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DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-161434

SOLAR HOT WATER SYSTEM INSTALLED AT QUALITY INN, KEY WEST, FLORIDA -- FINAL REPORT

Prepared by

Quality Inn of Key West
420 Lincoln Road No. 394
Miami Beach, Florida 33139

Under Contract EG-77-G-01-1633

Monitored by

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

(NASA-CR-161434) SOLAR HOT WATER SYSTEM INSTALLED AT QUALITY INN, KEY WEST, FLORIDA Final Report (Quality Inn of Key West) 25 p HC A02/MF A01 CSCL 10A

N80-23774

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U.S. Department of Energy

Solar Energy

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TECHNICAL REPORT STANDARD TITLE PAGE

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DOE/NASA CR-161434		

4. TITLE AND SUBTITLE	5. REPORT DATE
Solar Hot Water System Installed at Quality Inn, Key West, Florida--Final Report	April 1980
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS Quality Inn of Key West 420 Lincoln Road No. 394 Miami Beach, Florida 33139	10. WORK UNIT NO.
	11. CONTRACT OR GRANT NO. EG-77-G-01-1633
	13. TYPE OF REPORT & PERIOD COVERED
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, DC 20546	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This work was done under the technical management of Mr. Lary Lawson, Marshall Space Flight Center, Alabama.

16. ABSTRACT

This report describes the solar energy hot water system installed in the Quality Inn, Key West, Florida, which consists of four buildings. Three buildings are low-rise, two-story buildings containing 100 rooms. The fourth is a four-story building with 48 rooms. The solar components were partly funded by the Department of Energy under Grant EG-77-G-01-1633.

The solar system was designed to provide approximately 50 percent of the energy required for the domestic hot water system. The solar system consists of approximately 1400 square feet of flat plate collector, two 500 gallon storage tanks, a circulating pump, and a controller. Operation of the system was begun in April 1978, and has continued to date with only three minor interruptions for pump repair. In the first year of operation, it was determined that the use of the solar facility resulted in forty percent fuel savings.

17. KEY WORDS	18. DISTRIBUTION STATEMENT UC-59a Unclassified-Unlimited WILLIAM A. BROOKSBANK, JR. Mgr, Solar Energy Applications Projects

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COOPER HOTELS
SUITE 304
420 LINCOLN ROAD
MIAMI BEACH, FL 33139
(305) 538-4674

STATEMENT OF IPC CERTIFICATION

I hereby certify that the solar system herein, built under Agreement No. EG-77-G-01-1633, complies with the "Interim Performance Criteria for Commercial Solar Heating and Combined Heating/Cooling Systems and Facilities" Document No. 98410001; Revision: Basic, Dated February 28, 1975, as applicable.

Signed: _____
Leon Cooper

Date: December 28, 1979

Title: President

1. KEY WORD ABSTRACT:

Application	Domestic Hot Water (preheat)
Collector Type	Flat Plate, Liquid
Collector Area	1400 square feet (approx.)
Storage Capacity	1000 gallons
Design Hot Water Load	6.81×10^8 BTU/year
Design System BTU Produced	3.19×10^8 BTU/year
Building Owner	Cooper Hotels
Solar System Designer, Manufacturer, Installer	Capital Solar Heating, Inc. Miami, Florida

2. INTRODUCTION:

Cooper Hotels retained Capital Solar Heating, Inc., Miami, Florida, to retrofit the Quality Inn, Key West, Florida, with a domestic hot water preheat system. The Inn consisted of 100 rooms in three two-story low-rise buildings, and it was planned to construct an additional 48 rooms, in a four-story structure, at about the same time as the solar installation. The system was designed to supply approximately 50% of the total energy demand for both the old and the new buildings.

3. DESIGN PHILOSOPHY:

Prior to installation of the solar system, domestic hot water was heated by a single 700,000 BTU oil-fired boiler, feeding a 500 gallon storage tank. System demand estimates, following completion of the new 48 room wing, and based on previous occupancy records, were 1.089×10^6 gallons per year, at a 75° temperature differential, giving a total system demand of 6.81×10^8 BTU/year. The solar system was designed to provide approximately 3.19×10^8 BTU/year. The solar panels were mounted on the roof of the low-rise building in two groups (to fit the shape of the roof, rather than for any technical reason) - one group of 5 rows with 5 collectors per row, and one group of 2 rows with 6 collectors per row. The storage tanks, pump and controller were installed in the boiler room directly below the panels. Complete details of the design and installation are attached as Appendix A.

4. OPERATION OF THE SYSTEM:

Installation of the system was started in February, 1978, and completed in April, 1978. Since this was basically a small, simple system, instrumentation was minimal. Start-up procedures were limited to bleeding air from the system, a visual inspection for leaks and general appearance, and later verification of operation by feeling the warmth of the piping in the return line from the solar panels. Prior to startup, an Operating Time meter was installed on the boiler. By measuring boiler operating time (per occupied room) with and without the solar system, it was determined that use of the solar system resulted in approximately a 40% fuel saving during the first year of operation.

In September, 1978, there was a breakdown of boiler operation which took one week to repair. During that one week period, the solar system was the only source of domestic hot water. With a motel occupancy of just under

50%, there was no complaint of lack of hot water - the solar system carried the entire load.

5. PROBLEMS ENCOUNTERED:

During the first year of operation, the only problem encountered was a solar pump failure. The pump was replaced under the warranty, and the system was back in operation within two days.

In May, 1979, and again in June, 1979, the system failed to maintain continuous flow through the collectors. Investigation by a team from the Marshall Space Flight Center, headed by Lary Lawson, determined that the magnetically coupled circulation pump impeller thrust bearing had failed. Replacement of the pump by a direct-drive pump solved the problem. Reports on the problem are attached in Appendix B. The reports also suggest some piping modifications for greater efficiency.

