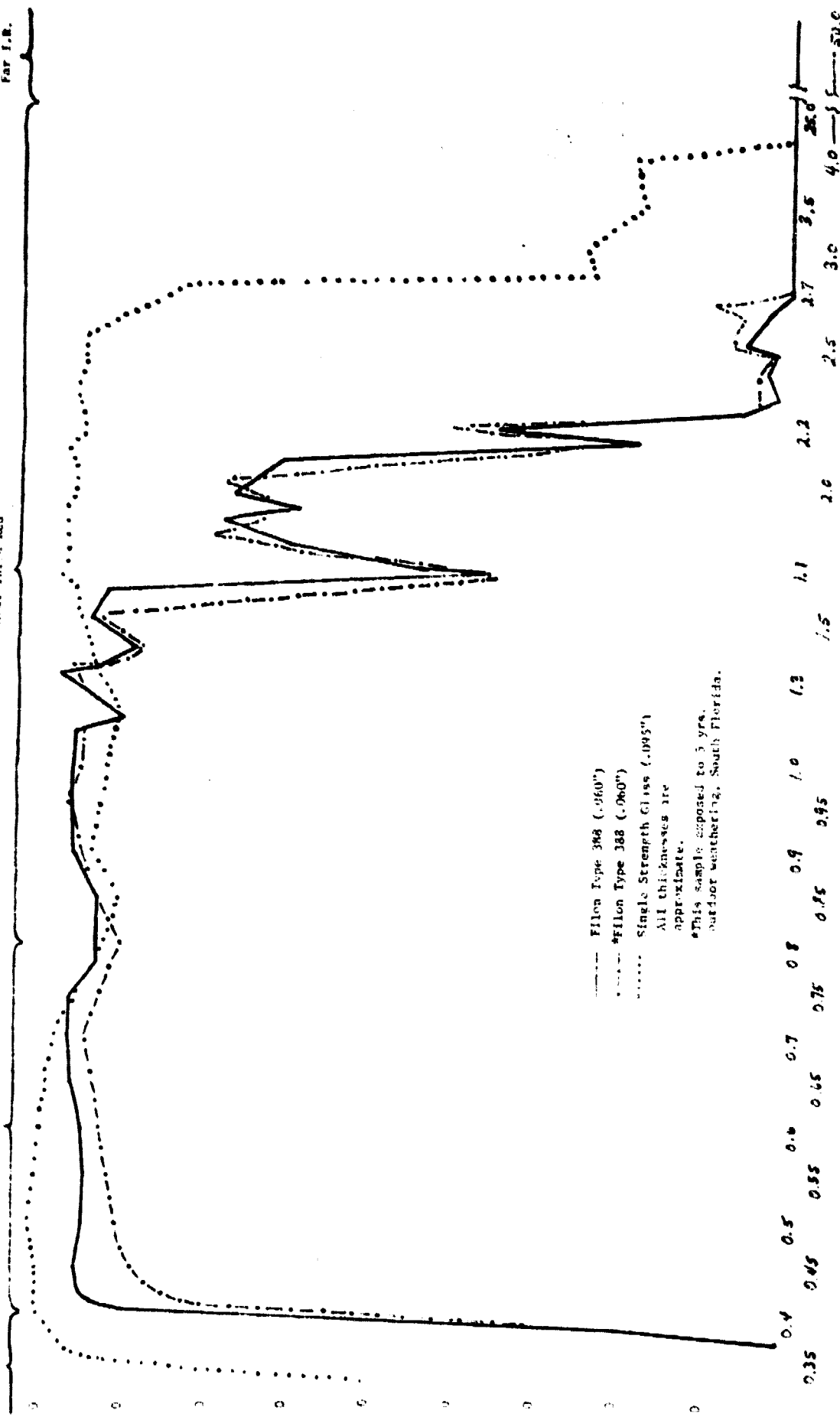
Transmittance (Percent)

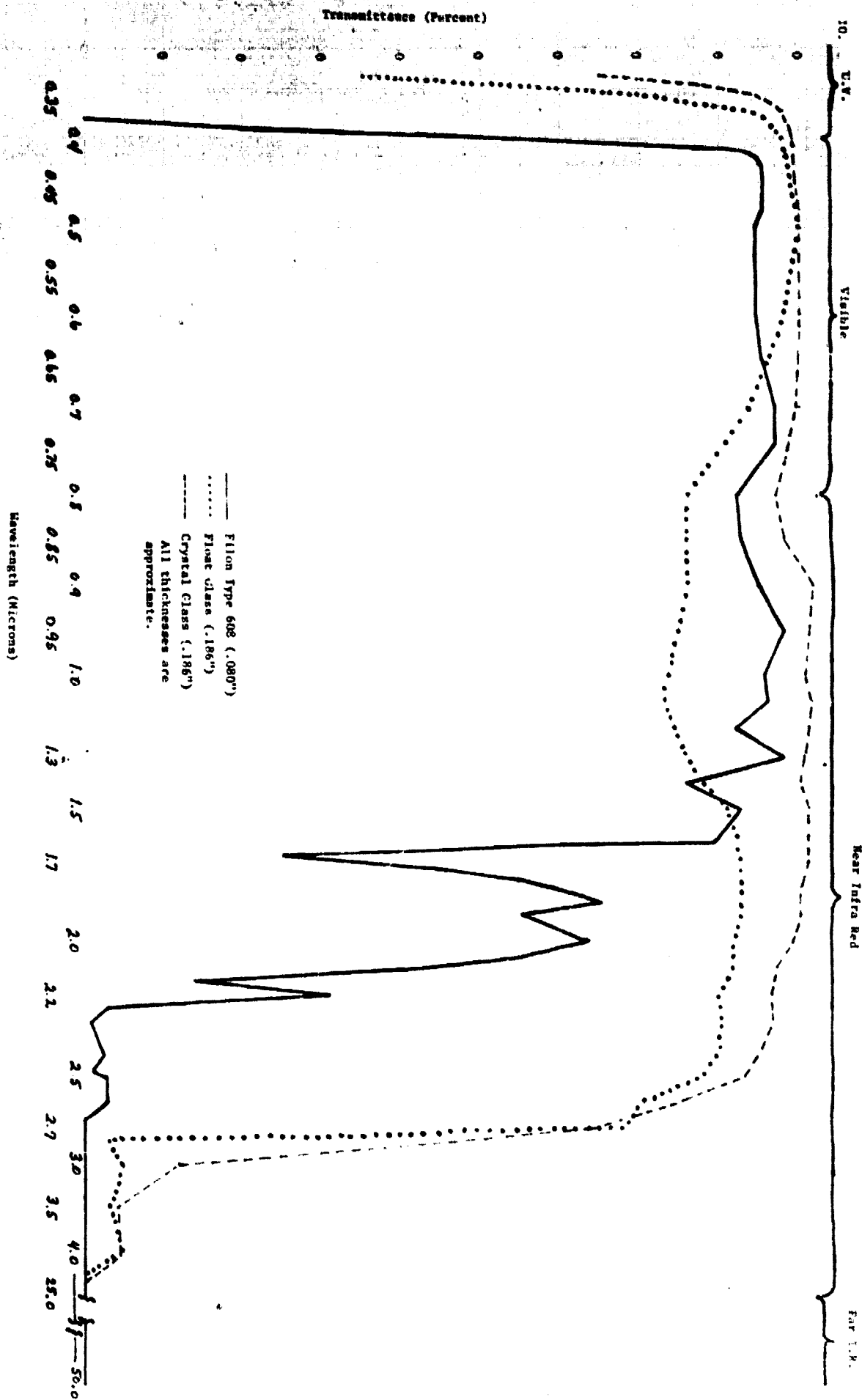
100

- Filon Type 388 (.060")
- - - Filon Type 388 (.060")
- Single Strength Glass (.095")
- All thicknesses are approximate.
- *This sample exposed to 3 yrs. outdoor weathering, South Florida.

0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 1.0 1.2 1.5 2.2 2.5 2.7 3.0 3.5 4.0 50.0

Wavelength (Microns)





Twelve (12) pages have been deleted because of copyright information. For information on FILON solar products, accessories, "How to Design with Daylight" and sales offices, contact FILON, Hawthorne, California 90250.

MARCH

HOT
WATER

CIRCULATORS

featuring

Exclusive

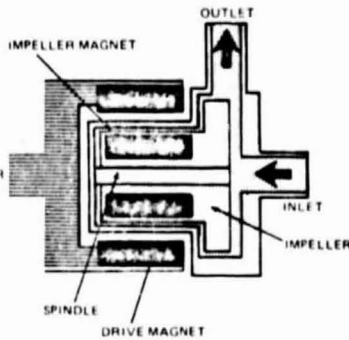
Magnetic Drive

March Circulators are designed for closed and open boiler or domestic hot water systems, and as replacements for hydronic zone valves. Eight models with three capacities are offered. Bronze head pumps are recommended for open systems to resist rust and foreign deposit build-up. Cast iron volutes should be used only on closed circuits where the water is circulated constantly and mineral deposits are minimized.

March's proven magnetic drive eliminates the troublesome, old-fashioned shaft seal. There can be no seal wear, power-robbing friction or leakage thru the seal. Impeller and drive magnets are permanent ceramic type. They prevent slippage and insure that full motor horsepower is converted into pumping power.

Energy requirements are lowered as all the energy produced by the motor is utilized, especially important in solar energy systems. Seal-less drive also provides for faster, easier motor service, as the motor can be removed without draining, refilling and reheating the system.

