DOE NASA CONTRACTOR REPORT

DOE NASA CR-161537

SOLAR HOT WATER DEMONSTRATION PROJECT AT RED STAR INDUSTRIAL LAUNDRY, FRESNO, CALIFORNIA - FINAL REPORT

Prepared by

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Under DOE Contract EX 76-C-01-2384

Monitored by

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George C. Marshall Space Flight Center. Alabama 35812

For the U. S. Department of Energy

(NASA-CR-161537) SOLAR HOT WATER DEMONSTRATION PROJECT AT RED STAR INDUSTRIAL LAUNDRY, FRESNO, CALIFORNIA Final Report (ARATEX Services, Inc.) 82 p HC A05/MF A01 CSCL 10A

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U.S. Department of Energy

Solar Energy

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SYSTEM DESCRIPTION

SECTION 1.0 INTRODUCTION & SUMMARY

In response to a request by Truman Temple and Associates in November 1975, ARATEX Services, Inc. (then Work Wear Corporation) agreed to participate in a response to a Phase I Program Opportunity Notice (PON-I) issued by the U.S. Department of Energy (DOE), then the Energy Research and Development Administration (ERDA). At that time it was decided that the Red Star Industrial Service Laundry at 3333 No. Sabre Avenue, Fresno, California would be an ideal site to demonstrate energy conservation through the use of an advanced wastewater heat recovery system combined with solar pre-heating of the incoming water. With a projected future hot water consumption of 60,000 gallons per day, the plant was considered to be representative of the typical medium sized industrial laundry facility. Other considerations in the site selection included:

- Proximity to a National Weather Service Station at the Airport, approximately 1 mile away, from which good meteorological data could be derived.
- Seasonal weather conditions which range from foggy, cloudy, freezing conditions in winter to very low humidity and summer temperatures exceeding 100° F.
- A building constructed within the last 10 years, having a reasonably flat roof.

Following announcement of the award of a contract to the Work Wear Corporation in April 1976, it became apparent that Truman Temple and Associates lacked the facilities to produce the large number of flat-plate collectors required for this particular project. Subsequent negotiations with other solar collector contractors confirmed the fact that it was going to be very difficult to find a contractor who could produce the required number of collectors in conformance with the specifications laid down, specifically with respect to the weight of the individual collectors. It was recognized, even at this early stage of the project, that roof loading was going to be a critical problem. Similar problems were encountered in obtaining performance data from most of the manufacturers. A further problem related to the inadequacy of the funding proposed for this project. Protracted negotiations with the Energy Research and Development Administration failed to achieve any resolution of this problem. Finally, the California State Energy Commission agreed to provide additional funding in the amount of $17,000.00 to the project. The Energy Research and Development Administration agreed to fund the project to a maximum of $165,000.00. With this total of $182,000.00, plus an estimated $51,000.00 to be contributed by the Contractor, it appeared that the project was viable.

Meanwhile, in the interest of energy conservation, the Contractor had decided to go ahead with the installation of an advanced wastewater heat recovery system. Work was completed on this phase of the project in early 1976. Final system definition and selection of Ying Manufacturing Corporation as the supplier of the flat-plate collectors was not completed until late in 1976. In November 1976, one year after the submittal of the proposal, a joint venture team consisting of Ying Manufacturing Corporation of Gardena, California with Clark Mechanical Inc. of Long Beach, California was selected for the installation of the solar system. Contracts were signed at that time. The solar system was to consist of 6,500 square feet of flat-plate collectors, with a 12,500 gallon storage tank integrated into the wastewater heat recovery system and auxiliary process hot water system at the facility. Theoretical performance data for the system is presented in Section 6.0 of this report. Following preliminary and final design reviews with NASA personnel, fabrication of the solar system was commenced in December 1976. At that time, work was also begun on site preparation, which included resurfacing of the roof to accept the solar array. Work proceeded smoothly on the manufacture of the solar panels through March 1977, when the panels and storage tank were delivered to the site. Installation and integration of the system and work was essentially completed in July 1977. The installation of IBM Instrumentation, for which a separate contract was awarded, led to a delay of between two and three weeks in completion and start-up of the system. Subsequently, it has been found necessary to make additional modifications to the instrumentation, which were not completed until August 1978. Accurate performance data on the system has only recently become available (September 1978).

The system was declared operational at the end of July 1977, and was formally dedicated by California's Governor Brown on September 23, 1977. The system is, at this time, fully operational and has been since the end of July 1977, although some minor storm damage was experienced in January 1978. In addition to the need to repair the storm damge, which included breakage or partial separation of several of the Lexan covers and some damage to the absorptive coating, there is a need to study the phenomena, believed to be electro-static, which has resulted in excessive accumulation of dust in the Lexan covers. Ninety (90) of the solar collector panels have been resurfaced and reglazed, using Tedlar. It is anticipated that the remaining fifty (50) panels will eventually be re-worked, if DOE funding is made available to the project.

SECTION 1.1 WASTEWATER HEAT RECOVERY SUBSYSTEM

This subsystem, responsible for between 35% and 40% reduction in energy used for process water heating, consists of the following elements:

- Ludell insulated tube-and-shell heat exchanger (Three 8" dia. x 20' sections)
- Hydr-O-Matic wastewater pump (4") with 5 H.P. motor.
- Mercoid low-level cut-off switch and high level override.
- DeZurik (or equivalent) butterfly valves for flow regulation of cold water and wastewater.
- DeZurik 4-port 2-way backflush valve, with pneumatic actuator and timer.
- Control circuits associated with demand control by the solar subsystem or the auxiliary energy subsystem.

In the "NORMAL" mode of operation, the wastewater pump serves to transfer energy from the wastewater storage pit (16,000 gallons maximum capacity) through the tube-and-shell heat exchanger to the incoming city water, which has been softened by ion exchange.

The control circuits and flow rates are set to transfer energy on a near-continuous basis from wastewater to incoming water during the working day. This ensures maximum effeciency of heat transfer, while satisfying the basic requirement for optimum system U-value (Btu/hr/ft^2/^{o}F.). The "Approach Temperature" or temperature differential between wastewater inlet temperature and freshwater outlet temperature (typically between 3^{o}F. and 8^{o}F.), is a measure of the efficiency of heat transfer.* The system was designed to improve the figure-of-merit for hot water supplied to the plant from 78.3 gallons of hot water/therm to 138.5 gallons/therm.

During the "WEEK-END" mode (See Section 1.2, below) the heat exchanger and wastewater pump - with associated change-over valves - are used to transfer excess heat from the solar storage tank at temperatures above 190^{o}F. to pre-heat wastewater for a "Hot Start" at the end of a week-end or holiday. Unfortunately, operational problems not directly associated with this subsystem or the solar subsystem have so far precluded full utilization of this mode. In brief, the necessity for frequent pump-out of the wastewater pit at weekends to prevent excessive build-up of sludge and pollutants has prevented the full capabilities of the week-end mode from being realized. Alternate sludge removal procedures are currently being investigated, together with a timed drain/re-fill system.

* Older, less efficient heat exchangers, if used at all, may have approach temperatures of 10^{o}F. to 25^{o}F., being considerably less efficient.