6. CONCLUSIONS:

The solar system, as installed, appears to be simple and cost-effective. Maintenance requirements are minimal. The grantee/owner would certainly consider a solar installation for future projects.

APPENDIX A

System Design and Installation Information

Capital Solar Heating, Inc.

376 N. W. 25th STREET MIAMI, FLORIDA 33127

Tel. (305) 576-2880

The solar energy system consists of 1400 sq. ft. of flat plate collectors, a 1,000 gallon storage tank, and associated circulating pump, controller, piping and miscellaneous valves. The collectors were roof-mounted. The remaining equipment is housed in the existing boiler room. The system (which consists of a boiler, storage tank, circulating pumps, thermostatic controls, and assorted valves) and is designed to supply all required hot water, without additional heat from the oil-fired boiler, when the motel is 50% occupied.

This solar system is a hot water preheat system. Cold water is circulated through the copper solar collectors and stored in two 500 gallon insulated tanks, at times of no usage of hot water, the water in the storage tanks is circulated through the solar collectors to increase the temperature of the stored water. During times of increased hot water usage the solar preheated water is transferred to the boiler storage tank either directly or through the boiler depending on the leaving temperature of the solar heated water.

Capital Solar Heating, Inc.

376 N. W. 25th STREET MIAMI, FLORIDA 33127

Tel. (305) 576-2380

Dimension: 48"x120"x3½"

Weight: 85 pounds

GENERAL DESCRIPTION:

- Unitized Cabinet constructed of heavy-gauge annodized aluminum assures rigidity and squareness of the complete unit.
- Absorber Plate is die formed for greater surface contact with copper tube water-ways.
- Chemical Bond between absorber plate and copper tube waterways assures superior heat transmission.
- Glazing is available in single or double layers using a fiberglass reinforced plastic sheet, specially formulated with a proprietary resin system, providing for high light transmission with superior heat and ultra-violet resistance.
- Poly-Urethane Insulation, one inch thick, reduces bottom and side losses to surrounding air.
- Factory Testing assures integrity of all joints in the copper tube water-ways.
- Silver Solder at all tubing joints insures even heat transmission through the copper tube water-ways.
- Limited Warranty is extended for five years on all component parts of the solar collector panel.

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Figure #1

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QUALITY INN
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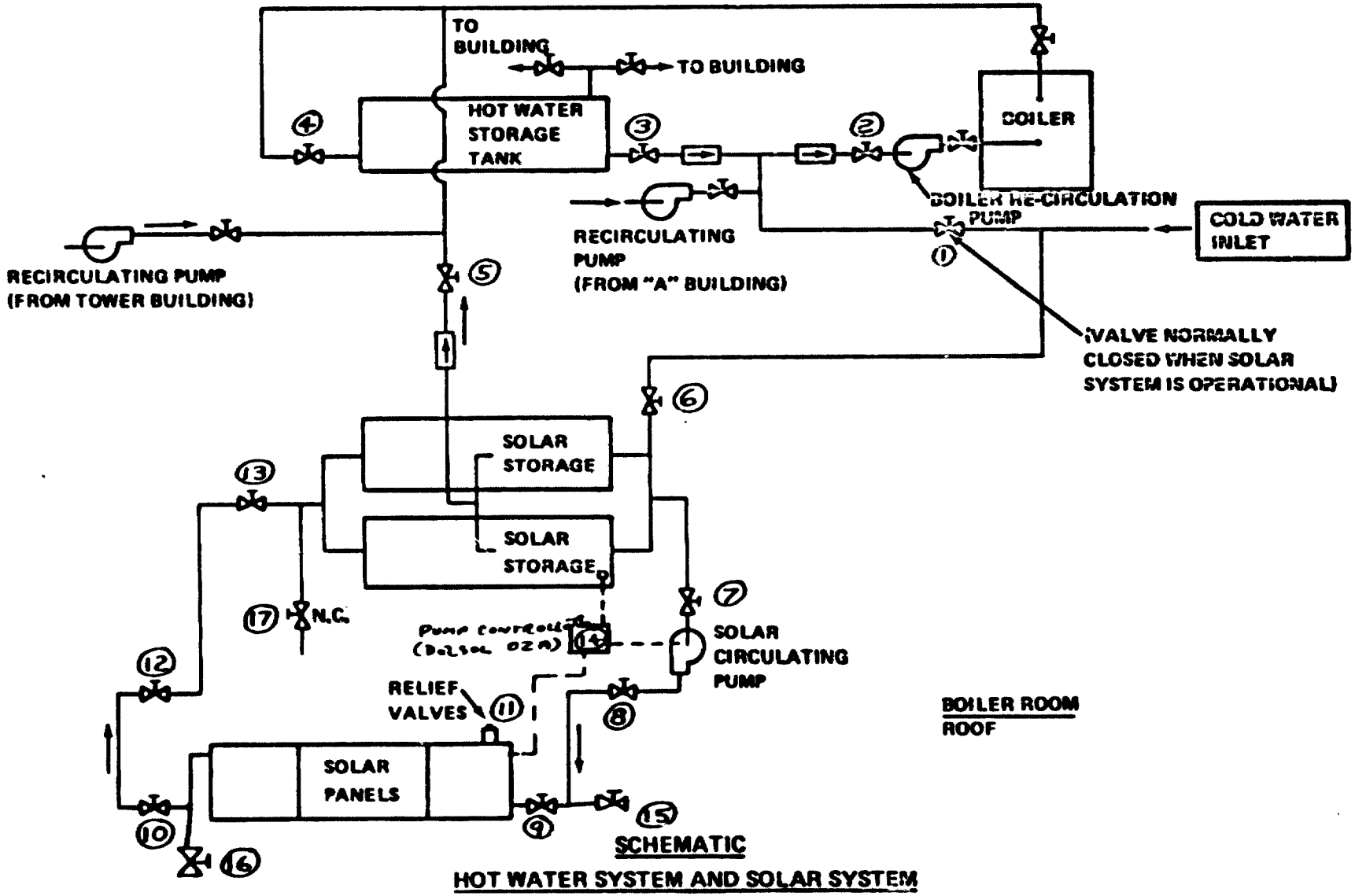