March circulators are easily installed, either vertically or horizontally, with a choice of standard flanges on the 821 series. Whisper-quiet operation is assured by micro-balanced motor fan and dynamically balanced magnets. Just two more reasons why March should be your first choice for most every application!



SERIES 809

The compact, bronze head Model 809 is ideal for domestic and commercial loops, providing instantaneous hot water at every outlet. Compared with standard circulators, the 3 gpm 809 is smaller, lighter and more economical to buy and operate.

Model 809 HS

3500 RPM model for almost twice the capacity and nearly three times the head.

Model 809 -24

24 volt version to replace troublesome hydronic zone valves. Eliminates the need for a main boiler circulator.



SERIES 821

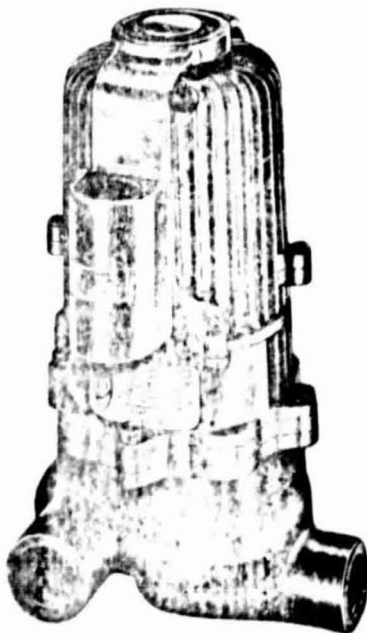
Model 821 is a high capacity, 22 gpm, cast iron circulator for closed systems not requiring bronze construction. The March design drastically reduces weight and bulk and costs less than conventional circulators. Common flange sizes of 3/4", 1", 1 1/4", and 1 1/2" plus a standard 6 3/8" flange to flange dimension makes the 821 a perfect replacement pump.

Model 821-BR

Same as above except for bronze pump head and flanges. The right one for domestic hot water systems.

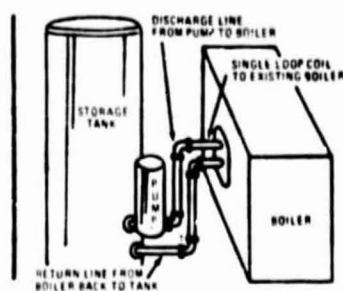
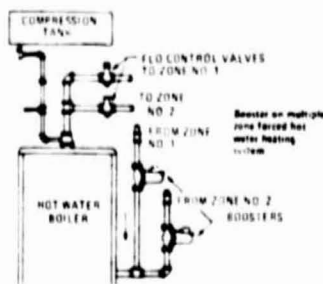
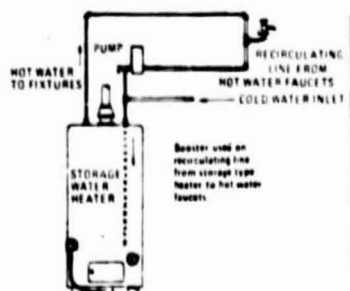
Model 821-VBR

Vertical mount bronze unit ideal for hot water heaters and aquastat boosters. 3/4" FPT inlet and outlet are 90° apart and in a horizontal plane, permitting fast and easy corner installation.



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TYPICAL INSTALLATIONS



SPECIFICATIONS

Model	Max. Flow	Max. Head	Max. PSI	Inlet & Outlet	Motor							Pack Wt.
					HP	RPM	Volts	Hertz	Phase	Watts	Amps.	
809 809 24	3 gpm	4.1'	1.8	1/2" MPT	1/100	1750	115 24	60	Single	30	.3 1.5	4.5 lbs.
809HS	5.3 gpm	11.6'	5.0	1/2" MPT	1/25	3500	115 or 230	60	Single	80	1.2 or .6	8.0 lbs.
821 821-BR 869	22 gpm	8.5'	3.4	3/4", 1", 1 1/4", 1 1/2" Flanges	1/20	1600	115 or 230	60	Single	110	1.8	11 lbs.
821-VBR 869-V	22 gpm	8.5'	3.4	threaded 3/4" FPT	1/20	1600	115 or 230	60	Single	110	1.8	11 lbs.

* On flanged models, please specify flange size desired.

** Continuous duty motor, thermal overload protected. 230 volt and ball bearing motors available—consult factory.

*** Pumping room temperature water.

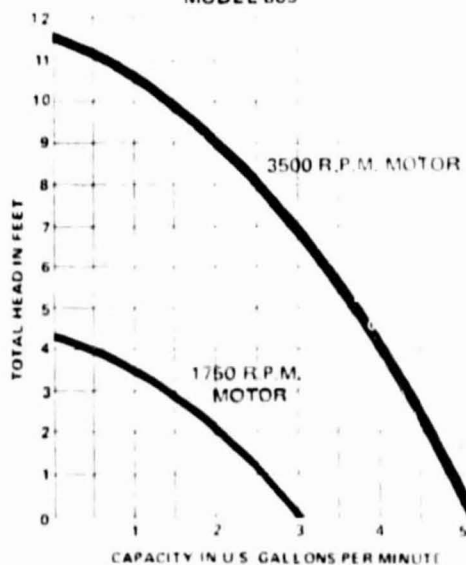
MODEL 869

HOT OIL CIRCULATORS

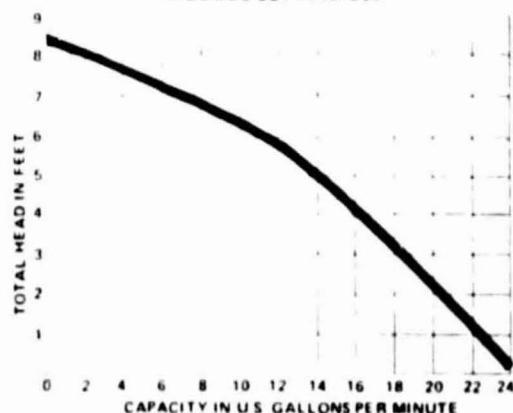
Applications include french-fry cookers, hot oil filters, and all high-temperature locations. Cast iron body with porcelain ceramic spindle, nylon impeller and teflon gaskets are all quality components designed for continuous oil circulation to 400°F. Motor protected by a thick heat shield and further cooled by dual motor fans.

MODEL 869-V
As above except vertical mount.

MODEL 809



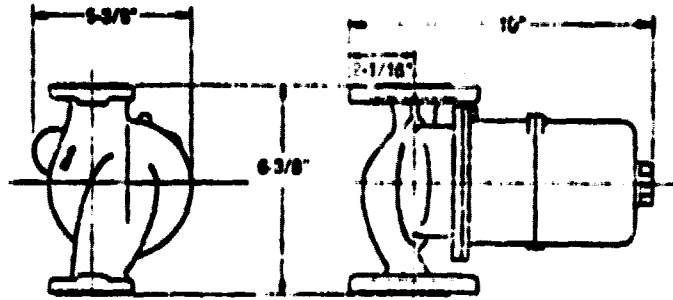
MODELS 821 AND 869



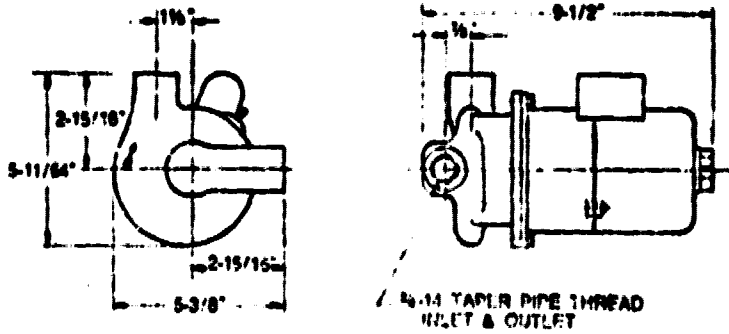
PERFORMANCE RATINGS

DIMENSIONS

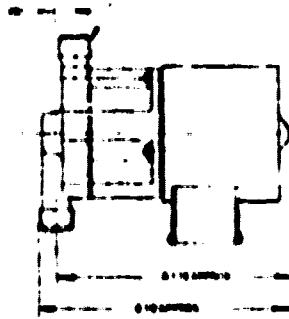
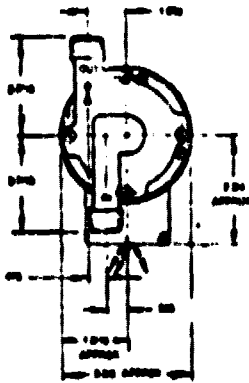
MODELS
821
800



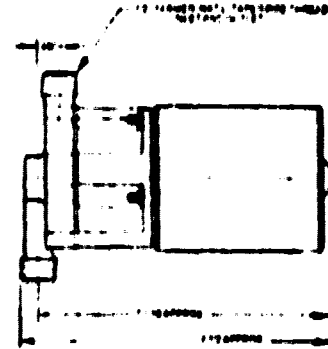
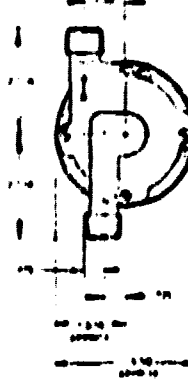
MODELS
821 VBR
800 V



MODEL 809 and 809-24



MODEL 809HS



LIMITED WARRANTY

March pumps are guaranteed only against defects in workmanship or materials for a period of one year from date of manufacture. Warranty will be extended up to one year from date of purchase, providing the warranty card is returned to the factory within 10 days of purchase date. Liability in all events is limited to the purchase price paid and is limited to replacing or repairing any pump or parts which are defective in materials or workmanship. All warranty pumps must be returned to our factory, shipping costs prepaid. This guarantee shall not be effective if the pump has been subjected to misuse, negligence, or if the electric cords have been cut off. This guarantee pertains only to pumps used to pump water. For all other solutions contact the factory for prior written approval before pump is installed.