SECTION 1.2 SOLAR SUBSYSTEM

This subsystem, designed for a nominal input to the hot water supply system of 2×10^9 BTU/year, is designed to derive the maximum benefit from the total insolation at the site through the use of two alternate modes of operation; the "NORMAL" mode and a "WEEK-END" mode of operation. (See Figure 1-1)

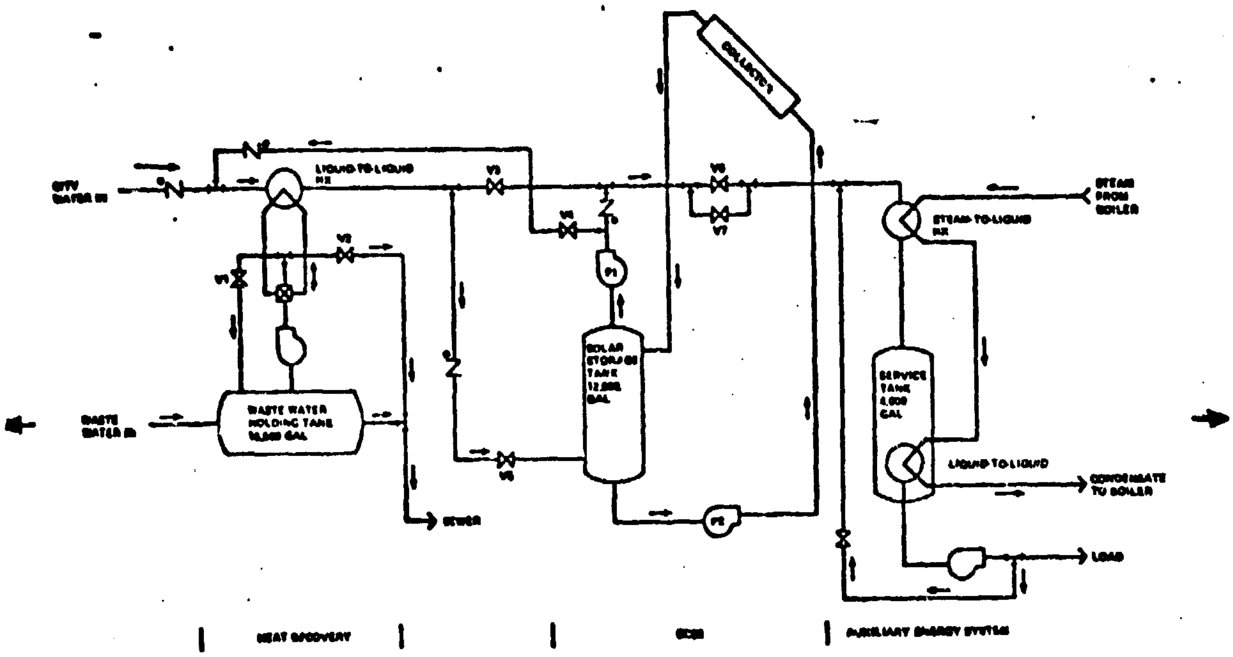

FIGURE 1.1

ARATEX SOLAR ENERGY SYSTEM SCHEMATIC

During the normal mode of operation, the sequence of events is as follows:

Hot water demand on the auxiliary hot water tank activates a level control to open V-6, allowing preheated water from the solar storage tank to be transferred by P-1 to the auxiliary storage tank. Water withdrawn from the solar storage tank is replaced when a level control in the solar storage tank opens V-5, allowing fresh water to flow into the storage tank via the wastewater heat recovery exchanger through V-5. In the event that there is an unusually heavy demand for hot water from the auxiliary storage tank, a second level control on this tank activates V-3, thereby providing additional flow from the wastewater heat exchanger directly through the large diameter by-pass valve V-7 to the auxiliary storage tank. Under these conditions, fresh water is being supplied both from the solar storage tank by P-1 and from the wastewater heat exchanger directly through V-3, passing to the auxiliary storage tank through V-6 and V-7, both of which are open at this time.

Provided that there is sufficient wastewater in the pit, the wastewater circulating pump will be activated whenever there is a demand for fresh water by the solar storage tank; indicated by the opening of V-5. A timer is activated whenever the wastewater pump is operating to enable the wastewater heat exchanger to be back-flushed. Identical timers are used to initiate or discontinue circulation of water through the solar collectors after pre-set delays. Solar pumps P2-A and P2-B are activated by these timers, which serve to minimize circulation of water through the solar collectors due to intermittent insolation caused by clouds and spurious start-up at the beginning of the day. A solar temperature control unit inhibits operation of the solar collector loop when the temperature differential between the collectors and the solar storage tank temperature is less than 4.5°F. Similarily, this same unit shuts off P2-A and P2-B, allowing the solar collectors to drain back to the solar storage tank when the temperature differential between the solar collectors and the storage tank is less than 1.5°F.

In the "WEEK-END" mode of operation, activated by a manually controlled switch on the control panel, the solar collector loop and P2-A/P2-B operate under automatic control of the solar temperature control unit. In this mode of operation, neither cold water nor compressed air are normally available for use by the subsystems. Consequently, all valves and controls in this mode have to be electrically operated or make use of spring-return for actuation. Excluding only the solar collector circulation loop, all controls and pumps are normally quiescent until the temperature of the water in the solar storage tank reaches 170°F.

When the solar storage tank temperatures exceed 170°F., water from the solar storage tank is circulated by P-1 through V-4 and the wastewater heat exchanger back to the solar storage tank via V-5. Simultaneously, the wastewater pump P-3 is activated to circulate wastewater through the heat recovery unit, thereby transferring heat from the solar storage tank to the wastewater pit. This mode of operation continues until the temperature of the solar storage tank drops to 160°F., at which point the recirculating loop is disabled by the same temperature controller previously used for initiation of the recirculation cycle. It should be noted here that all temperature and level controls have a differential band over which they operate. This feature contributed significantly to the simplification of the control system for this project.

In the unlikely event that the temperature in the solar storage tank reaches 190°F., a high level temperature collector disables the solar collector circulating loop allowing the collectors to drain back into the storage tank. This condition obtains only if the level in the wastewater pit is too low to allow the wastewater pump P-3 to be activated, thereby inhibiting heat transfer to the wastewater pit. To mitigate this problem, a timed drain and re-fill system is being considered, in order to lower the initial storage tank temperature from 115°F. to 75°F. at week-end.

For diagnostic purposes, supplemented by alarm and display circuits discussed earlier, all pumps can be operated manually from the control panel. Alarm circuits and the display board allow for near instantaneous diagnosis of any major system component failure.

SECTION 1.3 SYSTEM INTEGRATION

The tie-in of the solar subsystem to the existing wastewater heat recovery subsystem and the auxiliary heating subsystem on a non-interference basis presented a few problems for the following reasons:

- The cold water tank, solar tank and auxiliary tank were not pressurized, i.e. they were open to atmosphere. They could, therefore, be by-passed at any time during system integration.
- An adequate number of by-pass valves had been provided, prior to installation of the solar subsystem, to allow for easy integration of all hydraulic connections.
- Extensive on-site instrumentation was provided - at no expense to the contract - including a manometer, pressure and temperature gauges, to allow all elements of the solar subsystem to be calibrated and tested with no interference to plant operations.
- The single electrical tie-in to the auxiliary subsystem, involving a change of operating voltage on valves V-6 and V-7 by the replacement of solenoids and rewiring in the solar control panel, was effected in two hours following plant shut-down in the evening.

System integration, test and calibration was completed in two days, with less than 30 hours man-hours of effort.

It cannot be too strongly emphasized that provision of adequate on-site instrumentation with analog read-out is essential to smooth integration of large systems. The failure of D.O.E. to provide an on-site monitor (OSM) to the project could have seriously jeopardized the test and integration phase of the project, if adequate instrumentation had not been provided by the sub-contractors at their own expense.

SECTION 1.4 SITE AND BUILDING DESCRIPTION

The site and building description has been adequately covered in earlier documentation.

Summary information presented in this report was prepared by Planning Research Corporation Energy Analysis Company, and is reproduced here only for the sake of completeness of this report.

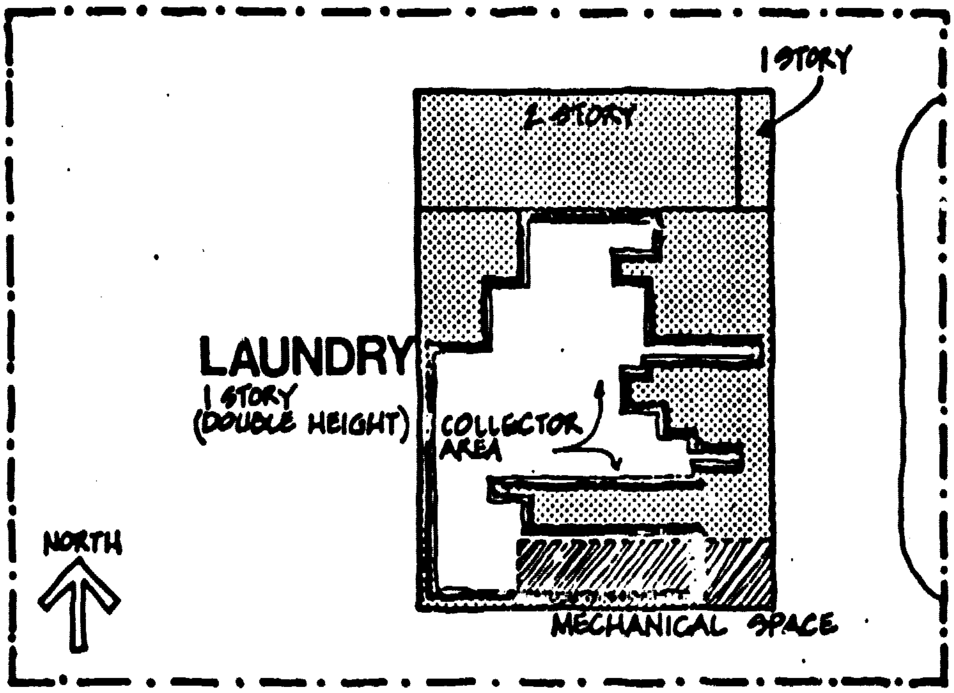

FIGURE III-1
Site Plan

Site Description

- Special topographic and climatic conditions - NONE
- Area topographic description - NONE
- Latitude - 36.75° N
- Annual degree days (65°F base)
  - Heating - 2699
  - Cooling - 1437
  - Data location - Fresno, California
  - Data source - "Local Climatological Data, Annual Summaries for 1976", U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