SCHEMATIC

HOT WATER SYSTEM AND SOLAR SYSTEM

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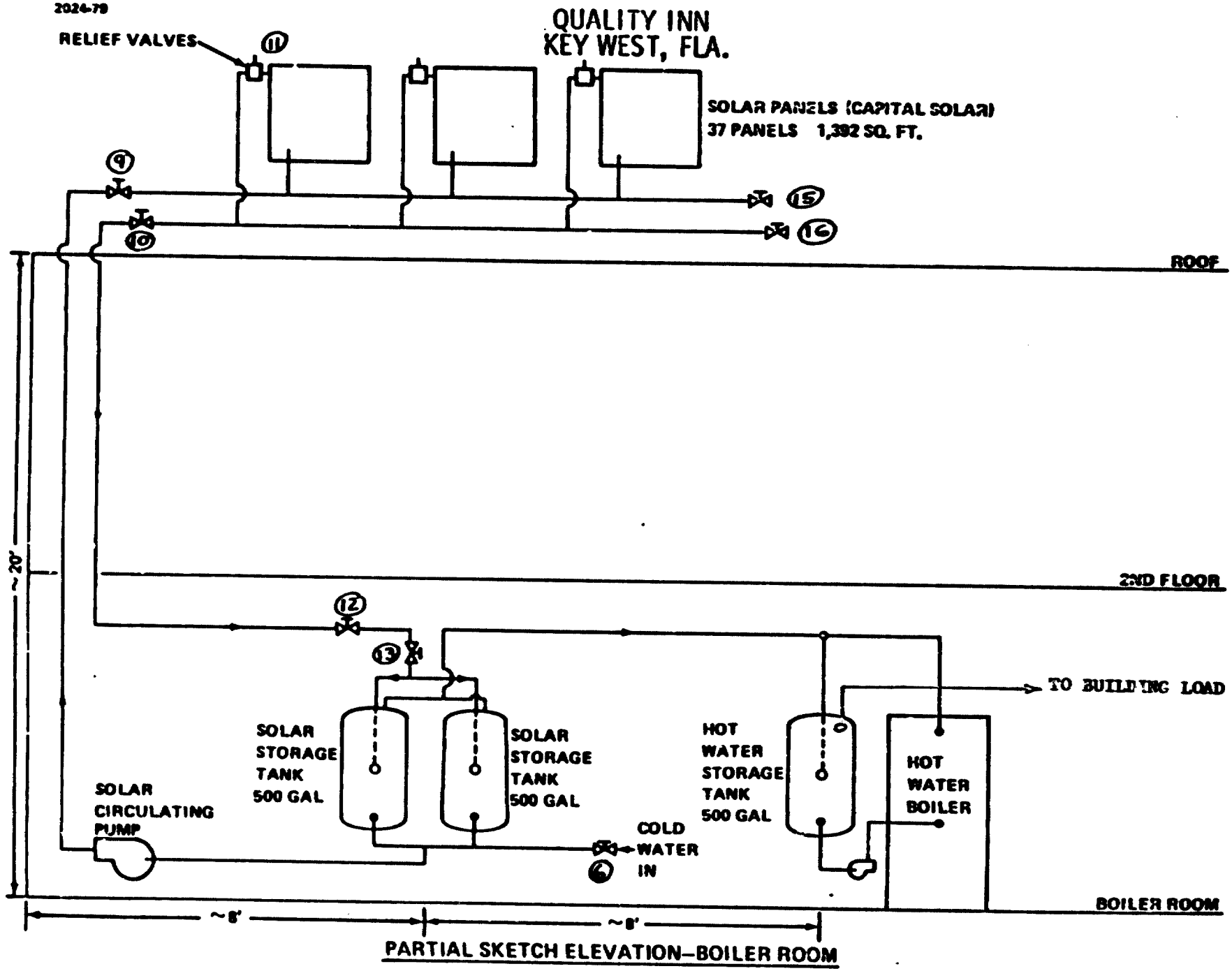