MARCH

MANUFACTURING CO., INC.

OFFICES IN PRINCIPAL CITIES

1819 PICKWICK AVENUE
GLENVIEW, ILLINOIS 60025
(312) 729-5300 TELEX 72-4378

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MARCH

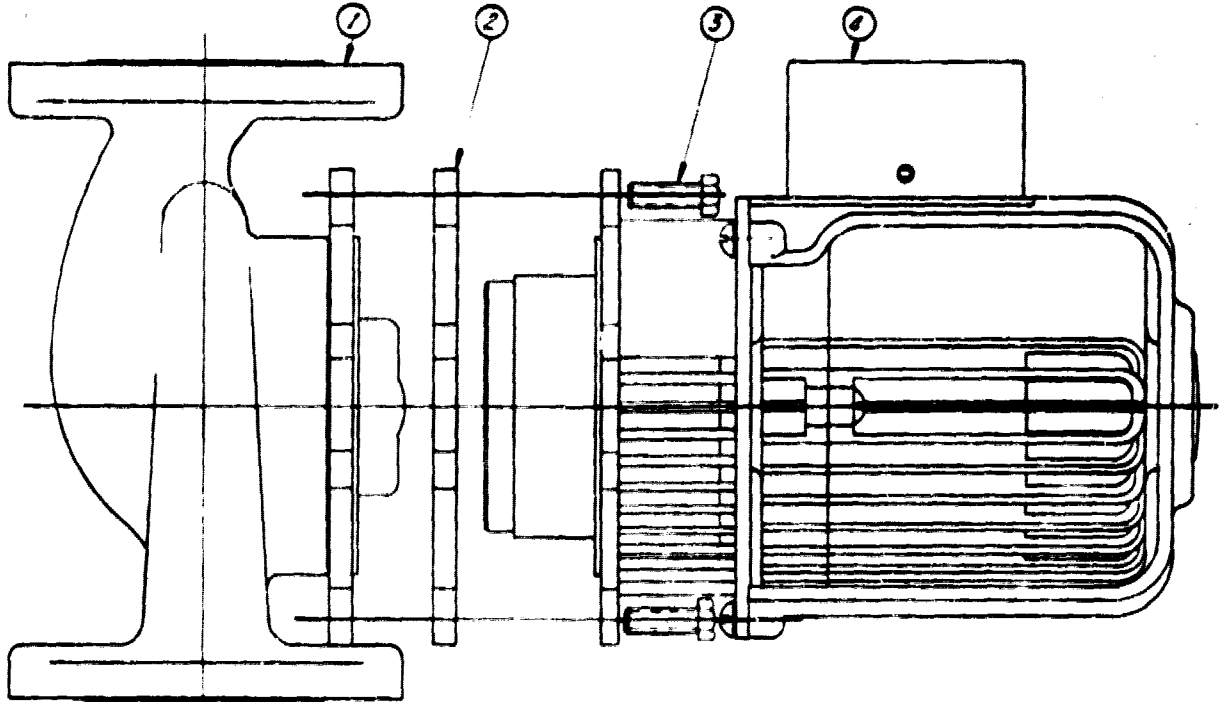
MODEL 821 PUMP INSTALLATION INSTRUCTION, SERVICE & REPAIR PARTS

The Model 821 Pump is assembled and ready for installation. The Pump should be mounted with the Electrical Conduit Box (item 4) on the top and the pump in a horizontal position. The oil ports will then be on top. The motor should be oiled upon installation and at least once a year thereafter. The Pump Volute (item 1) may be rotated at random in any one of 4 positions if desired. Remove the 4 screws (item 3) and rotate the Volute with respect to the Motor Assembly (item 4) then re-assemble the screws. The Pump may be operated with the Volute down and the motor vertical without any problems. If you wish to operate the Pump with the Volute up and the motor vertically down you must con-

tact the factory for instructions.

The Pump Volute has flange connections with 6-5/16 inches between flange faces. Volutes also available with 1/2-14 internal pipe threads in place of flange connections. The motor is 115 volt, 60 cycle, 1 Phase, A.C., 1.8 amp, 110 Watts, thermal overload protected, and is U.L. Yellow Card Listed.

The flange gaskets and screws and nuts are packed with each pump. The flanges come packed separate and customer must specify the size required i.e. 3/4", 1", 1 1/4" or 1 1/2" size.



(A) TO REMOVE MOTOR ASSEMBLY

The model 821 Pump is made up of 2 basic subassemblies. They are the Pump Volute and Impeller Assembly (item 1); and the Drive Magnet, Fan, Motor, Conduit Box Assembly (item 4). To separate the 2 assemblies, simply remove 4 hex head screws (item 3). The Pump will then separate into the 2 assemblies plus the Heat Shield (item 2) which is the glass filled plastic disk between the two assemblies.

If the motor has failed, the motor assembly can be removed from the Pump Volute without having to drain the water out of the system. The Pump Volute flange connections do not have to be removed. The water cannot escape from the Volute unless the flange connections are loosened. Remove the 4 screws (item 3) as described above and simply slide the Motor Assembly (item 4) backwards. Replace the defective motor assembly with a new unit and re-attach to the Volute. Be sure the Heat Shield (item 2) is placed back between the 2 assemblies.

MARCH MANUFACTURING CO.
INCORPORATED



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AREA CODE • 312 PHONE: 729-5300

(B) TO REMOVE IMPELLER ASSEMBLY

If the motor assembly operates, but the pump does not push any water, the impeller assembly may be jammed or otherwise defective. Remove the Motor Assembly and the Heat Shield as in section A. Then remove the 4 flat head screws (item 11). A 5/32 Allen wrench is required. The water will now drain out of the system. The balance of the parts can then be removed by hand in the sequence as shown in the sketch. Check the Impeller-Magnet Assembly (item 7) and the Pump Volute (item 1) for any dirt or foreign particles. Check the busting inside the Impeller-Magnet Assembly for wear. Check the Shaft (item 6) for wear. Check the Housing Gasket (item 8) for cuts or flatness. If repair parts are needed, see Repair Parts Chart below. Re-assemble the pump and bleed air out of the system.



REPAIR PARTS			
ITEM	DESCRIPTION	PART NUMBER	QUANT.
1	Pump Volute, Flanged, Bronze	821-064-10	1
1	Pump Volute, Flanged, Cast Iron	821-025-10	1
1	Pump Volute, Threaded, Bronze	821-075-10	1
1	Pump Volute, Threaded, Cast Iron	821-010-10	1
2	Heat Shield	804-021-10	1
3	1/20 Hex. Hd. Screws	804-052-10	4
4	Drive Magnet & Motor Ass'y	821-014-01	1
5	Thrust Washer, Ceramic	821-079-10	1
6	Shaft	821-036-10	1
7	Impeller-Magnet Ass'y	821-023-02	1
8	Housing Gasket	804-050-10	1
9	Impeller Magnet Housing	821-035-01	1
10	Housing Connecting Ring	821-044-10	1
11	1/20 Flat Hd. Screws	804-051-10	4
12	Flange Rubber Gasket	804-057-10	2
13	Steel Flanges, 1/2", 1", 1 1/2", 1 3/4"	Specify Size	2
14	Bronze Flanges, 1/2", 1", 1 1/2", 1 3/4"	Specify Size	2
15	Drive Magnet Ass'y Only	821-037-01	1

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Mr. Plumber and Homeowner

PLEASE READ

Thank you for buying a March Hot Water Circulating Pump. I will work many years for you and for the home or apartment where I'm installed, but I need a little drink of oil once in awhile.

Approximately every 120 days, I need a few drops of oil in each of my two ports. Please use a 20 wt. non-detergent oil. I was last oiled when I left the factory on _____.

Maintenance Schedule:

--	--	--	--	--	--

Please hang me near the hot water heater.

CAUTION: DO NOT OVER OIL.

P.S. Please mail my warranty card to activate the warranty!

Pump Model _____ Serial No: _____

Date Purchased: _____ Purchased From: _____

Pump Application: _____

Solution _____

Type Concentration Pressure

Customer _____

Name Address

MARCH PUMP WARRANTY

March pumps are guaranteed only against defects in workmanship or materials for a period of one year from date of manufacture. Warranty will be extended up to one year from date of purchase, providing this warranty card is returned to the factory within 10 days of purchase date. Liability in all events is limited to the purchase price paid and is limited to replacing or repairing any pump or parts which are defective in materials or workmanship. All warranty pumps must be returned to our factory, shipping costs prepaid. This guarantee shall not be effective if the pump has been subjected to misuse, negligence, or if the electric cords have been cut off. This guarantee pertains only to pumps used to pump water. For all other solutions contact the factory for prior written approval, before pump is installed.

F-4109

DIFFERENTIAL TEMPERATURE THERMOSTAT

... for solar heating and
solar hot water system control

DELTA-T.