- Average horizontal insolation
  - January - 1750 BTU/FT^2-DAY
  - July - 2228 BTU/FT^2-DAY
  - Data location - Fresno, California
- Site topographic description - FLAT
- Shading - NONE

Building Description

- Occupancy - INDUSTRIAL LAUNDRY
- Total building area - 32,500 FT^2
- Solar conditioned space - NONE
- Number of stories - one story, approximately 20 FT high in laundry area, and about 20% of total floor area has a second story (above office space).
- Roof slope - FLAT
- Special features - Combined solar hot water and wastewater heat recovery system - large single collector area.

Structure

- Walls
  - Frame - CONCRETE TILT-UP PANELS
  - Exterior finish - PAINTED CONCRETE
  - Insulation - NONE
- Interior finish - PAINTED CONCRETE
  - Windows - NONE
  - Doors - About 60% of rear (west) wall of laundry section opens with motorized overhead roll-up doors (12 FT x 14 FT), approximately 1,000 FT^2 overall

- Roof
  - Frame - STEEL BEAMS, METAL JOISTS, CORRUGATED METAL ROOFING
  - Exterior finish - 3 LAYERS BUILT-UP ROOF WITH GRAVEL
  - Insulation - R-8, 2 IN OF RIGID INSULATION
  - Interior finish - PAINT
  - Roofing protection - Additional strip of rolled roofing laid between collectors.
- Floor - CONCRETE SLAB ON GRADE

SECTION 2.0

ACCEPTANCE TEST PLAN

SECTION 2.0 GENERAL

Following the Final Design Review with NASA personnel, an Acceptance Test Plan was drawn up and approved by NASA. The Acceptance Test Plan Schedule and the Acceptance Test Plan Reports follow in Section 2.1 of this report. It should be pointed out that in dealing with commercial contract... it is difficult to follow the format and procedures normally followed on government contracts. Commercial contractors are, in general, not familiar with government procedures; nor does the funding on these demonstration projects allow for the formal procedures to be followed. On this project in particular, shortage of funds and personnel limited the usefulness of the Acceptance Test Plan as a configuration management tool.

SECTION 2.1 ACCEPTANCE TEST PLAN AND SCHEDULE

It should be noted that Item 5.0 of the Acceptance Test Plan was not documented by the Project Manager, since the tasks under Item 5.0 were, theoretically, strictly supervisory under the jurisdiction of IBM. However, it should be further noted that funding limitations and the exigencies of the program were such that much of the electrical interfacing between the sensors and the SDAS were performed personally by the Project Manager and the Plant Engineer at no cost to the project.

2.1 ACCEPTANCE TEST PLAN (ATP)

NO.	ITEM	INSPECTION/TEST REQUIREMENTS	LOCATION	INSPECTION/TEST DATE (1977)
ATP 1.0	SOLAR PANELS			
1.1		VISUAL INSPECTION	YING MFG., CA	END-MARCH
1.2		PERFORMANCE TEST	DESERT SUNSHINE, ARIZONA	END-MARCH
1.3		PRESSURE TEST	YING MFG., CA	MARCH (DURING ASS'Y)
1.4		FLOW CONTROLLER P/V TEST	YING MFG., CA	MID-MARCH
ATP 2.0	STORAGE TANK			
2.1		VISUAL INSPECTION & LEAK TEST	FRESNO, CA	END-MARCH
2.2		VISUAL INSPECTION OF INSULATION	FRESNO, CA	1ST WEEK APRIL
ATP 3.0	ON-SITE INSTALLATION			
3.1		VISUAL INSPECTION OF ROOF	FRESNO, CA	END-MARCH
3.2		VISUAL INSPECTION OF SUPPORT STRUCTURE	FRESNO, CA	END-MARCH
3.3		VISUAL INSPECTION OF PLUMBING	FRESNO, CA	1ST WEEK APRIL
3.4		PRESSURE TESTS AT 60 psi	FRESNO, CA	MID-APRIL
ATP 4.0	CONTROL SYSTEM			
4.1		VISUAL INSPECTION		MID-APRIL
4.2		FUNCTIONAL TEST OF NORMAL MODE		END-APRIL
4.3		FUNCTIONAL TEST OF FAIL-SAFE MODES		END-APRIL
4.4		FUNCTIONAL TEST OF WEEKEND MODE		END-APRIL
ATP 5.0	INSTRUMENTATION			
5.1		VISUAL INSPECTION OF WIRING, SENSOR INSTALLATION, J-BOX AND SDAS INSTALLATION	FRESNO, CA	MAY
5.2		CALIBRATION OF SENSORS	FRESNO, CA	MAY
5.3		INTERFACE WITH SDAS	FRESNO, CA	MAY

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
TP 1.0 Solar Panels	1.1 Visual Inspection	Visual Inspection of Solar Panels during Fabrication, Assembly, and Packaging for Transport.	O.K.	No Problems during fabrication.

INSPECTION/TEST PERFORMED BY: Ying-Nien Yu	APPROVED BY: Eric S. Burnett
SIGNATURE: Ying-Nien Yu DATE: 3/28/77	SIGNATURE: Eric S. Burnett DATE: 3/28/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
TP 1.0 Solar Panels	1.2 Performance Test	Review of Test Data	Apparently consistent with theoretical estimates of performance based on very limited data at reduced flow rates from Desert Sunshine test facility.	Additional test data at required flow rate of 1.5 to 2 gpm requested ASAP.

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INSPECTION/TEST PERFORMED BY: Ying-Nien Yu
SIGNATURE: [signature] DATE: 3/25/77

APPROVED BY: Eric S. Burnett
SIGNATURE: [signature] DATE: 3/25/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
TP 1.0 Solar Panels	1.3 Pressure Test	Pressure test performed on each panel at 140 P.S.I.	98%	New technique for assembling water ways to headers using plasma arc welding - first applied to this project - very satisfactory.

INSPECTION/TEST PERFORMED BY: Ying-Nien Yu		APPROVED BY: Eric S. Burnett	
SIGNATURE: Ying-Nien Yu	DATE: 3/25/77	SIGNATURE: Eric S. Burnett	DATE: 3/25/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
TP 1.0 Solar Panels	1.4 Flow Controller P/V test.	Flow Controller P/V test on selected units at variable flow rates.	Available constant flow controllers have excessive pressure drop; need modification.	Units modified by increasing orifice diameter to stabilize pressure drop at lower value (<1.5 PSI) for design flow rate of 2.0 gpm. Re-inspected and found to be O.K.

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INSPECTION/TEST PERFORMED BY: Ying-Nien Yu		APPROVED BY: Eric S. Burnett	
SIGNATURE: Ying-Nien Yu	DATE: 3/4/79	SIGNATURE: Eric S. Burnett	DATE: 3/4/79

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE
3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
TP 2.0 Storage Tank	2.1 Visual Inspection and Leak Test	Tank was inspected and leak tested on site prior to application of foamed insulation & aluminum protection.	O.K.	None.

INSPECTION/TEST PERFORMED BY: Ying-Nien Yu		APPROVED BY: Eric S. Burnett	
SIGNATURE: [signature]	DATE: 4/25/77	SIGNATURE: [signature]	DATE: 4/25/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE
3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
TP 2.0 Storage Tank	2.2 Visual Inspection of Insulation	Visual examination and depth measurements of insulation during foaming operation.	O.K.	Results were outstanding.