PARTIAL SKETCH ELEVATION–BOILER ROOM

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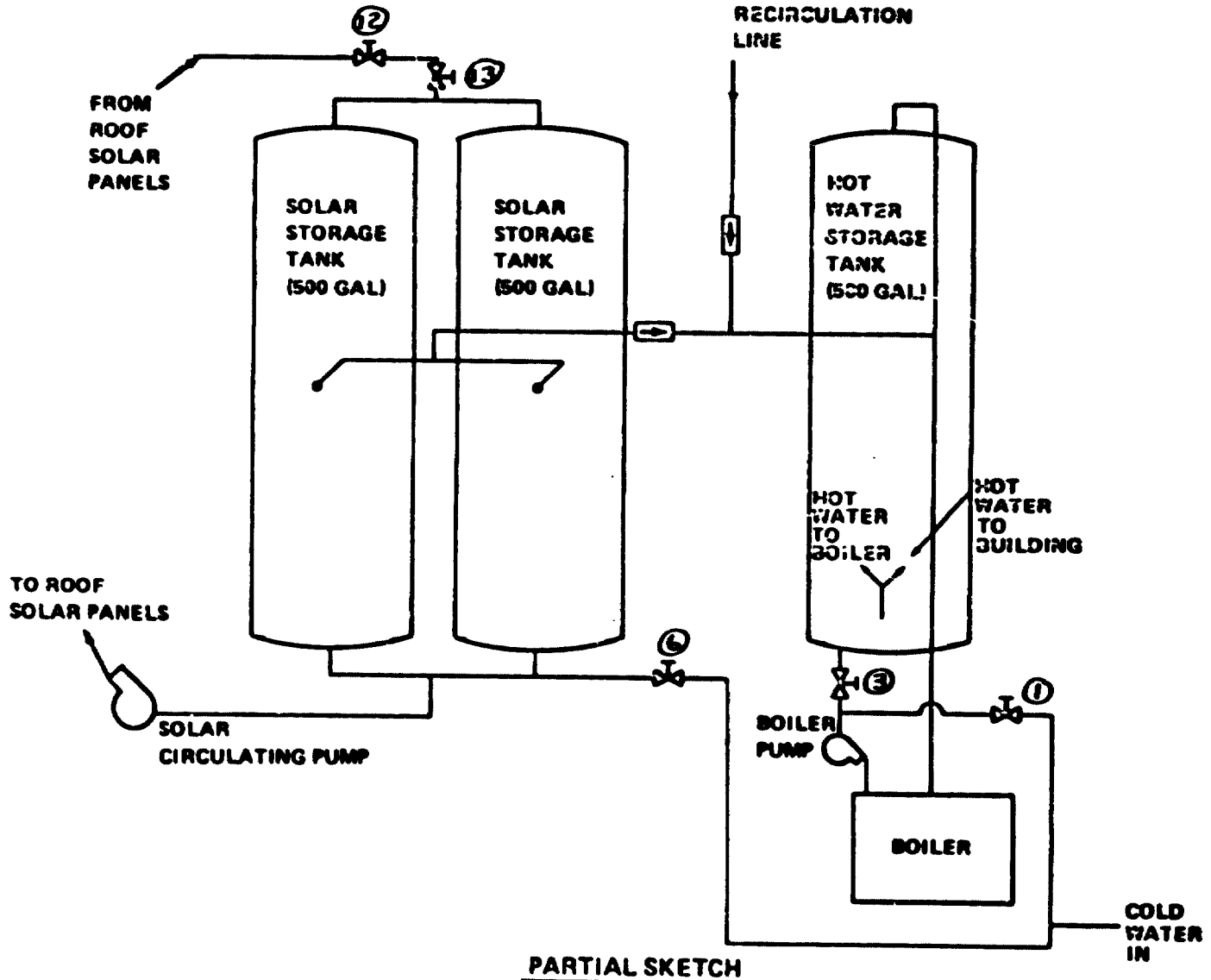
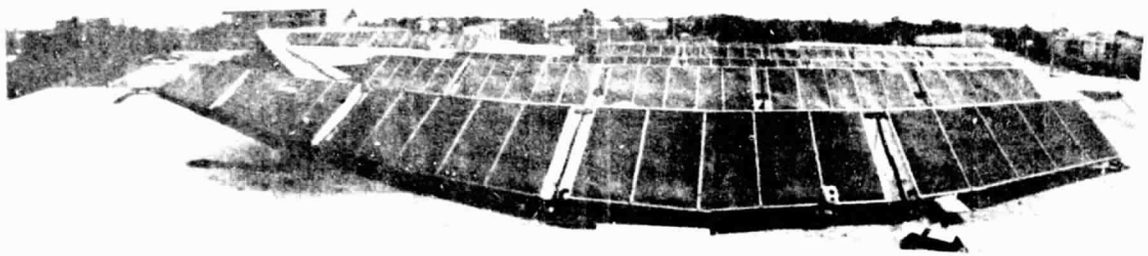


PARTIAL SKETCH
PLAN VIEW–BOILER ROOM

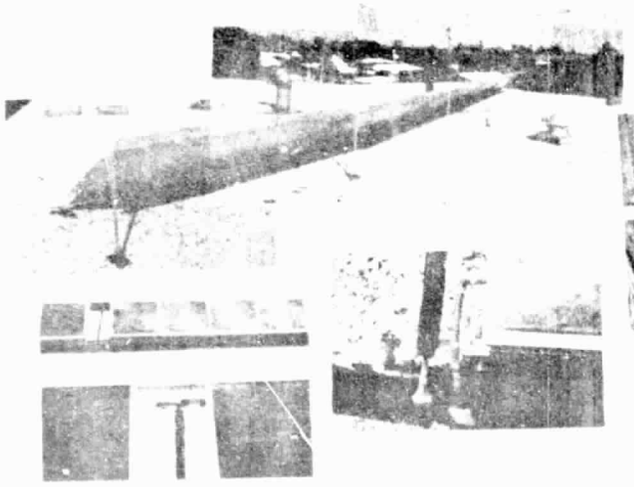
QUALITY INN SOLAR SYSTEM

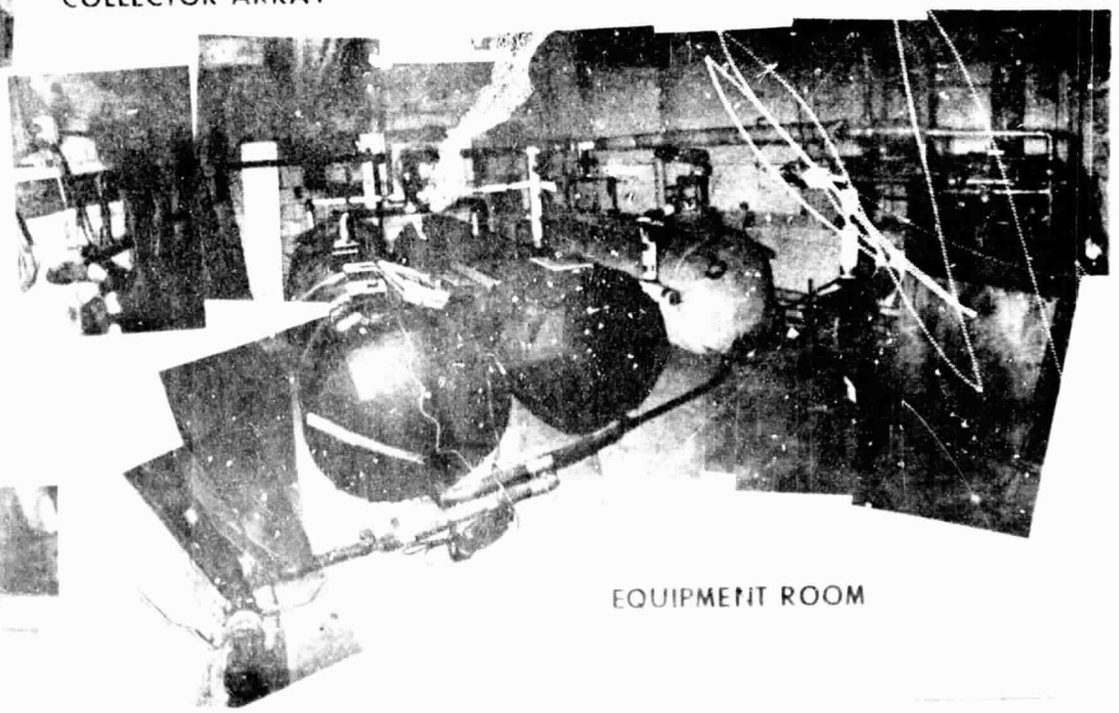
KEY WEST, FLA.