PATENT PENDING

DESCRIPTION

The DELTA-T™ Differential Temperature Thermostat is an automatic motor control which turns on and off the circulation pump/blower in a solar heating or solar hot water system when the collector temperature exceeds the storage temperature by preset differentials.

Also, in reverse, the DELTA-T™ may be utilized in solar nocturnal cooling systems to control summer night cold pick-up. By reversing the sensor locations (high temperature sensor at storage and low temperature sensor at cool exterior location), the pump or blower will go on when the exterior is colder than storage.

The DTT-90, 290 and 690 Series are designed to be hooked-up without the need to hire an electrician as they are equipped with a grounded power supply cord and a receptacle outlet in the box cover. The 690 series has two receptacles, one for the pump and one for the freeze protection valves.

A feature of the DTT-100 series is an AUTOMATIC OFF condition when the collector temperature is below 80°F. This feature prevents the pump turning on at night when a large amount of heat has been extracted from storage. — MODE 1

A circuit to turn the pump on during freezing temperatures is incorporated into the DTT-200 series. This feature prevents damage to the collector from freezing by circulating the warmer storage water. The pump turns on at 36°F and off when the collector is heated up to 37.5°F. — MODE 2

The DTT-400 series is designed with a high limit control of the storage temperature. When the storage tank is 160°F or higher, the pump will not run. By keeping the water temperature below 160°F, the fear of scalding is eliminated and a precautionary mixing/tempering valve is not needed. — MODE 4 (Other temperatures are available upon special order.)

For the Freeze-Fail-Safe™ system the DTT-690 series is available which incorporates a second 120V receptacle output to hold electric valves in position to allow water flow through system. (The motor control is also a receptacle outlet and the box is equipped with a 120V line cord input.) Upon power failure or freezing conditions, 42°F, the valve circuit turns off allowing the valves to return to their normal position which causes the collector to drain. The sensor for the Freeze-Fail-Safe™ system is a low voltage, hermetically sealed bi-metallic element designed for military/space applications under U.S. Government Spec. MIL-S-24236. — MODE 6

To add versatility and more accurate control of functions the DTT-70 and DTT-790 series offer an externally adjustable Turn-On Differential with a fixed Turn-Off of 1.5°F. Another adjustable model is the DTT-3410 series which incorporates an external adjustment for the High Limit, MODE 4, off temperature.

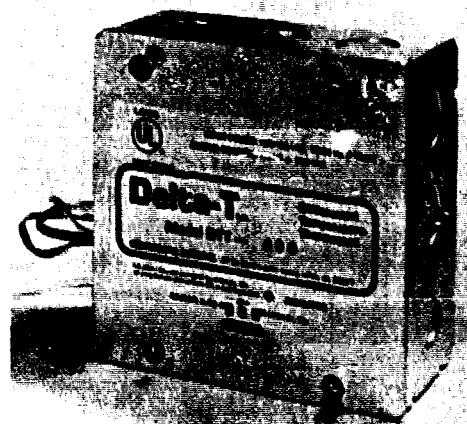
All models without receptacles have a bypass switch which allows the pump to be turned OFF or ON, bypassing the thermostat.

Construction is all solid state electronics except the UL Listed 10 Amp, 1/3 HP, 120V relay which is designed for 10 million mechanical cycles. 240V is also available.

All models are optionally available with a Normally Closed relay function by specifying "NC" after the part number.

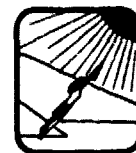
For applications requiring higher than 1/3 HP, or 24V AC output, compatible relays and transformers are shown on the reverse side.

An indicator light on the front plate of the DELTA-T shows when the temperature differentials are in an ON condition.



Enclosure is standard 4-11/16" by 4-11/16" UL Listed electrical outlet box (11.9mm x 11.9mm).

(over)



INSTALLATION

Installation is easily accomplished by running 115V to the box and from the box to the motor. Thermistor Ends for the sensor leads are furnished with the unit. The customer provides the interconnecting 18/2-lead wire which connects the low voltage DC sensor leads to the Thermistor Ends for which connectors are furnished. Hardware to attach Thermistor Ends to pipes, flat surfaces or curved surfaces is also furnished.

SPECIFICATIONS, PRICING

DIFFERENTIAL TEMPERATURE THERMOSTATS Output Control 1/2 HP @ 120 VAC (for higher HP use with R-120)

MODEL	ON differential @ 50°C		OFF differential @ 50°C		Electrical Hookup		Electrical Input		MODE 1 OFF Below 80°F	MODE 2 ON Below 36°F	MODE 4 OFF Above 160°F	MODE 6 Valve Recp. OFF Below 42°F	UL Listed	PRICE Includes Thermistor Ends	
	*F	*C	*F	*C	Thru box knockouts	Line Cord/ Cover Recp.	120VAC 50/60 Hz	12 VAC 12 VDC							
DTT-80	9.0	5.0	3.0	1.7	x		x						Yes	\$38.00	
DTT-81	4.5	2.5	1.5	0.8	x		x						Yes	38.00	
DTT-82	15.0	8.3	5.0	2.8	x		x						Yes	38.00	
DTT-83	15.0	8.3	1.5	0.8	x		x						Yes	38.00	
DTT-90	9.0	5.0	3.0	1.7		x	x						Pending	41.50	
DTT-91	4.5	2.5	1.5	0.8		x	x						Pending	41.50	
DTT-92	15.0	8.3	5.0	2.8		x	x						Pending	41.50	
DTT-93	15.0	8.3	1.5	0.8		x	x						Pending	41.50	
DTT-100	9.0	5.0	3.0	1.7	x		x		x				Yes	43.00	
DTT-101	4.5	2.5	1.5	0.8	x		x		x				Yes	43.00	
DTT-102	15.0	8.3	5.0	2.8	x		x		x				Yes	43.00	
DTT-103	15.0	8.3	1.5	0.8	x		x		x				Yes	43.00	
DTT-200	9.0	5.0	3.0	1.7	x		x			x			Yes	43.00	
DTT-201	4.5	2.5	1.5	0.8	x		x			x			Yes	43.00	
DTT-202	15.0	8.3	5.0	2.8	x		x			x			Yes	43.00	
DTT-203	15.0	8.3	1.5	0.8	x		x			x			Yes	43.00	
DTT-290	9.0	5.0	3.0	1.7		x	x			x			Pending	46.50	
DTT-291	4.5	2.5	1.5	0.8		x	x			x			Pending	46.50	
DTT-292	15.0	8.3	5.0	2.8		x	x			x			Pending	46.50	
DTT-293	15.0	8.3	1.5	0.8		x	x			x			Pending	46.50	
DT-400	9.0	5.0	3.0	1.7	x		x				x		Yes	43.00	
DTT401	4.5	2.5	1.5	0.8	x		x				x		Yes	43.00	
DTT402	15.0	8.3	5.0	2.8	x		x				x		Yes	43.00	
DTT403	15.0	8.3	1.5	0.8	x		x				x		Yes	43.00	
DTT500	9.0	5.0	3.0	1.7	x			x					No	35.00	
DTT501	4.5	2.5	1.5	0.8	x			x					No	35.00	
DTT502	15.0	8.3	5.0	2.8	x			x					No	35.00	
DTT503	15.0	8.3	1.5	0.8	x			x					No	35.00	
DTT690	9.0	5.0	3.0	1.7		x	x				x	x	Pending	68.00	
DTT691	4.5	2.5	1.5	0.8		x	x				x	x	Pending	68.00	
DTT692	15.0	8.3	5.0	2.8		x	x				x	x	Pending	68.00	
DTT693	15.0	8.3	1.5	0.8		x	x				x	x	Pending	68.00	
DTT300	Cust. Spec.		Cust. Spec.		Customer Specify		Customer Specify		Cust. Spec., One Only			X		No	53.00

For normally closed relay contact function specify "NC" after part number. Add \$5.00 to price.
For 240 VAC Input with 240 VAC Double Pole Output Control specify "240V" after part number, add \$7.50 to price.

DIFFERENTIAL TEMPERATURE THERMOSTATS ADJUSTABLE, Output Control: 1/2 HP @ 120 VAC

MODEL	ON differential @ 50°C		OFF differential @ 50°C		Electrical Hookup		Electrical Input		MODE 1 OFF Below 80°F	MODE 2 ON Below 36°F	MODE 4 OFF Above 160°F	MODE 6 Valve Recp. OFF	UL Listed	PRICE Includes Thermistor Ends
	*F	*C	*F	*C	Thru box knockouts	Line Cord/ Cover Recp.	120VAC 50/60 Hz	12 VAC 12 VDC						
DTT 70	Adjustable		1.5	0.8	x		x						Yes	\$48.00
DTT 71	Adjustable		1.5	0.8	x		x		x				Yes	53.00
DTT 72	Adjustable		1.5	0.8	x		x			x			Yes	53.00
DTT 74	Adjustable		1.5	0.8	x		x				x		Yes	53.00
DTT790	Adjustable		1.5	0.8		x	x						Pending	51.50
DTT791	Adjustable		1.5	0.8		x	x		x				Pending	56.50
DTT792	Adjustable		1.5	0.8		x	x			x			Pending	56.50
DTT794	Adjustable		1.5	0.8		x	x				x		Pending	56.50
DTT3410	9.0	5.0	3.0	1.7	x		x				Adjustable		Yes	53.00
DTT3411	4.5	2.5	1.5	0.8	x		x						Yes	53.00
DTT3412	15.0	8.3	5.0	2.8	x		x						Yes	53.00
DTT3413	15.0	8.3	1.5	0.8	x		x						Yes	53.00

For normally closed relay contact function specify "NC" after part number. Add \$5.00 to price.
For 240 VAC Input with 240 VAC Double Pole Output Control specify "240V" after part number, add \$7.50 to price.