INSPECTION/TEST PERFORMED BY: Ying-Nien Yu		APPROVED BY: Eric S. Burnett	
SIGNATURE: Ying-Nien Yu	DATE: 4/25/77	SIGNATURE: Eric S. Burnett	DATE: 4/25/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE
3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
ATP 3.0 On-site Installation	3.1 Visual Inspection of Roof.	Visual inspection of roof during various stages of gravel removal and re-surfacing.	1 Inadequate removal of gravel due to time constraints and labor problems. 2 Roof loading factors inadequate to allow re-surfacing at coverage of 300 lbs/ square. 3 Surface tacky during periods of hot weather; difficult to work on.	The least satisfactory part of the whole project.

INSPECTION/TEST PERFORMED BY: Eric S. Burnett	APPROVED BY: Eric S. Burnett
SIGNATURE: Eric S. Burnett — DATE: 3/25/77	SIGNATURE: Eric S. Burnett — DATE: 3/25/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
ATP 3.0 On-site Installation	3.2 Visual Inspection of Structure	Visual Inspection of a) Wooden sub-framing b) Metal Support Structure for Solar Panels	a) Generally satisfactory but some concern over integrity of weather proofing of roof at sub-frame attachment points. b) Metal Support Structure - OK	a) In future projects an alternate method of attachment must be devised. b) None

INSPECTION/TEST PERFORMED BY: Eric S. Burnett		APPROVED BY: Eric S. Burnett	
SIGNATURE: Eric S. Burnett	DATE: 5/2/77	SIGNATURE: Eric S. Burnett	DATE: 5/2/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
TP 3.0	3.3 Visual Inspection of Plumbing	Visual inspection of plumbing at all stages of installation.	O.K.	None

INSPECTION/TEST PERFORMED BY: Richard Blumenthal		APPROVED BY: Eric S. Burnett	
SIGNATURE: [signature]	DATE: 5/2/77	SIGNATURE: [signature]	DATE: 5/2/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
TP 3.0 On-Site Installation	3.4 Pressure tests at 60 P.S.I.	Use city water pressure (24-hour test) for leak detection.	Three small leaks only in laterals; no-leaks in headers.	None.

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INSPECTION/TEST PERFORMED BY: Richard Blumenthal	APPROVED BY: Eric S. Burnett
SIGNATURE: [signature] DATE: 5/2/77	SIGNATURE: [signature] DATE: 5/2/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
ATP 4.0 Control System	4.1 Visual Inspection	Visual Inspection of Wiring and Sensor Installation.	O.K.	None.

INSPECTION/TEST PERFORMED BY: Eric S. Burnett		APPROVED BY: Eric S. Burnett	
SIGNATURE: Eric S. Burnett	DATE: 7/1/77	SIGNATURE: Eric S. Burnett	DATE: 7/1/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE 3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
ATP 4.0 Control System	4.3 Functional test of Fail-Safe Modes	Sequential test of electrical, pneumatic & hydraulic failure modes.	1) Loss of 110 volt control voltage could cause exhaustion of boiler-room hot water tank without warning, resulting in damage to condensate return heat exchanger in tank. 2) Indicator lights on pumps did not indicate pump outage. 3) Possible to "dead-head" P_1 when V_3 open & V_7 open, with possible burn-out of P_1 motor.	Necessary electrical changes made.

INSPECTION/TEST PERFORMED BY: Eric S. Burnett		APPROVED BY: Eric S. Burnett	
SIGNATURE: Eric S. Burnett	DATE: 7/30/77	SIGNATURE Eric S. Burnett	DATE 7/30/77

ACCEPTANCE TEST OF THE SOLAR HOT WATER HEATING DEMONSTRATION PROJECT (INDUSTRIAL LAUNDRY) AT RED STAR INDUSTRIAL SERVICE
3333 SABRE AVENUE, FRESNO, CA

PROJECT ELEMENT	PROJECT SUB-ELEMENT	ACCEPTANCE INSPECTION/ TEST DESCRIPTION	RESULTS OF INSPECTION OR TEST	COMMENTS
ATP 4.0 Control System	4.4 Functional test of week-end mode.	Set temperature limits and operate system up to 190° F. during week-end to confirm operation to reverse heat-reclaimer loop.	O.K.	None.

INSPECTION/TEST PERFORMED BY: Eric S. Burnett	APPROVED BY: Eric S. Burnett
SIGNATURE: Eric S. Burnett DATE: 7/30/77	SIGNATURE: Eric S. Burnett DATE: 7/30/77

SECTION 2.2 TEST RESULTS AND CORRECTIVE ACTIONS

The Acceptance Test results and corrective actions are summarized in the data sheets of the previous section. Enumerated in this section are certain specific problems, the solutions of which are considered relevant to similar solar hot water heating installations for industrial applications.

1 Assembly of Collector Tubes to Headers

Having had difficulty in attaining a satisfactory acceptance rate for solar collectors in which the stainless steel tubes and headers had been brazed, the decision was made to use plasma arc welding throughout. This proved to be a very cost-effective technique for use with thin-wall stainless steel tubing, since process cost was more than offset by reduced rejection rates (2%).

2 Modification of Constant Flow Controllers

At the time of initiation of the project, available constant flow controllers operating at 2.0 gpm had an excessive pressure drop which could only be mitigated, but not completely eliminated by increasing the orifice diameter. More recently, improved units have become available from other manufacturers with better P-V characteristics at low flow rates (1 to 2 gpm).

3 Inadequate Roof Loading Factors

Despite the use of the Ying collectors, with an installed roof loading factor of only 2 lbs/ft^2, it proved impossible to meet all the requirements for resurfacing the roof in accordance with the specification of 300 lbs/square (3 lb/ft^2) without exceeding the maximum permissible loads in certain areas (see Section 7.0). Consequently, it was necessary to compromise through the use of light weight lava rock between the solar arrays and minimum gravel surfacing below the solar collectors.

4 Integrity of Collector Support Structure Attachments

The large number of penetrations for structural support of the collectors led to considerable problems in waterproofing the roof. (Penetrations for plumbing caused minimal problems, since laterals, risers and headers could be flashed.) This problem has not been completely overcome at this time. Pressure injection of a hot sealant is being considered to mitigate the problem.

5 Fail-Safe Modes of Operation

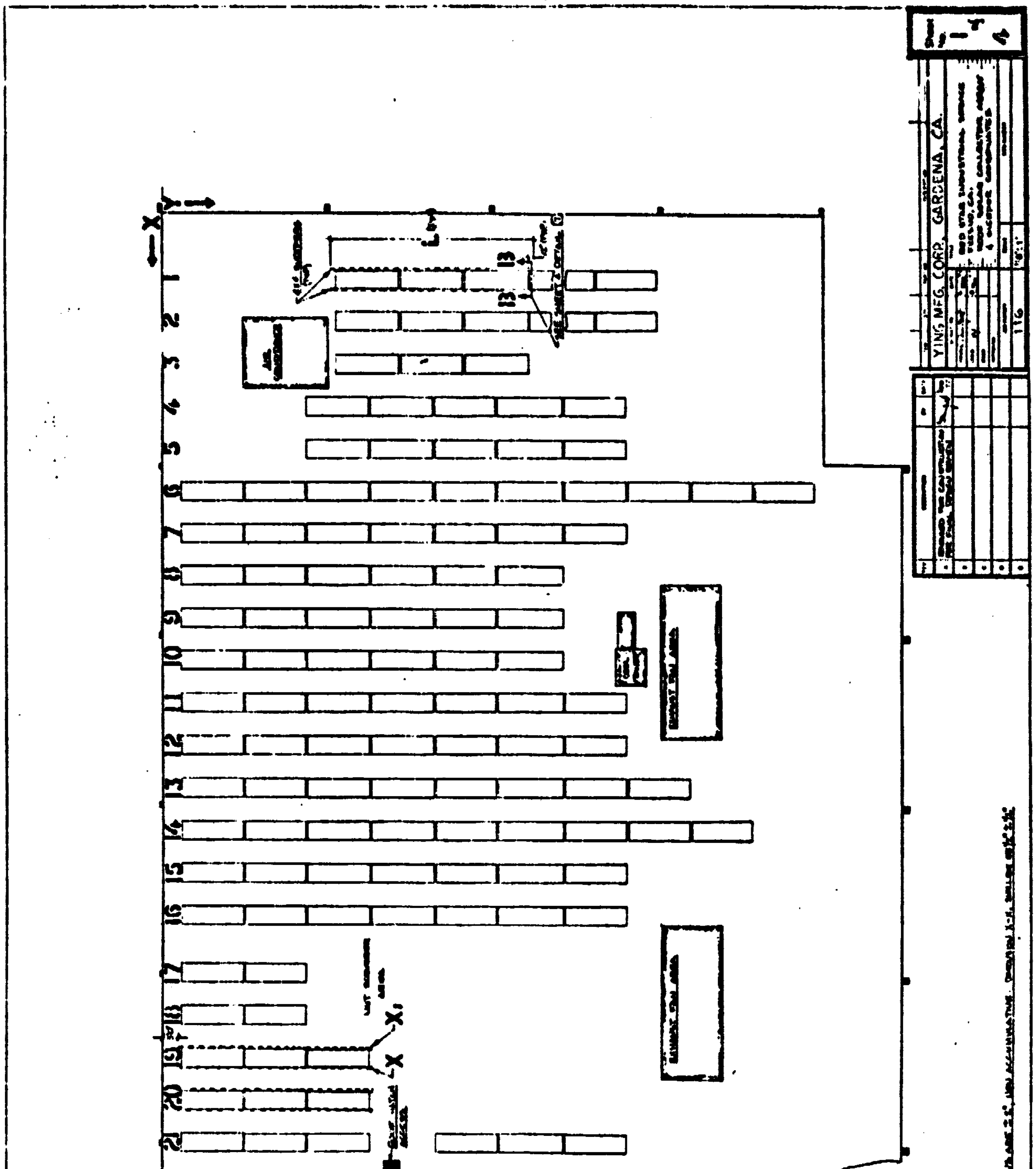
As discussed in Section 2.1, Sheet 12 of the Acceptance Test Plan data, preliminary system tests indicated the need for additional alarm circuits to mitigate against specific fault conditions. Additional alarm circuits were installed to provide audible and visual warning of these fault conditions, since which time the system has operated in a totaly "hands-off mode" for over 2½ years without a single malfunction.