COLLECTOR ARRAY

RETURN FROM COLLECTORS





EQUIPMENT ROOM

FAILED PUMP

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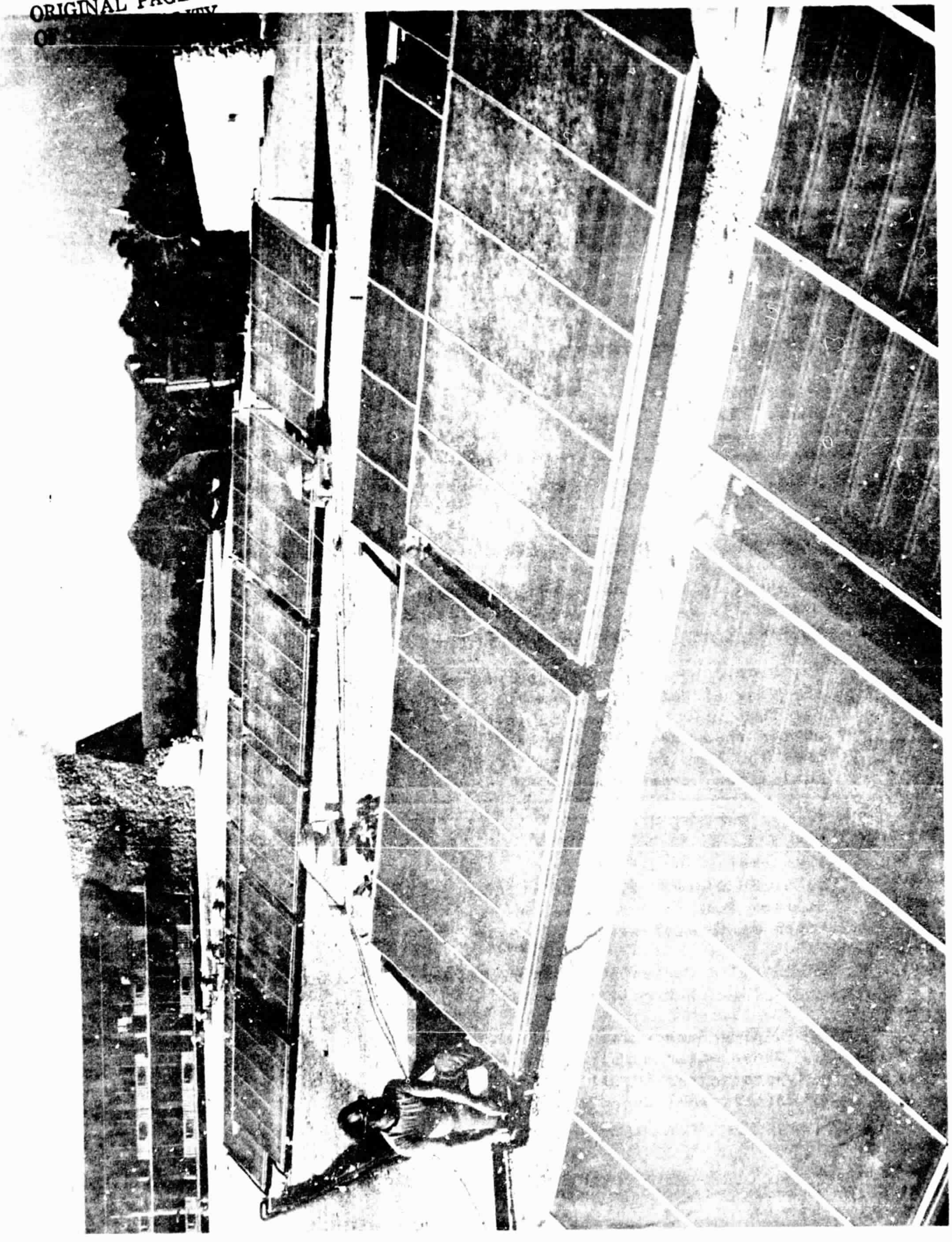

Capital Solar Heating, Inc.

376 N. W. 25th STREET MIAMI, FLORIDA 33127

Tel. (305) 576-2380

OPERATION AND MAINTENANCE OF YOUR SOLAR WATER HEATING SYSTEM USING THE 4896HWP or 48120HWP

Normal Mode of Operation

Your system consists of three major units. They are the Solar Collector Panel, the Pump and Sensor, and the Storage Tank. (Normally, a standard Hot Water Heater is used for storage).

During periods of normal sunshine, the system will store enough hot water so that the existing heater has no need to come on. However, in times of poor sun conditions or excessive use of the stored hot water, the heater will be available as a back up to maintain the hot water requirements.