THERMISTOR END SENSOR (included with DTT-series)

TES-1 \$4.00

10" long, teflon wire, 3000 ohm @ 25°C. Includes wire nuts for electrical hookup and silicone fiberglass tape for surface mounting. (For replacement use with DTT-series or with Electronic Thermometer ET-0/350.)

BP-25 \$6.50

3000 ohm @ 25°C. Thermistor Sensor with 1/4" MPT.

BP-50 \$7.00

3000 ohm @ 25°C. Thermistor Sensor with 1/2" MPT.

RBP-50 \$7.00

Same as BP-50 except leads extend from reverse end. For direct immersion into tanks. Utilize customer furnished 1/2" coupling and any length of pipe. Wire connections are enclosed inside pipe.

FREEZE SENSOR (included with DTT-690 series)

FS-1 \$20.00

"ON" above 42°F ± 5°F. "OFF" below 52°F rising temperature. Hermetically sealed non-adjustable bimetalic type. Includes strap hardware for attachment to pipe. (May also be used in conjunction with DTT-400 and HELIO-MATIC series to provide additional feature of freeze recirculation protection.)

WEATHERPROOF CASE

2T 511 GA \$14.30

INTERMATIC, NEMA type II, hasp for lock, hinged door with rubber seal. (For use as enclosure when the DTT-series is to be mounted outside.)

TRANSFORMERS

T-120/24, knockout mounted \$4.50

T-120/24P, plug mounted \$5.00

120V AC Primary, 24V AC Secondary, 20 VA
UL listed. (Use when DTT signal output needs to be 24V AC.)

T-240/12, knockout mounted \$7.50

240V AC Primary, 12V AC Secondary, 20 VA

RELAYS with ENCLOSURES

R-120 \$14.30 R-24 \$14.30 R-12 \$18.20

AC Coil Voltage indicated in part number. All Are DPDT, 25 Amp, 1 HP. UL listed. Two piece enclosure has four 1/2" conduit knockouts.

FREEZE-FAIL-SAFE™ VALVE PACKAGE

VP-1 \$72.50

Use in conjunction with DTT-690 series. Five connections (to and from collectors, to and from storage tank, and drain). Collector will automatically drain upon removal of electrical signal.

VACUUM RELIEF VALVE

VRV-36A \$6.95

Valve required on all draining type systems. 3/4" MPT. Mount at highest location above collector. (Allows atmospheric air to enter collector so that collector will drain.)

AIR VENTING VALVES, Float Type

AV-426, 1/4" MPT, 150 Max PSI \$11.90

AV-67, 1/8" MPT, 35 Max PSI \$7.60

Valve required on all draining type systems. Mount at highest point above collector. (Allows trapped air to be released from system when pump is started.)

STOREX™ TANK with double-wall heat-exchanger.

For closed loop systems where solar heated antifreeze solutions heat water in tank through integral heat exchanger.

All tanks have auxiliary 4.5 KW heater.

65 Gallon	10 sq. ft. Exchanger	TC-65E-DW	\$228
80 Gallon	15 sq. ft. Exchanger	TC-80E-DW	\$263
120 Gallon	20 sq. ft. Exchanger	TC-120E-DW	\$314

Separate data sheet available upon request.

EXPANSION TANK

ET-442 \$20.50

Tank required on all closed loop systems. 1/2" MPT, 8" dia. x 13" high for systems up to 20 gallons of Heat Exchange Fluid capacity, diaphragm type captive air. (When Heat Exchange Fluid becomes heated the expansion is absorbed by the Expansion Tank.)



TEMPERING VALVE

TV-526 \$11.90

Externally adjustable from 120-180°F. 3/4" sweat fittings, completely non-ferrous construction, thermostatic element replaceable without removing valve. (For use with domestic hot water tank. Cold water is mixed with hot to regulate exit water temperature at valve setting, preventing scalding water temperatures at the faucet. Lengthens out the delivery of hot water from tank by mixing cold at the tank, not the faucet. Necessary for all solar systems.)



TEMPERATURE AND PRESSURE RELIEF VALVE

T&P-100XL \$5.12

3/4" MPT, 150 lbs., 210 F.



GRUNDFOS CIRCULATION PUMPS

CAST IRON, Closed loop systems only, including two valves.

UGP-20-42F \$60.20

1/20HP @ 115V AC. 5-position variable flow control by external adjustment plus two-speed motor control.



UP-26-64F \$68.60 Same as above except 1/12 HP and without two speed

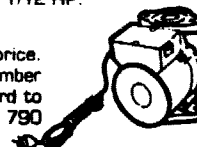
STAINLESS STEEL, Open loop, potable water systems, including two valves.

UM-25-18SU \$75.15

1/35 HP @ 115V, AC. Single speed without flow control

UP-25-42SF \$91.00 Same as above except 1/20 HP.

UP-25-64F \$107.70 Same as above except 1/12 HP.



LINE CORD with pump, add \$3.00 to pump price. Specify "with line cord" after any pump part number and the pump will be pre-wired with a line cord to simply plug into the DTT-90, 290, 690 and 790 series.

ELECTRONIC THERMOMETER

ET 0/350 \$74.50



Temperature range 0° to 350° displayed on a four inch wide dial. Dial shows temperature in both Fahrenheit and Celsius. Thermistor sensors may be located up to 1,000 feet away from thermometer. Customer provides interconnecting two-conductor wires (18 to 24 ga. recommended) which are attached to the electronic thermometer terminal strip and to the Thermistor End Sensors. Twelve position rotary switch allows temperature sensing at up to 11 different locations plus an "OFF" position. Response time is immediate upon changing switch location. Thermometer comes with three Thermistor End Sensors. For sensing at additional locations, purchase one TES-1, listed above, for each additional location. 115V AC input with three-wire line cord. Dimensions: 11" wide x 4" high x 8 1/4" deep. Separate data sheet available upon request.

Ask about our two location strip chart recorder and a hand-held battery powered digital.

SOLAR HEATED SWIMMING POOL CONTROL SYSTEM

HELIO-MATIC I_{TM}

Assembly of Delta-T, 12V transformer, Weatherproof Case, and 12V Electric Valves with complete instructions. Both 120 and 240 Voltage inputs available. Separate data sheet available upon request.



INSULATION METER

IM 5 \$57.50

Hand held meter, indicates solar intensity.



All prices shown are delivered prices within the U.S.A. except STOREX TANKS which are shipped Freight Collect. C.O.D. or check must accompany order unless credit has been established. Foreign customers add 7% to cover freight and handling.

Five year limited warranty satisfaction guarantee on all DTT products. One year from date of purchase liability is limited to replacement of defective merchandise with a tested replacement. After one year and before five years from date of purchase, liability is limited to replacement of defective merchandise with a tested replacement for a flat service charge of 50%. Damage due to weather exposure on units not designed for outside installation is not covered by the warranty.

DIFFERENTIAL TEMPERATURE THERMOSTAT

... for solar heating and solar hot water system control

DELTA-T



Enclosure is standard 4-11/16" by 4-11/16" UL Listed electrical outlet box (11.9mm x 11.9mm).

DESCRIPTION

The DELTA-T™ Differential Temperature Thermostat is an automatic motor control which turns on and off the circulation pump in a solar heating or solar hot water system when the collector temperature exceeds the storage temperature by preset differentials.

The DTT-90 is designed to be hooked-up without the need to hire an electrician as it is equipped with a grounded power supply cord and a receptacle outlet in the box cover.

A feature of the DTT-100 is an AUTOMATIC OFF condition when the collector temperature is below 80° F. This feature prevents the pump turning on at night when a large amount of heat has been extracted from storage.

A circuit to turn the pump on during freezing temperatures is incorporated into the DTT-200. This feature prevents damage to the collector from freezing by circulating the warmer storage water. The pump turns on at 36°F and off when the collector is heated up to 37°F.

For complete freedom in selecting any desired ON and OFF differentials, as low as an OFF differential of 2°F, the Model DTT-300 is available.

All models except the DTT-90 have a bypass switch on the side of the unit which allows the pump to be turned OFF or ON, bypassing the thermostat.

Construction is all solid state electronics except one UL Listed 10 Amp, 1/4 HP, 115V relay which is designed for 10 million mechanical cycles.

INSTALLATION

Installation is easily accomplished by running 115V to the box and from the box to the motor. Thermistor Ends for the sensor leads are furnished with the unit. The customer provides the interconnecting 18-2 lead wire which connects the low voltage DC sensor leads to the Thermistor Ends for which connectors are furnished. Hardware to attach Thermistor Ends to pipes, flat surfaces or curved surfaces is also furnished.