SECTION 3.0

ENGINEERING DRAWINGS

WIRING AND PIPING SCHEMATICS

Sheet 1	-	Roof Solar Collector Array & Sleeper Coordinates
Sheet 2	-	Mechanical & Control Schematic; Sequencing Logic
Sheet 3	-	Piping & Collector Details
Sheet 4	-	Installation Details



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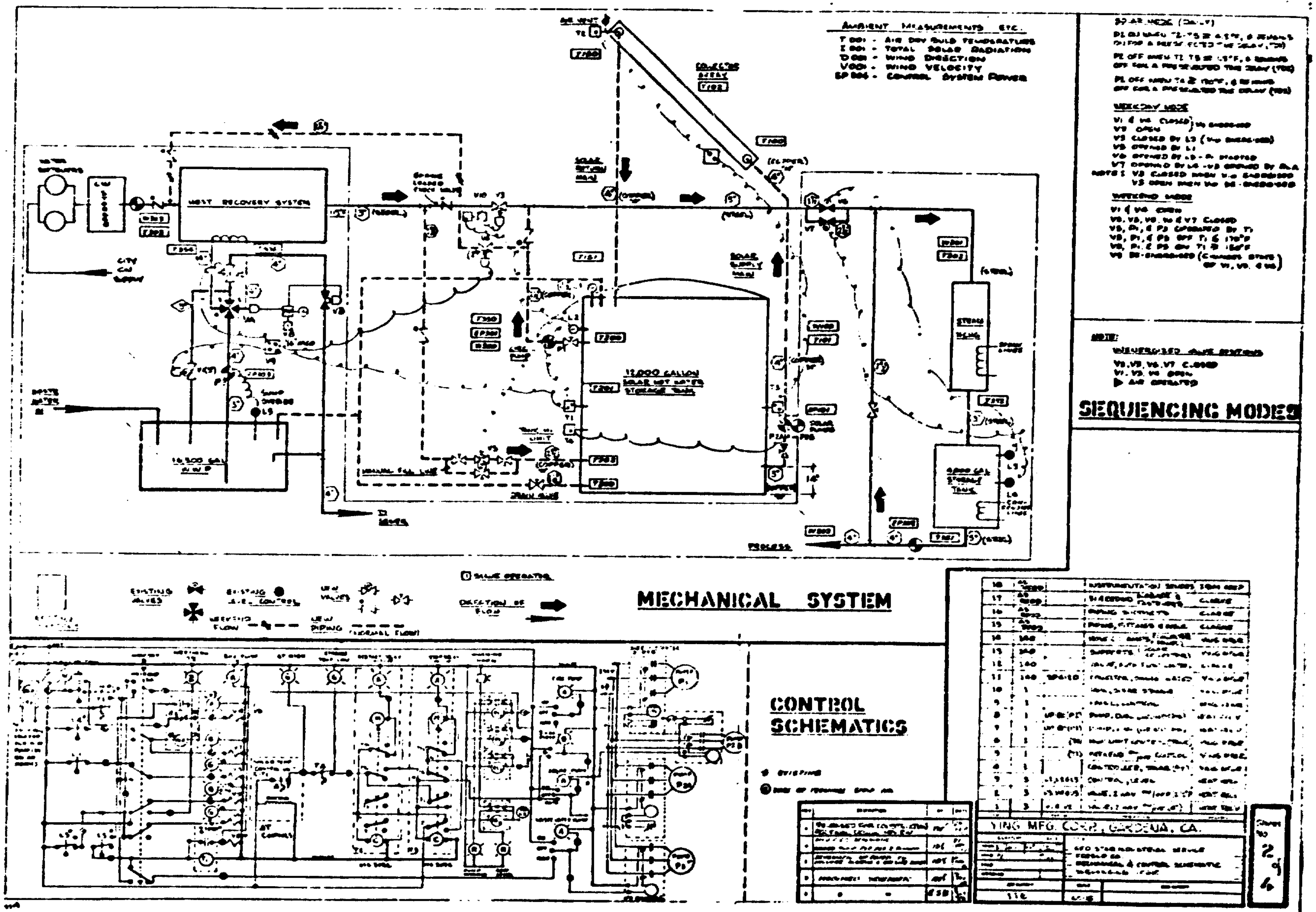
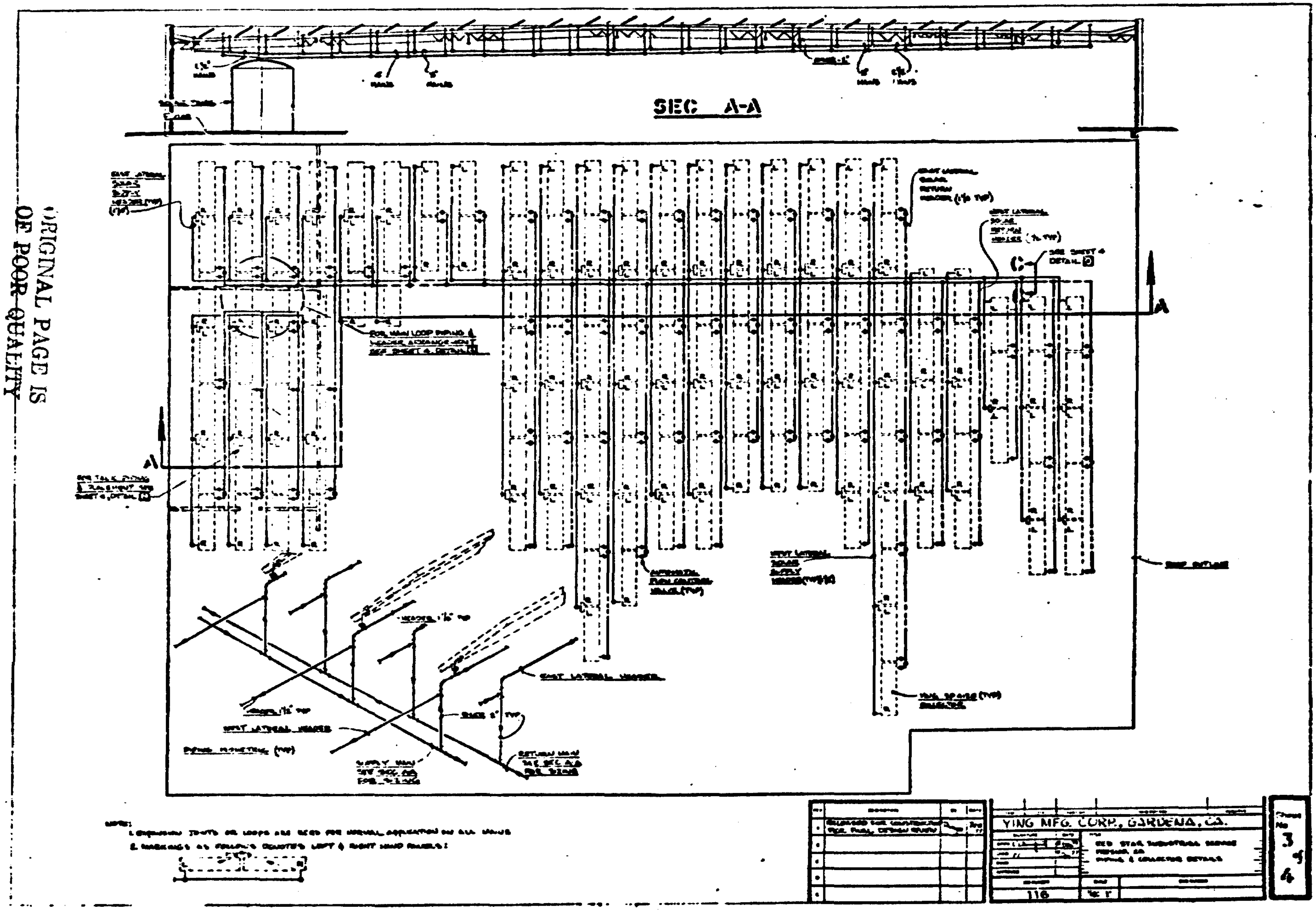