The Pump & Sensor operate as one unit to automatically control the flow of hot water from the Solar Panel to the Storage Tank. The Pump will only come on when the water in the Collector is hotter than the water in the Storage Tank. (Check to make sure that the Pump is not operating during periods of poor sun conditions, overcast, etc.)

Freeze Protect Mode

Your system contains a freeze sensor which will cycle the pump on at 36 degrees F. This will circulate hot water from the Storage Tank to the Collector Panel to prevent freezing of the water in the Collector.

IMPORTANT: During power failure (Freeze Protect Mode refer to Schematic Diagram).

1. Unplug Sensor Pack
2. Close water supply valve #6
3. Open valves 10, 11, 12, 13, 15, 16, 17
4. After panel and piping have drained, close valves 10, 12, 13, 17

Capital Solar Heating, Inc.

376 N. W. 25th STREET MIAMI, FLORIDA 33127

Tel. (305) 576-2380

FILL PROCEDURE: (Refer to Schematic Diagram)

1. Make sure all fittings are soldered completely.
2. Close drain valves 15 and 16.
3. Open P&T (relief) valves #11.
4. Open cold water inlet valve #6 and valves 5, 7, 8, 9, 10, 12, 13. (see safety note below)
5. When water flows in steady stream from P&T valve #11, system is full.
6. Close valve #11. Turn on power to water heater.
7. Plug in extension from control pack (#14) to 115 volt AC outlet.

Note: For safety reasons, be careful to avoid contact with water flow from P&T valve #11, as the water temperature may be in excess of 140 degrees F.

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FLORIDA SOLAR ENERGY CENTER
HUD INITIATIVE
SYSTEM ACCEPTANCE CERTIFICATE

Accepted January 25, 1978 **Void After** September 30, 1978

The solar domestic water heating system described herein has been reviewed by the Florida Solar Energy Center and is considered to be in compliance with the requirements of NBSIR 77-1272, "Intermediate Standards for Solar Domestic Hot Water Systems/HUD Initiative" for the purpose of the Florida Residential Solar Water Heating Initiative Program. This is not to be construed as specific approval for any other HUD funded programs. This acceptance shall not supersede requirements of local jurisdictions and the installation must meet the applicable codes and standards set forth by local jurisdictions. This acceptance is not to be construed as an endorsement or warranty by the Florida Solar Energy Center and is subject to the conditions set forth below:

System Model Number 48120HWP

System Description: NO SUBSTITUTIONS ALLOWED WITHOUT PRIOR APPROVAL FROM FSEC.
RESTRICTION: The Capital Solar Heating Co., Inc. warranty only applies when the solar system is installed by an authorized installer.

Domestic water heating system consisting of:
(See Attachment)

System Vendor: Capital Solar Heating Co., Inc.
376 NW 25th Street
Miami, FL 33127

System Distributor:

This acceptance is for the period indicated herein and is void after the date shown above. Any change in design, material or marking without prior approval of the Florida Solar Energy Center or evidence of inferior workmanship or failure to follow an equitable service policy may result in revocation of this acceptance.

Thomas S. Hill
Chairman - System Evaluation Board

Director - Florida Solar Energy Center

FLORIDA SOLAR ENERGY CENTER
Attachment to:
HUD INITIATIVE
SYSTEM ACCEPTANCE CERTIFICATE

Accepted January 25, 1978 Void After September 30, 1978

System Model Number 48120HWP

System Description (Continued): NO SUBSTITUTIONS ALLOWED WITHOUT PRIOR APPROVAL FROM FSEC. RESTRICTION: The Capital Solar Heating Co., Inc. warranty only applies when the solar system is installed by an authorized installer.

Collector: One (1) Capital Solar Heating Co., Inc. Model 48120

Pump: Choice of one (1) March Model 809 or one (1) Teel Model 1P760

Control: One (1) Del Sol Model 02A

Storage Tank: Choice of one (1) Duro Matic Model 66ADR or one (1) Duro Matic Model 82ADR

To be installed in accordance with the Capital Solar Heating Co., Inc. Installation Manual and in accordance with applicable local codes. Appropriate building permits must be obtained prior to installation. The Capital Solar Heating Co., Inc. HUD Grant Program collector and system warranties must be given to the consumer along with the Capital Solar Heating Co., Inc. Operation and Maintenance Manual.

System Vendor: Capital Solar Heating Co., Inc.
376 NW 25th Street
Miami, FL 33127

System Distributor:

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APPENDIX B

Problem Reports

REQUEST FOR SUPPORT
FROM PROBLEM ASSESSMENT GROUP

DATE: June 7, 1979

SITE: Quality Inn

LOCATION: Key West, Florida LATITUDE: 24.55

APPLICATION: HEATING ____ ;COOLING ____ ;HOT WATER X ;ETC. ____

SYSTEM DESCRIPTION: INSTRUMENTED ? YES ____ NO X

COLLECTOR: MFG Capitol Solar TYPE: FP ; # GLAZING 1 ;

AREA 1392 FT^2; FLUID: City Water ; TILT: 34° ;

STORAGE: VOLUME: HOT 1000 Gal. ; COLD ____ ; TYPE Water ;

BRIEF DESCRIPTION OF OPERATIONAL/CONTROL MODES:

(SYSTEM SCHEMATICS, CONTROL DWGS., COMPONENT LISTS, FINAL REPORT)

Solar Hot Water System Utilizes roof mounted collectors piped to 2-500 gallon preheat storage tanks. Output of solar tanks goes to previous existing hot water storage tank.

Sketches attached.

SIGNIFICANT EVENTS: (COMPLETION OF CONSTRUCTION. ACCEPTANCE TEST, PERIOD OF SATISFACTORY OPERATION, ETC., PREVIOUS PROBLEMS AND ATTEMPTED FIXES)

Completed 4-1-78. Operated satisfactory from 4-1-78 to Spring of 79. Solar pump failed once and was warranty replaced. New H_2O pressurization system installed Fall of 78 to boost city pressure from 15-30 psig to 30-65 psig required by new four story model addition.