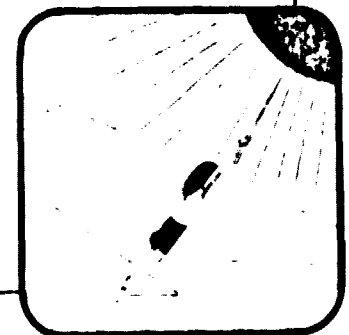
SPECIFICATIONS, PRICING

INPUT: 105-135V AC, 50/60 cycle, single phase OUTPUT: 115V AC, 10 Amp, 1/4 HP

	MODEL	ON DIFFERENTIAL		OFF DIFFERENTIAL		ADDITIONAL FUNCTION	ON/OFF/BYPASS SWITCH	AC WIRING HOOK UP	PRICE
		°F	°C	°F	°C				
NEW →	DTT-80	9 ± 2	5.0 ± 1.1	3 ± 1	1.7 ± 0.6	None	Yes	Inside Box	\$29.50
NEW →	DTT-90	9 ± 2	5.0 ± 1.1	3 ± 1	1.7 ± 0.6	None	No	8 ft. 3 wire plug and 3 prong receptacle on box cover.	\$31.00
	DTT-100	9 ± 1	5.0 ± 0.6	3 ± 1	1.7 ± 0.6	OFF when collector at 80° F or less (26.7° C)	Yes	Inside Box	\$34.50
NEW →	DTT-200	9 ± 1	5.0 ± 0.6	3 ± 1	1.7 ± 0.6	ON when collector at 36° F or less (2.2° C)	Yes	Inside Box	\$34.50
NEW →	DTT-300	Customer Specify		Customer Specify		Customer Specify	Yes	Inside Box	\$44.50

Add \$3.50 for postage and handling. California customers add 4% sales tax. Check must accompany order unless credit has been established. Delivery from stock. One year satisfaction guarantee. Order directly from:

HELIOTROPE GENERAL, 1869 hidden mesa rd., el cajon, ca 92020
(714) 447-1600



DELTA-T, DIFFERENTIAL TEMPERATURE THERMOSTAT INSTALLATION INSTRUCTIONS

Mount box on inside wall close to an electric source and the motor to be controlled. The 115V service goes directly to the DTT box and then to the motor.

SENSOR HOOK-UP: All sensor wires carry 10 VDC. The 24 gauge zip cord sensor leads which are stubbed out of the box are to be attached to any two-conductor lead wire which will run from the box to the storage and from the box to the collector. (An 18 gauge zip or bell lead wire is recommended and no longer factory-furnished.) Size 7/16 Wire-Nuts are provided for these attachments. At the termination of the lead wires at the collector and storage, attach the 4" Thermistor Ends. **WEATHER INSULATING PROCEDURES SHOULD BE EXERCISED** if the Wire-Nut connections are exposed to outside conditions.

The clear lead wire is to be attached to a storage location where a low temperature will be sensed. The white and grey wires are to be attached near the collector discharge where a higher temperature will be sensed. (Certain models of the DELTA-T do not have the grey wire.)

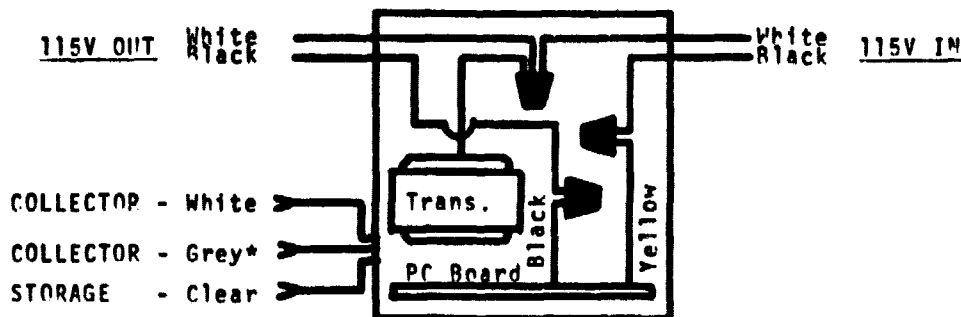
CAUTION SHOULD BE EXERCISED WHEN HANDLING THE THERMISTOR ENDS as the internal construction is of glass which is brittle and could crack if roughly handled. Attach the Thermistor Ends to the surface to be sensed with the silicon/fiberglass tape included. Use approximately 1 1/2" tape and secure to a clean surface. The tape included is rated to 350°F. It may also be advisable to mechanically secure the lead wire just before the tape connection by tying the lead wire to a secure portion of the collector and tank.

After installation of the Thermistor Ends, cover the tape and thermistors with any kind of thermal insulation so that the sensors will pick up only the temperature of the surface, not the ambient air.

Should it be necessary to place the storage sensor into a liquid, it is recommended to utilize a closed-end plastic or copper pipe to hermetically seal the sensor from the liquid. The Thermistor End should be epoxy-attached inside the pipe at the end being sensed. The purpose of the epoxy is to create as good a thermal bond with the pipe as possible. (If suspended in air inside a pipe, the true liquid temperature would not be sensed.)

115V HOOK-UP; ALL MODELS EXCEPT DTT-90: With customer-furnished Wire-Nuts, attach together the two incoming white wires to the wire from the transformer. Also attach incoming service black wire to the yellow wire connected to the PC Board. Also attach outgoing pump black wire to the black wire connected to the PC Board. **FOR MODEL DTT-90:** Plug the cord into any 115V outlet and plug the pump cord into the receptacle on the box cover.

WIRING DIAGRAM:



*NOTE: Certain models do not utilize grey wire.



HELIOTROPE GENERAL
1869 hidden mesa road
el cajon, california 92020

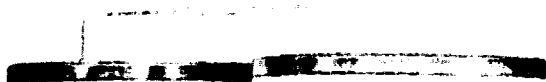
Rheemglas Storage Systems consist of one or more insulated and jacketed tanks (2, 3, 4), perfectly manifolded, to supply the stored water demands of all commercial, industrial and institutional applications. This system takes the guesswork out of draw-off efficiencies and manifold pressure drops.

The Rheemglas Storage System (tanks and manifolds), combined with a Rheem Commercial Water Heater, gives a system with all major components warranted by Rheem Manufacturing Company.

WARRANTY — The Rheemglas Storage System carries a full 5 year warranty against tank failure. Local delivery and costs of removal, reinstallation, labor and materials are not covered. The complete terms of the warranty are available at our sales office.

RHEEMGLAS
STORAGE SYSTEMS

singles or multiples
of
insulated storage tank



GENERAL SPECIFICATIONS

System Model No.	Gallons Stored	No. of Tanks	Manifold Supplied
RSS-120	120	1	—
RSS-240	240	2	120SS-2L
RSS-360	360	3	120SS-3L
RSS-480	480	4	120SS-4L

Note: Single Insulated and Jacketed Glasslined Tank Weighs 400 lbs.

MANIFOLD APPLICATION INFORMATION

120SS-2L	Duplex	For Two Units
120SS-3L	Triplex	For Three Units
120SS-4L	Quadruplex	For Four Units

MODEL APPLICATIONS

This system can be installed wherever the demand utilizes stored water from 120 gallons to 480 gallons or more. Unlike other storage tanks, this system can pass through a 30" opening—ideal for small boiler room doors.

No saddles are necessary as tanks stand vertically on the floor.

CONSTRUCTION FEATURES

- STORAGE TANK**—The tank is lined with a double coating of a high temperature glass formula. It is built for long life under any water condition. A magnesium anode rod is factory installed. Each tank is designed for 300 psi test pressure—150 psi working pressure.
- FIBER GLASS INSULATION**—A heavy blanket of Fiber Glass insulation completely surrounds the tank. The effectiveness of this material in preventing heat loss is well known and its use assures minimum losses.
- STEEL JACKET**—Complete unit is encased in baked enamel steel jacket. With minimum care, jacket will remain attractive and colorful for years.
- HAND-HOLE CLEANOUT**—Large hand-hole cleanout is standard equipment. Opening is used for removal of scale (lime), salt, sand, and other foreign material that might accumulate. Opening is equipped with a glass coated cover plate and is sealed with a replaceable gasket.
- TANK OPENINGS**—Circulating line connections are 1½" NPT. Other openings are provided for hot water outlet, relief valve, temperature control and drain valve.
- COPPER MANIFOLDS**—Copper sweat fittings and tubing are precut and packaged at the factory. Each component is identified for ease of assembly and installation. This method will assure that tanks will perform as a single unit and give the advantage of extreme flexibility.

OPTIONAL EQUIPMENT

- Shut-off valves for manifolds
- Temperature and pressure relief valve
- Tank temperature control
- Drain valve