AMBIENT MEASUREMENTS ETC.
HEAT RECOVERY SYSTEM
12,000 GALLON SOLAR HOT WATER STORAGE TANK
SEQUENCING MODES
MECHANICAL SYSTEM
CONTROL SCHEMATICS
YING MFG. CORP. GARDENA, CA.



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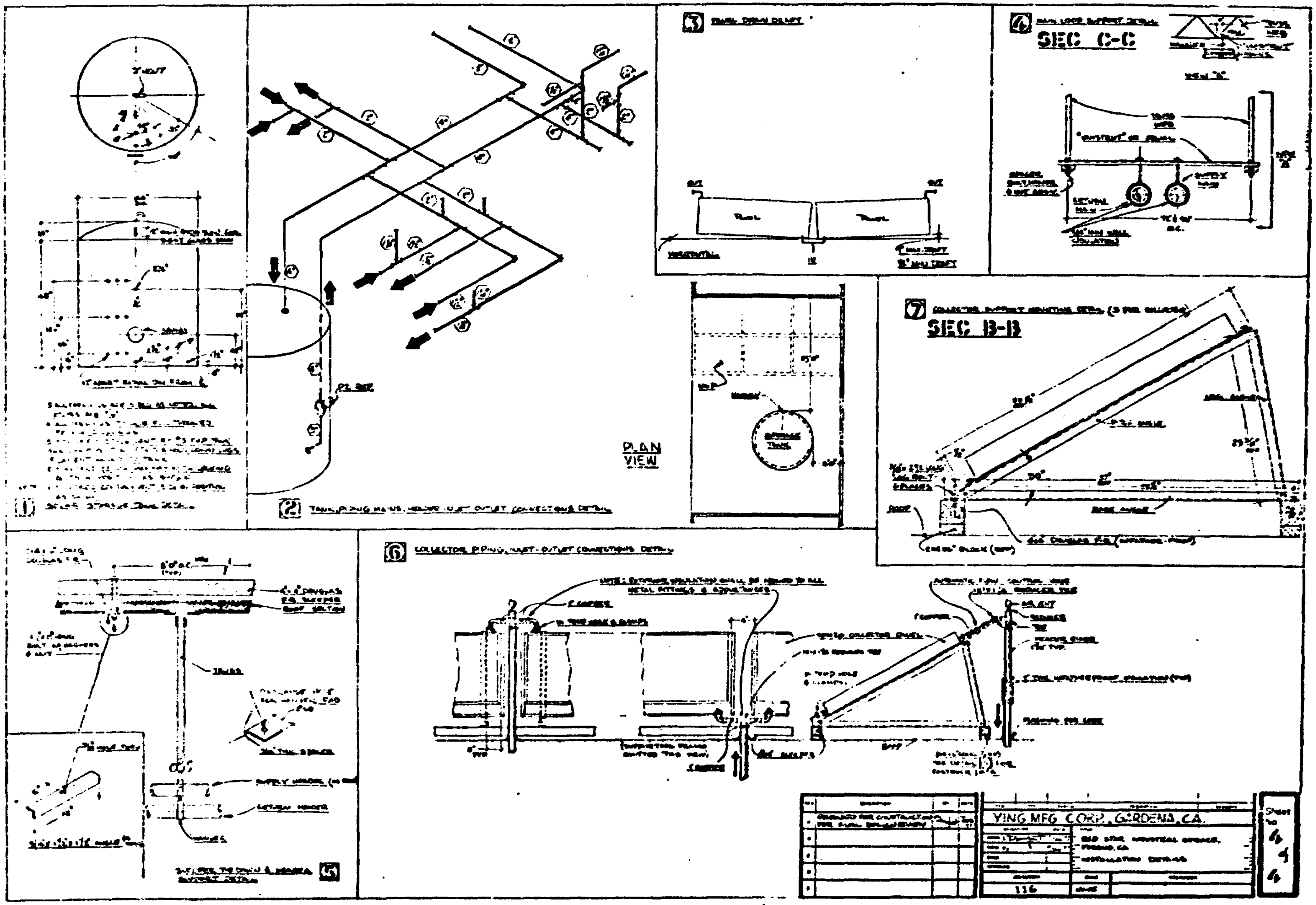


SEC C-C
SEC B-B
PLAN VIEW
YING MFG CORP, GARDENA, CA.

SECTION 4.0

OPERATION AND MAINTENANCE INSTRUCTIONS

SECTION 4.0 OPERATION AND MAINTENANCE INSTRUCTIONS

Introduction

The total system as designed comprises three major subsystems:

- The wastewater heat recovery subsystem
- The solar subsystem
- The auxiliary hot water subsystem

Each subsystem is capable of independent operation. In the event of a malfunction of the wastewater heat recovery subsystem or the solar subsystem, either or both of the subsystems can be isolated from the auxiliary hot water subsystem. The system configuration allows all cold water coming into the hot water system, after being conditioned in the water softeners, to pass sequentially through the wastewater heat recovery subsystem, the solar subsystem and then to the auxiliary hot water subsystem, where the temperature is raised to 180°F. for use in the plant. The subsystems are designed for a maximum flow rate of 200 gpm of hot water. The system is fully automatic in operation at all times, whether in the "NORMAL" mode of operation or the "WEEK-END" mode (see Subsection 4.1 below). The combination of level controls and temperature probes controls the operation of each of the subsystems. These controls will be described in Subsection 4.1. Audible and visual alarms are provided to indicate loss of control voltage, loss of any of the pumps in the system, low level in the solar hot water tank and low level in the auxiliary hot water tank (see Figure 4-1). Automatic shut-down and drain-down of the solar system, with appropriate time delays, is provided in the event that there is insufficient insolation or low level in the solar hot water storage tank. Dial gauges are provided to measure temperature and pressure in critical elements of the subsystems. Also provided is a display board which serves as a diagnostic tool in the event of a malfunction in addition to the alarms discussed above.

SECTION 4.1 OPERATIONAL MODES

Because lack of funding precluded providing the 23,000 gallons of storage capacity for the solar subsystem that the system design dictated, it was necessary to provide two distinct operational modes: namely, the "NORMAL" mode and a "WEEK-END" mode. This latter mode, never fully operational for reasons outlined below, was designed to transfer heat from the solar storage tank (with a capacity of 12,500 gallons) to the wastewater pit (with a capacity of 16,500 gallons) during week-ends and holidays. The purpose of this mode of operation was to ensure that the maximum amount of solar energy collected during week-end and holiday periods was utilized. With a maximum capacity of only 12,500 gallons and a temperature limitation on the fiberglass storage tank of 190°F., additional storage was required under conditions of maximum insolation during the summer months, which could only be provided by using the thermal capacity of the wastewater pit. Unfortunately, operational considerations, which included the necessity to lower the level in the wastewater pit every other week in order to remove sludge from the pit, have precluded maximum utilization of this capability. This has undoubtedly led to some degradation in system performance, in addition to the added complexity that was added to the solar subsystem.