DESCRIPTION OF CURRENT PROBLEM(S) AND ATTEMPTED FIXES (IF ANY):

System fails to maintaim continuous flow thru collectors since (1) new pump was installed or (2) pressurization system was installed. Air has been vented from collectors; two different plumbers called to investigate, no positive results.

SPECIAL INFLUENCING FACTORS AND/OR BACKGROUND:

SITE MGR Larry Lawson ; TEAM MEMBER Ronald Toelle ; A/C # MAC00121

SOLAR HEATING AND COOLING
COMMERCIAL DEMONSTRATION PROGRAM
ADVISORY CIRCULAR

August 6, 1979
MAC00121

SUBJECT: Stalling of Magnetically Coupled Pumps

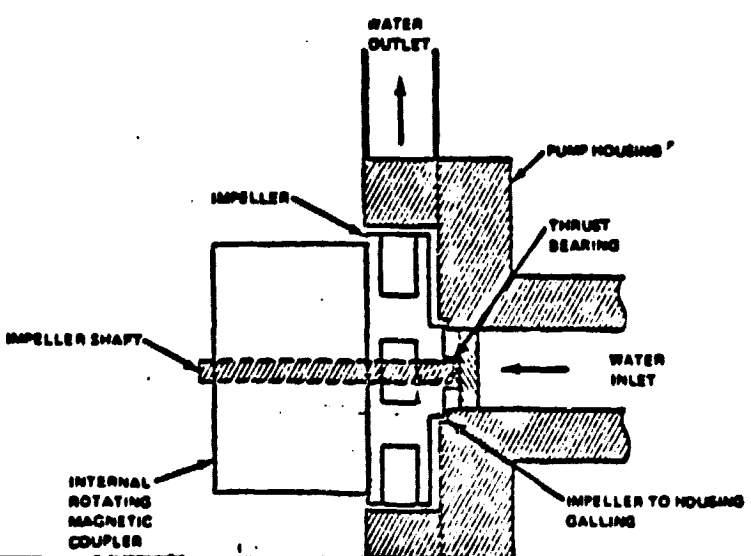
LOCATION: Key West, FL

APPLICABILITY: All solar systems utilizing or proposing to use magnetically coupled pumps.

PROBLEM: After approximately one year of successful operation, the solar system randomly experienced loss of circulation between storage and the collectors. A site inspection revealed that the magnetically coupled water pump was loosing its coupling resulting in a no-flow condition. Disassembly of the pump revealed the impeller thrust bearing to be worn so that the impeller was rubbing on the pump housing enough to cause galling and eventual complete lockup of the impeller. Once the magnetic coupling was lost, it would not pickup the load until power to the motor was shutoff and the motor stopped.

CORRECTIVE ACTION: The magnetically coupled pump was replaced with a direct-drive hot water circulator pump.

REMARKS: If the above problem is experienced with this type pump in a solar system, it should be immediately dismantled and the impeller and thrust bearing inspected for wear or galling.



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NASA
Marshall Space Flight Cen
Alabama 35812

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35912

NASA

Reply to Attn of: FA33 (79-350)

August 10, 1979

TO: FA33/L. Lawson

FROM: FA33/R. Toelle

SUBJECT: Site Visit to Quality Inn Motel Solar System at Key West, Florida

In response to your request of assistance, a site visit inspection and analysis of the problem was performed by Mr. W. T. Powers, EC23, and the undersigned on July 16 and 17, 1979. The following documents the results of that visit.

There is absolutely no monitoring equipment on the complete solar installation, not even a thermometer. The drawings provided in the specification showed a flowmeter but it was not installed.

Monday, July 16, was spent analyzing the solar system by taking temperature and insolation readings. Inspection of the collector array revealed that the outlet valves on four of the seven rows of collectors were closed. All valves were fully opened such that full potential flow of the system was attained. Measured temperature rise across the collector array was 35° to 40° F. with outlet temperatures reaching 135°F.

The system appeared to be operating correctly until ≈1:45 p.m. EST. The pop off valves on each collector relieved and vented water and steam. Examination of the strip chart data being taken at that time showed the array outlet temperature dropped from 135°F. to about 93 or 94° F. in about three minutes.

This showed that water flow from the collector to storage had stopped and had flow direction reversed. About 2:10 p.m. EDT, the outlet header temperature began to rise showing flow being reestablished. The outlet temperature rose to 130° F. at 2:30 and then began to fall, due to decrease of insolation. At 4:20 p.m., a rain shower moved over the area and the solar system stopped for the day. We did not have an ammeter on the circulator pump so we do not know whether the pump lost its magnetic coupling and the flow stopped.

A circular water flow between the two solar storage tanks was observed by temperature measurements and will be discussed later. The motel water pressurization system was operating continuously during the above observations.

The testing performed on Tuesday, July 17, was similar to that performed on Monday except we were trying to understand the circular flow between the two parallel piped storage tanks. Mr. Lee Cooper (owner) was present observing both our work and that of the plumber who was working on the rapid cycling of the pressurization systems. The system operated continuously from about 10:30 a.m. EDT until 1:45 p.m. when all pop-off valves relieved (H_2O temp. measured at 212°F.) At this time, the ammeter reading was taken and showed a reduction of about 4 amps compared to an earlier reading. The pump was unplugged and allowed to run down. This run down took about 45 seconds. It was plugged in and amps recorded at full load. The array outlet temperature started a rapid rise which showed that flow had been reestablished. The pump stalled a couple more times in a fairly short time and Mr. Cooper instructed us to "do what we had to do to get the thing running." We proceeded to isolate and dismantle the pump and found a solder ball inside the pump housing. This was thought to be the problem and the pump was reassembled and turned on. Flow was established, based on temperature readings and current draw of the pump. The system ran for about 5 minutes and the pump loss the magnetic coupling. Current draw dropped to about 1/2 of full load and the pump made a loud rattling sound. It was cycled on and off repeatedly and the results were the same. It would run for a few minutes and uncouple and flow would stop. The pump was dismantled and the impellar thoroughly inspected for wear. It was noted that there was galling between the impellar and housing, so much that brass stringing was occurring at the contact point. Further inspected revealed the thrust bearing extremely worn and cracked in two places. No replacement was available closer than Miami. Mr. Cooper had departed earlier in the day and a call was made to inform him of our findings. The recommendation made to Mr. Cooper was as follows:

If a warranty replacement pump or impellar could be obtained at no or minimum cost, use that but if a new pump had to be purchased, he should get a direct drive, hydronic circulator pump and a spare shaft seal to be shelved onsite.