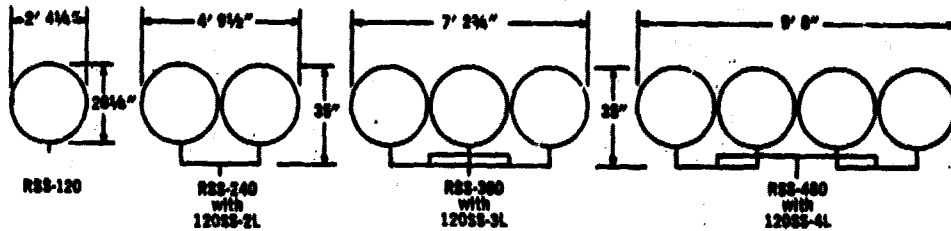
RHEEM MANUFACTURING COMPANY

WATER HEATING PRODUCTS DIVISION/Chicago, Illinois 60652

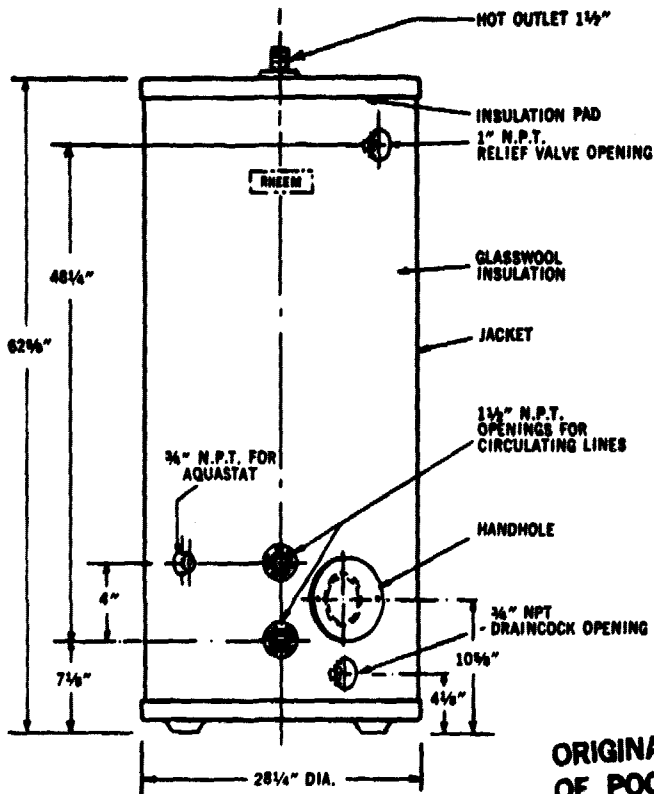


DIMENSIONS AND INSTALLATION SPECIFICATIONS

RHEEMGLAS STORAGE SYSTEMS FLOOR SPACE REQUIREMENTS



DIMENSIONS

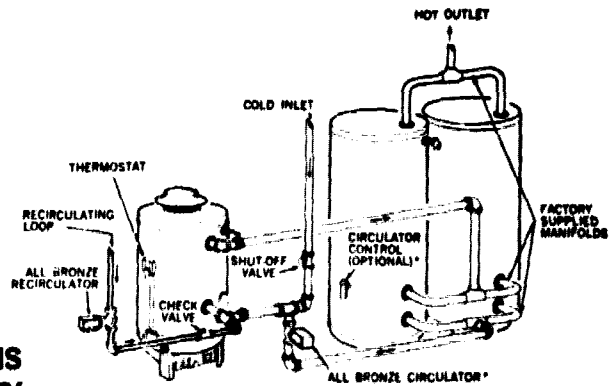


EQUIVALENT PRESSURE DROP CHART FOR CIRCULATING MANIFOLDS

Model No.	Manifold Description	LENGTH OF STRAIGHT PIPE IN FEET WITH EQUIVALENT PRESSURE DROP*						Flow Coefficient C _v
		1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	
120SS-2L	Large Duplex	1.0	4	9	30	62	250	61
120SS-3L	Large Triplex	1.1	5	11	36	96	300	86
120SS-4L	Large Quadruplex	0.5	2	5	18	47	165	80

* For manifolds with shut-off valves multiply length of straight pipe by 1.10.

RHEEM WATER HEATER WITH RSS-240 STORAGE SYSTEM



ORIGINAL PAGE IS
OF POOR QUALITY

SAMPLE SPECIFICATION

Hot water storage shall be provided by a Rheemglas Storage System, Model No. _____ with insulated and jacketed tank(s) perfectly manifolded to store _____ gallons maintained at _____ °F. This system shall utilize tank(s) that have a double coating of a high temperature glass formula and are equipped with a magnesium anode rod. Tank(s) shall be designed for 300 psi test pressure — 150 psi working pressure and shall be

equipped with a boiler type hand-hole cleanout. Unit(s) shall be insulated with heavy blanket of Fiberglas that completely surrounds tank and be encased in baked enamel steel jacket. Manifold shall be pre-cut copper and packaged at factory with necessary sweat fittings to insure component tanks performing as a single unit. Tank(s) shall be covered by a 5 year manufacturer warranty against corrosion.



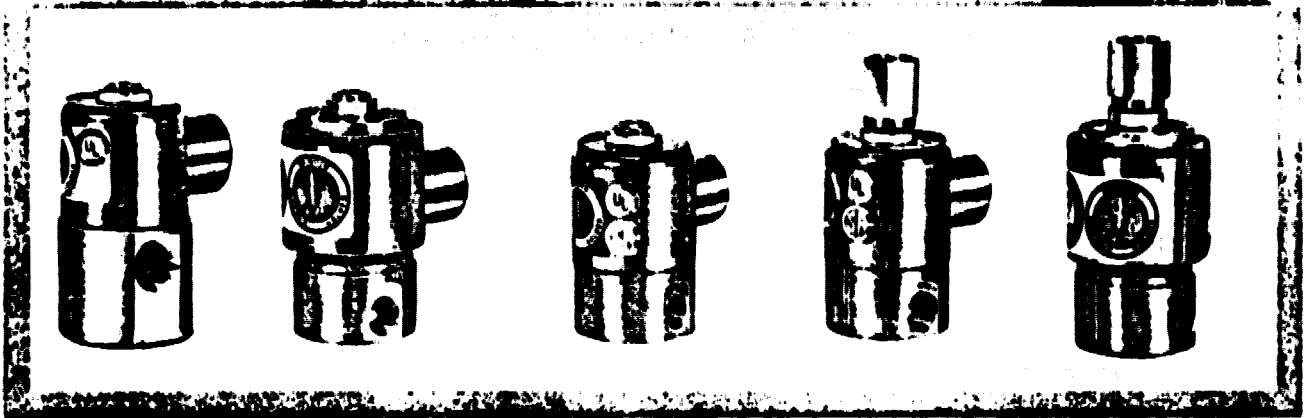
RHEEM MANUFACTURING COMPANY

WATER HEATING PRODUCTS DIVISION/Chicago, Illinois 60652

Rheem also makes other Environmental Control Products/Residential Heating and Air Conditioning Equipment/
Commercial and Industrial Heating — Cooling and Air Treatment Products.

In keeping with its policy of continuous progress and product improvement, Rheem Manufacturing Company reserves the right to make changes without notice.

SKINNER STAINLESS STEEL, TWO-WAY SOLENOID VALVES—V5 AND X5 SERIES



THE MOST VERSATILE TWO-WAY STAINLESS STEEL SOLENOID VALVES AVAILABLE

The design of these valves is so flexible that the basic valve can be modified to provide almost any arrangement of porting, mounting, flow control, voltages and frequencies to meet almost any application.

Each valve is 100% tested to specifications similar to those of the aerospace industry, and quality control procedures cover every manufacturing and assembly operation. The highest standards of the Underwriters' Laboratories Inc. are used as minimum operating specifications.

V5 Series valves are available two-way normally open, two-way normally closed and two-way normally closed dual purpose. All are available in standard construction and most

in explosion-proof construction.

Most explosion-proof construction valves are UL approved for use under Class I, Groups C and D, hazardous locations, gasoline vapors, etc.; Class II, hazardous locations; Group F, coal and coke dust, and Group G, grain dust.

APPLICATIONS

- Aircraft
- Automation
- Dehumidifiers
- Dispensing
- Instrumentation
- Laundry Equipment
- LPG Equipment
- Machine Tools
- Oil Burners
- Transportation
- Vending
- Dental Equipment

SPECIFICATIONS

VALVE TYPES

General Purpose

- Normally open types V51, X51
- Normally closed types V52, X52
- Normally closed dual purpose type V57

Special Purpose

- Normally closed, high pressure types V52H, X52H
- Normally closed, low pressure type V52 3/8"

ORIFICE DIAMETER

- Normally open
- V51, X51 3/4", 1/2", 3/32"

- Normally closed
- V52, X52 3/4", 1/2", 3/32", 1/8", 3/32", 3/16", 1/4", 3/16"

- Normally closed dual purpose
- V57 1/32", 3/4", 1/2", 3/32", 1/8"

- Normally closed high pressure
- V52H, X52H 1/32", 3/4", 1/2", 3/4"

Normally closed low pressure
V52 3/8"

FLOW RATE—Refer to C_v factor in Catalog listings and flow charts in Section 1

C_v FACTOR—Refer to catalog listings

PIPE SIZE—3/8", 1/2", 3/4" NPT (3/8" available with 3/8" orifice only) 1/8" and 1/4" BSP for most valves

VOLTAGE—Most AC and DC voltages and frequencies including wide voltage ranges and frequencies used overseas. See coil listings, Section 16

RESPONSE TIME—AC—4 to 8 milliseconds to open or close
DC—10 to 15 milliseconds to open
6 to 12 milliseconds to close

OPERATING SPEED—Up to 600 cycles per minute

CURRENT DRAWN—Refer to tables in Section 16

POWER CONSUMPTION—N—10 watts

SPECIFICATIONS (Continued)

HEAT RISE—185°F (85°C) maximum for continuous duty

MAXIMUM OPERATING PRESSURE DIFFERENTIAL—Up to 3000 PSI, see catalog listings

LEAKAGE—down to 5 microns—all types having a maximum operating pressure of 15 PSI or higher except types V52H, X52H.

SHOCK PRESSURE—1½ times maximum operating pressure differential

MAX. PRESSURE—10,000 PSIG

MEDIA—ALL common media including air, inert gases, hydraulic fluids, petroleum products, freons, water, steam and many corrosive media. NOTE: Use with steam, water and some petroleum products normally requires plunger assembly insert modification. Refer to Section 1.