SECTION 4.2 NORMAL MODE

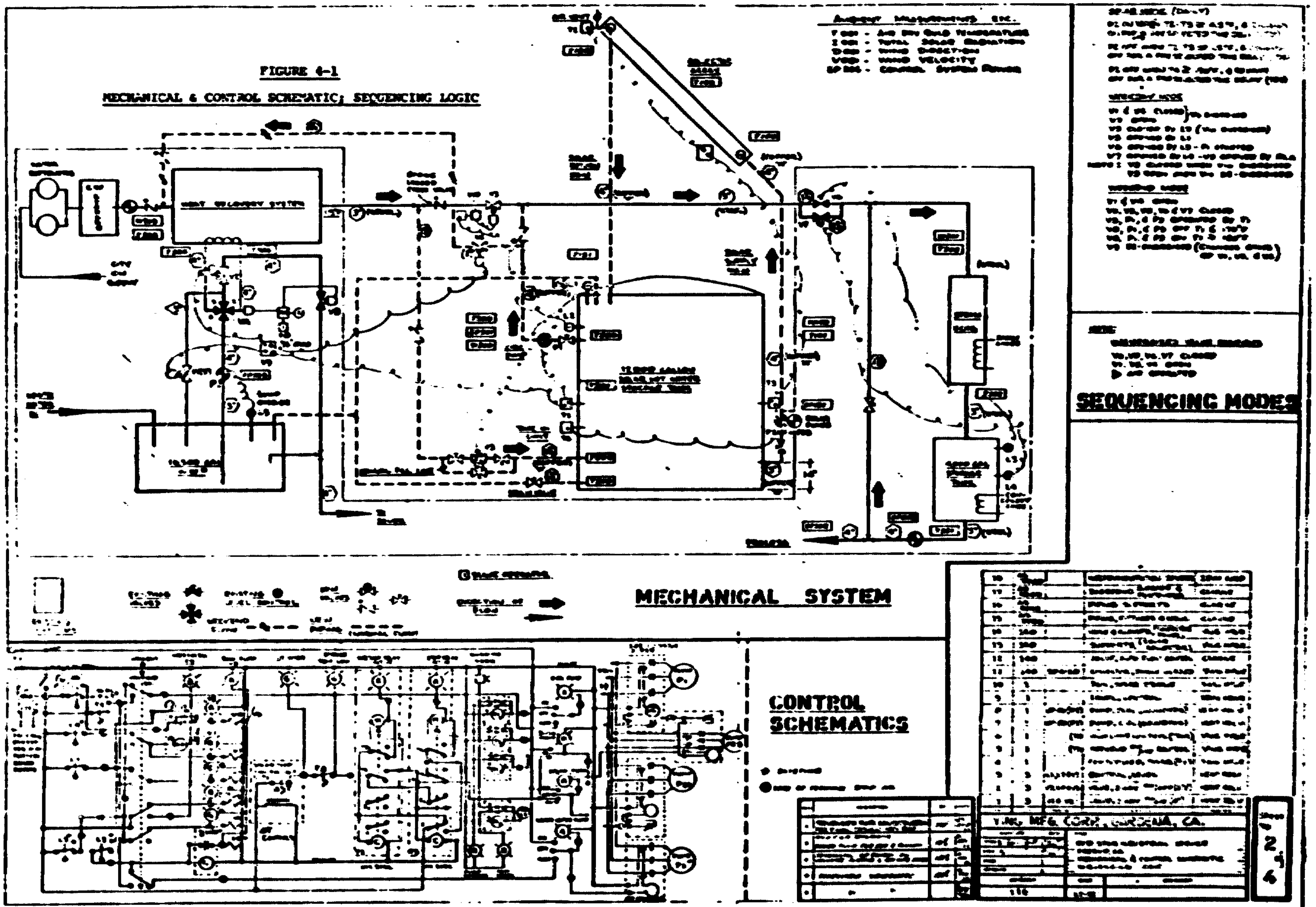
The "NORMAL" mode of operation is characterized by flow-through operation, with initial heat exchange via a three-section tube and shell heat reclaimer from the wastewater to the incoming softened water, followed by solar heating and storage in a 12,500 gallons storage tank from which water at a nominal temperature of 135° F. is withdrawn on demand to the auxiliary hot water storage tank (4,000 gallons). In this tank the water is heated to 180° F. by a steam/water heat exchanger prior to being used on demand by the plant. (The overall system schematic is depicted in Figure 4.1 below.) As a sub-mode of operation, as discussed earlier, it is possible to by-pass either the wastewater heat recovery subsystem or the solar storage subsystem in the event of malfunction. Isolation of the wastewater heat recovery subsystem is performed manually using gate by-pass valves. Isolation of the solar subsystem is performed automatically by the de-activation of V-3, which effectively by-passes the solar storage tank.

During the "NORMAL" mode of operation the sequence of events is as follows:

1. Hot water demand on the auxiliary hot water tank activates a level control (L-3 in the mechanical and control schematic diagram, reproduced as Figure 4.1 in this section of the report), to open V-6, allowing preheated water from the solar storage tank to be transferred by P-1 to the auxiliary storage tank. Water withdrawn from the solar storage tank is replaced when L-1 level control in the solar storage tank opens V-5, allowing fresh water to flow into the storage tank via the wastewater heat recovery

FIGURE 4-1

MECHANICAL & CONTROL SCHEMATIC; SEQUENCING LOGIC



exchanger through V-5, which is an electrically actuated valve. In the event that there is an unusually heavy demand for hot water from the auxiliary storage tank, level control L-4 on this tank activates V-10, an electrically operated pilot valve which in turn activates V-3, thereby providing additional flow from the wastewater heat exchanger directly through the large diameter by-pass valve V-7 to the auxiliary storage tank. Under these conditions, fresh water is being supplied both from the solar storage tank by P-1 and from the wastewater heat exchanger directly through V-3, passing to the auxiliary storage tank through V-6 and V-7, both of which are open at this time.

Provided there is sufficient wastewater in the pit, as indicated by closure of level control L-5, the wastewater circulating pump will be activated whenever there is a cemand for fresh water by the solar storge tank, as indicated by level control L-1 closure and the opening of V-5. Timer T-1 runs whenever the wastewater pump is operating and is used to operate valve V-A: a four way Dezurik valve designed to enable the wastewater heat exchanger to be back-flushed. Identical timers T-2 and T-3 are used, respectively, to initiate or discontinue circulation of water through the solar collectors after preset delays. Solar pumps P-2A and P-2B are activated by these timers, which serve to minimize circulation of water through the solar collectors during periods of intermittent insolation caused by clouds or spurious start-up at the beginning of the day.

A solar temperature control unit inhibits operation of the solar collector loop when the temperature difference between the collectors and the solar storage tank temperature is less than 4.5°F. Similarily, this same unit shuts off P-2A and P-2B, allowing the solar collectors to drain back to the solar storage tank when the temperature differential between the solar collectors and the storage tank is less than 1.5°F.

V_3 Operation

To guard against failure of water supply to the boiler room, which could be serious if allowed to go uncorrected, valve V_3 is allowed to remain open (spring-loaded) under the following conditions:

- No control voltage
- No air supply

- Low level control L_2 open, indicating low level in solar storage tank.
- Demand from L_4/V_7 for high water rate.

Under all other conditions in the "NORMAL" mode of operation, V_3 is closed, to allow all water to the auxiliary hot water system to flow through the solar storage tank.

In the "WEEK-END" mode of operation (see below), there is no air supply and V_3 is open, guarded against back-flow by a spring-loaded check valve.