A flow phenomenon was observed at this site such that the single pipe returning from the roof was measured at 135°F. and after the flow had passed a tee which connected the two storage tanks in parallel, one pipe

was measured at ≈ 95° F. and the other pipe measured at ≈ 120° F. These two measurements were taken about 5 feet downstream from the 135° F. reading. The plumbing layout was analyzed (Figure 1) and the results are that there is a circular flow being set up between the two tanks due to the geometry of the inlet connections. The tank to tank flow pattern was observed with the system isolated from the load.

A discussion was held with Mr. Cooper as to this flow pattern and a suggestion made that the tanks be piped in series with only one tank supplying the load. Further discussion revealed that the benefits would not justify the cost because now he can use all the energy collected.

Further questions should be referred to the undersigned at 3-2054 or W.T. Powers at 3-5619.

Ron Toelle
Site Assessment and
Equipment Group

Enclosure

cc:
FA33/M. Myers
FA33/J. Brown
EC23/W. Powers

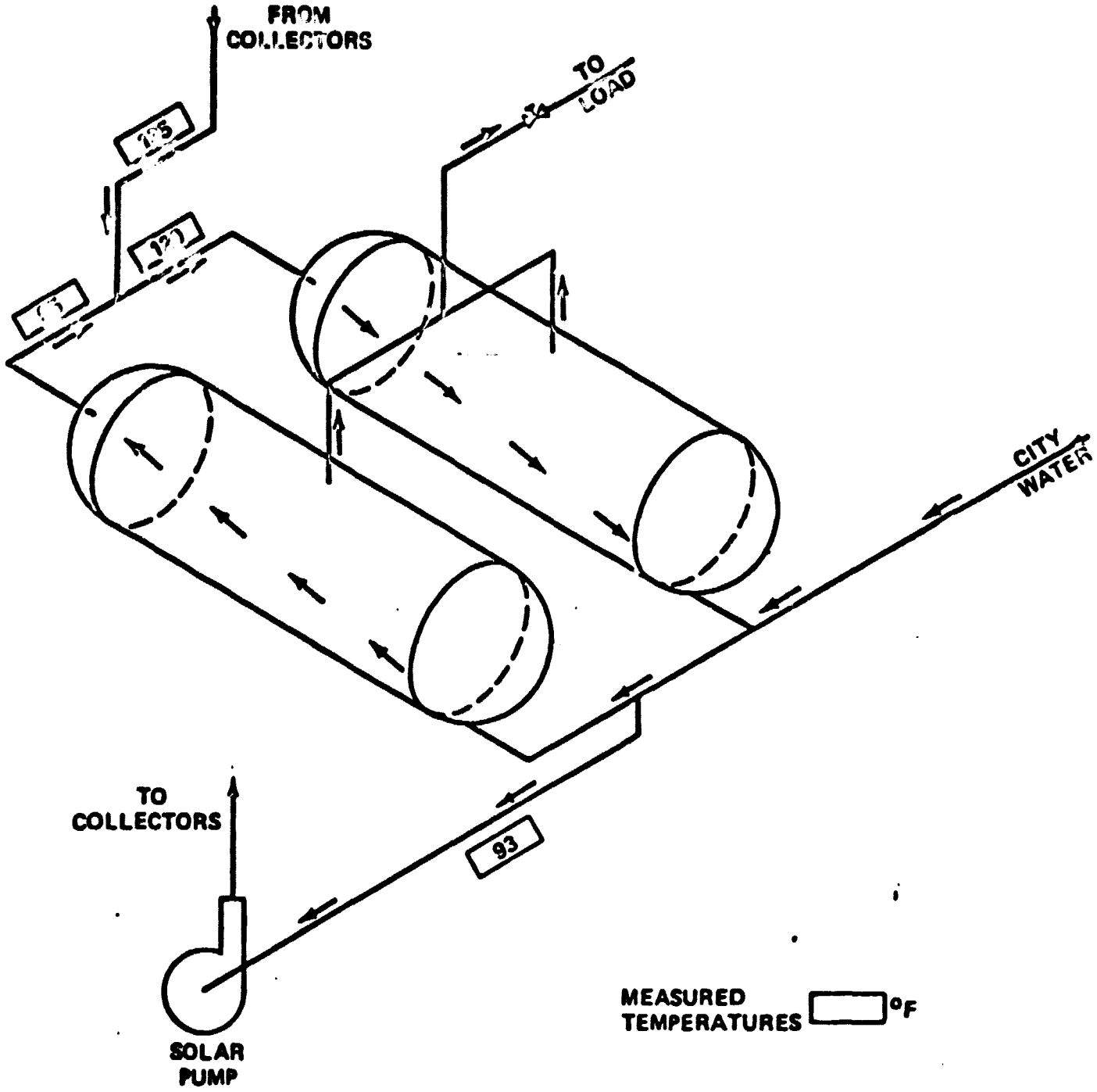

FIGURE 1

☆ U.S. GOVERNMENT PRINTING OFFICE 1980 - 640 247/474 REGION NO. 4