FILTRATION—Filtration of contaminants down to 100

TWO-WAY NORMALLY OPEN GENERAL PURPOSE VALVES, TYPES V51, X51

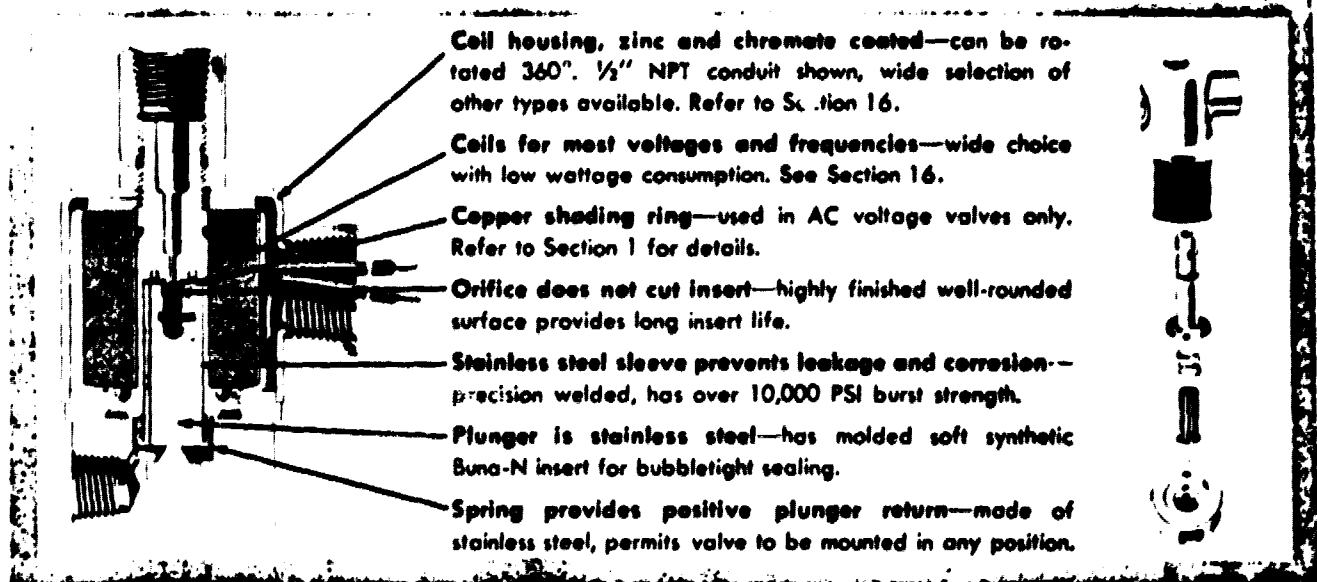
Two-way normally open valves are available in standard construction, Type V51, and explosion-proof construction, Type X51.

The valves are direct acting and have only two moving parts, the stainless steel spring and the stainless steel plunger.

The stainless steel plunger contains a molded soft synthetic insert which provides bubbletight sealing. This insert is molded into the top of the plunger and seals off the orifice machined in the sleeve.

There are many applications that require special insert material because of water, high heat, dead end air application or other media conditions. These conditions cause swelling or shrinking of the insert material and interfere with valve operation. For these conditions, on AC operation a floating top seal is employed instead of the standard plunger. This design compensates for any swelling or shrinking and helps seal the orifice. For further information see Section 1 under insert and media specifications.

FEATURES



Coil housing, zinc and chrome coated—can be rotated 360°. ½" NPT conduit shown, wide selection of other types available. Refer to Section 16.

Coils for most voltages and frequencies—wide choice with low wattage consumption. See Section 16.

Copper shading ring—used in AC voltage valves only. Refer to Section 1 for details.

Orifice does not cut insert—highly finished well-rounded surface provides long insert life.

Stainless steel sleeve prevents leakage and corrosion—precision welded, has over 10,000 PSI burst strength.

Plunger is stainless steel—has molded soft synthetic Buna-N insert for bubbletight sealing.

Spring provides positive plunger return—made of stainless steel, permits valve to be mounted in any position.

microns is recommended for V52H, X52H valves. All other types, none required.

LUBRICATION—None required

NOTE: Air line lubrication will substantially increase valve life on high-cycle air applications.

INTERNAL LEAKAGE—Bubbletight. Note: If V52H and X52H types are operated at lower than rated pressure slight leakage on gases should be expected.

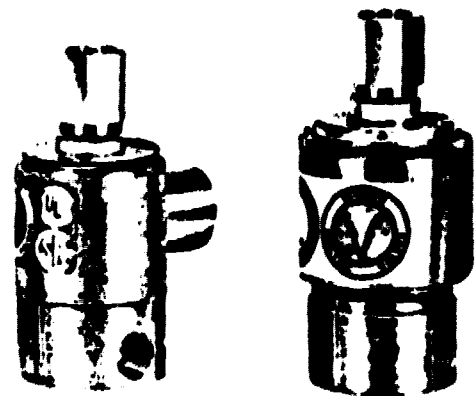
EXTERNAL LEAKAGE—None

TEMPERATURE RANGE—Minus 40°F (-40°C) to Plus 180°F (+82.2°C)

LIFE EXPECTANCY—Millions of cycles.

VIBRATION AND SHOCK—10 G's and above

APPROVALS—Most models are UL and CSA Approved. Consult Skinner for complete information.



ORIGINAL PAGE IS
OF POOR QUALITY

PRINCIPLES OF OPERATION

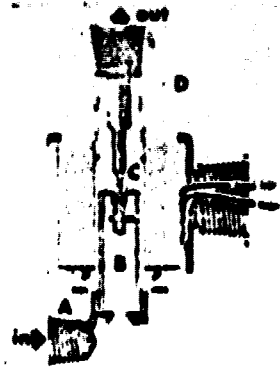
Two-way normally open, General Purpose Valves, Types V51, X51

DE-ENERGIZED

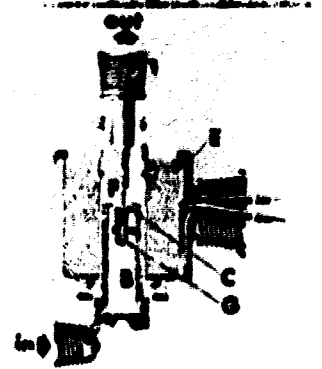
When the two-way normally open valve is de-energized, fluid flow is from the IN port located in the body up through the sleeve, A, around the plunger, B, and through the orifice, C, located in the sleeve, and through the sleeve adapter, D, to the OUT port.

ENERGIZED

When current is applied to the coil, E, a magnetic field is established that moves the plunger, B, upward against the stop, F. The soft synthetic insert, G, in the plunger seals the orifice, C, which stops the flow through the valve.



DE-ENERGIZED



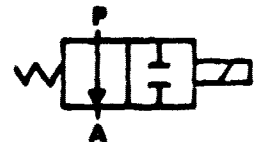
ENERGIZED

CATALOG LISTINGS

For ordering information see Section 1.

Note: Bold type and color indicate valves carried in factory stock.

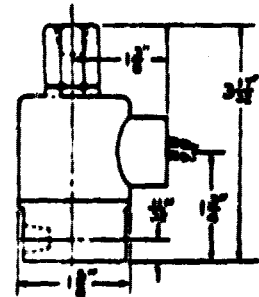
ANSI SYMBOL



TWO-WAY NORMALLY OPEN GENERAL PURPOSE VALVES, Type V51

CATALOG NUMBER

* maximum operating pressure differential (PSI)	AC	DC	orifice diameter (inches)	Cv factor	option ES		option FC	
					1/2" NPT	3/4" NPT	1/2" NPT	3/4" NPT
200 (235)	200 (275)	1/4	.052	V51DA1200	V51DA2200	V51DB1200	V51DB2200	
150 (175)	150 (200)	1/4	.093			V51DB1150		
125 (140)	125 (140)	1/4	.17					

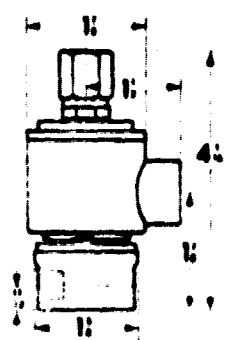


V51 DB2 125

TWO-WAY NORMALLY OPEN EXPLOSION-PROOF, GENERAL PURPOSE VALVES, Type X51

CATALOG NUMBER

* maximum operating pressure differential (PSI)	AC	DC	orifice dia. (inches)	Cv factor	option FC		weight pounds
					1/2" NPT	3/4" NPT	
200 (235)	200 (275)	1/4	.052	X51DB1200	X51DB2200	1.5	
150 (175)	150 (200)	1/4	.093	X51DB1150	X51DB2150	1.5	
125 (140)	125 (140)	1/4	.17	X51DB1125		1.5	



* Figures in parentheses indicate higher than standard pressure ratings available with slight modifications.
 ** Weights shown are for valves with conduit housings. Subtract 1 pound for valves with grommet housing.

APPENDIX B

PRC SOLAR PROJECT DESCRIPTION

(SOLAR/2005 - 78/50)

**Available through the National Technical
Information Service, Springfield, VA 22151**

APPENDIX C

IBM SYSTEM PERFORMANCE EVALUATION

(SOLAR/2005 - 77/14)

**Available through the National Technical
Information Service, Springfield, VA 22151**

APPENDIX D

MUELLER SOLAR PROJECT COST REPORT

(SOLAR/2005 - 78/60)

**Available through the National Technical
Information Service, Springfield, VA 22151**