SECTION 4.3 "WEEK-END" MODE

In the "WEEK-END" mode of operation, activated by a manually controlled switch on the control panel, the solar collector loop and P-2A/P-2B still operate under automatic control of the solar temperature unit. In this mode of operation, neither cold water nor compressed air are normally available for use by the subsystems. Consequently, all valves and controls in this mode have to be electrically operated or make use of spring-return for actuation. Excluding only the solar collector circulation loop, all controls and pumps are normally quiescent until the temperature of the water in the solar storage tank reaches 170°F. Through closure of temperature sensor T-1, water from the solar storage tank is circulated by P-1 through V-4 and the wastewater heat exchanger back to the solar storage tank via V-5. Simultaneously, the wastewater pump P-3 is activated to circulate wastewater through the heat recovery unit, thereby transferring heat from the solar storage tank to the wastewater pit. This mode of operation continues until the temperature of the solar storage tank drops to 160°F., at which point the recirculating loop is disabled by the opening of T-1; the same controller that had been used for initiation of the recirculation cycle. <u>It should again be emphasized here that all temperature and level controls have a differential band over which they operate. This feature contributed significantly to the simplification of the control system for this project.</u>

In the unlikely event that the temperature in the solar storage tank reaches 190°F., temperature controller T-4 disables the solar collector circulating loop, allowing the collectors to drain back into the storage tank. This condition obtains only if the level in the wastewater pit is too low to allow the wastewater pump P-3 to be activated via L-5, thereby inhibiting heat transfer to the wastewater pit.

For diagnostic purposes, supplemented by alarm and display circuits discussed earlier, all pumps can be operated manually from the control panel. Alarm circuits and the display board allow for near instantaneous diagnosis of any major system component failure.

SECTION 4.2 CONTROL LOGIC AND TEMPERATURE RANGES

The operational modes described in Section 4.1 of this report are summarized in the tables below.

Data presented in these tables describe the types of control components and pumps used and the modes of operation.

TABLE 4-1 COMPONENT TYPES, RANGES & MANUFACTURERS

Component	Valve Operation Electric	Valve Operation Pneumatic	Setting High	Setting Low	De-Activated State	Manufacturer	Comments
V_A		X			-	ITT - Grinnell	Timed Back Flush Via V_8
V_B		X			0	ITT - Grinnell	Slaved to V_8
V_1		X			0	ITT - Grinnell	Slaved to V_9
V_2		X			0	ITT - Grinnell	" "
V_3		X			0	DeZurick	Slaved to V_{10}
V_4		X			C	DeZurck	Slaved to V_9
V_5	X				C	ASCO	Activated by L_1
V_6	X				C	Marfed	Activated by L_3
V_7	X				C	Marfed	Activated by L_4
V_8	X				O	Asco	Actuates V_A & V_B
V_9	X				O	Asco	Actuates V_1, V_2 & V_4
V_{10}	X				O	Asco	Actuates V_3

TABLE 4-1 COMPONENT TYPES, RANGES & MANUFACTURERS

Component	Valve Operation Electric	Valve Operation Pneumatic	Setting High	Setting Low	De-Activated State	Manufacturer	Comments
P_1					-	PACO	Activated by L_1 or T_1(W/E)[1]
$P2_A$ & $P2_B$					-	Grundfos	Activated by T Controller
P_3					-	Hydr-O-Matic	Activated by L_1 or T_1(W/E)[1]
L_1			12'	10'	0	ASCO	Solar Storage Demand
L_2			11'	9'	C	ASCO	Low Level
L_3			5'	4'	0	ASCO	Normal H.W.[2] Demand
L_4			4'	3'	0	ASCO	Heavy H.W.[2] Demand
L_5			-	2'	0	Mercoid	W.W.[3] low level.
T_1			170°F.	160°F.	0	ASCO	Dump to W.W.[3] (W/E)[1]
$T = T_2 - T_3$			4.5°F.	1.5°F.	0	Rho-Sigma	Solar Pump Control
T_4			190°F.	168°F.	C	ASCO	High Temperature Over-ride

KEY

1 W/E - "Week-End Mode"
2 H.W. - Hot Water
3 W.W. - Wastewater

TABLE 4-2 OPERATIONAL MODES & CONTROLS FOR PUMPS

Function/Operation	"NORMAL" Mode P_1	P_2	P_3	"WEEK-END" Mode P_1	P_2	P_3	Control Element
P-1 Operation							
Normal water demand to auxiliary (4,000 gal) tank	ON						L_3
Heavy Water Demand* to auxiliary tank.	ON				—		L_4
P-2 Operation							
Collector 4.5°F above storage water temperature		ON			ON		ΔT
Collector 1.5°F below storage water temperature		OFF			OFF		ΔT
Storage Water $\geq$190°F		OFF			OFF		T_4
P-3 Operation							
Low Level in Wastewater sump			OFF			OFF	L_5
Water demand to solar tank & sump level O.K.			ON				L_1
P-1 & P-3 (Week-End Mode)							
Storage Water $\leq$160°F				OFF		OFF	T_1
Storage Water $\geq$170°F				ON		ON	T_1

* V_3 also opens via V_{10}

TABLE 4-3 CONTROL VALVE LOGIC

Operational Mode	V_A	V_B	V_1	V_2	V_3	V_4	V_5	V_6	V_7
WEEKDAY	*	O	X	O	●	X	⊗	●	●
WEEK-END	*	X	O	X	O	O	⊗	X	X

* Back Flush Valve for Heat Reclaimer

KEY O = OPEN X = CLOSED ● = OPEN/CLOSED ON DEMAND

For completeness in this section of the report, electrical interfaces to the boiler room are shown in Figure 4-2 below. External connections to the Control Panel are shown in Figure 4-3. Excluding only the pneumatic interfaces to control valves (and IBM instrumentation), all other interconnections are made within the pre-fabricated control panel, which was manufactured off-site by Ying Manufacturing Corporation.

FIGURE 4-2 ELECTRICAL INTERFACES BETWEEN BOILER ROOM & CONTROL PANEL

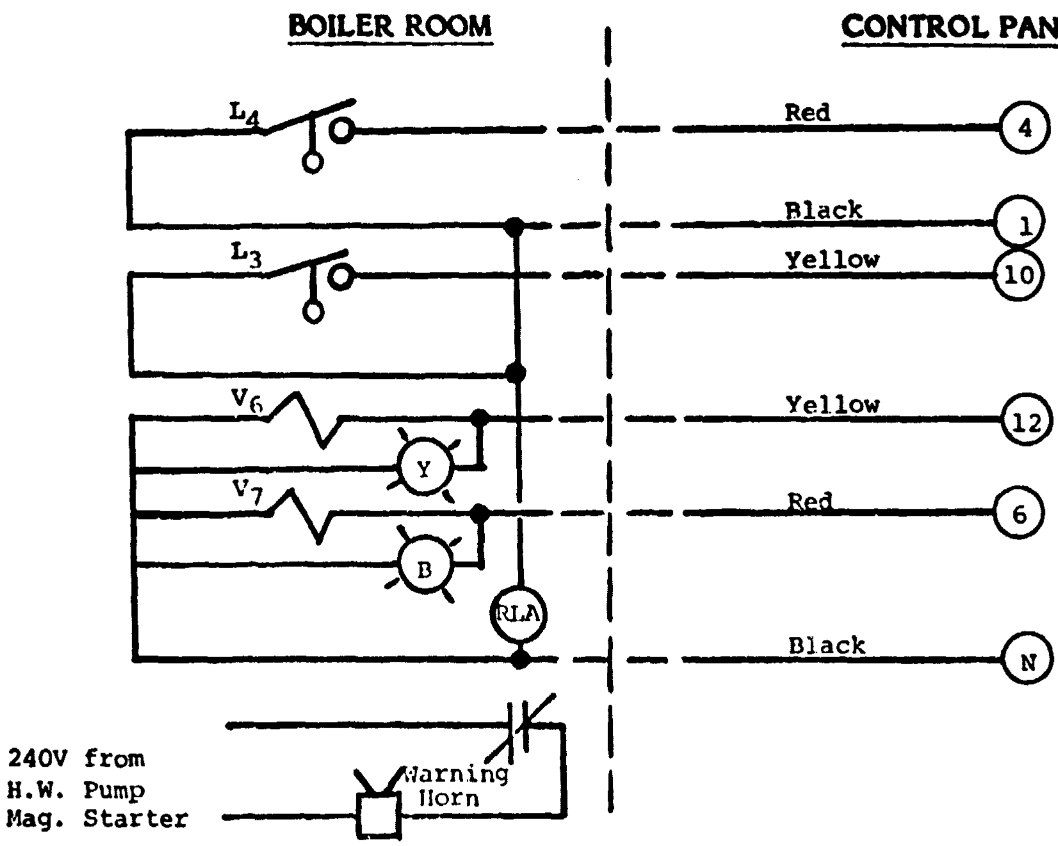
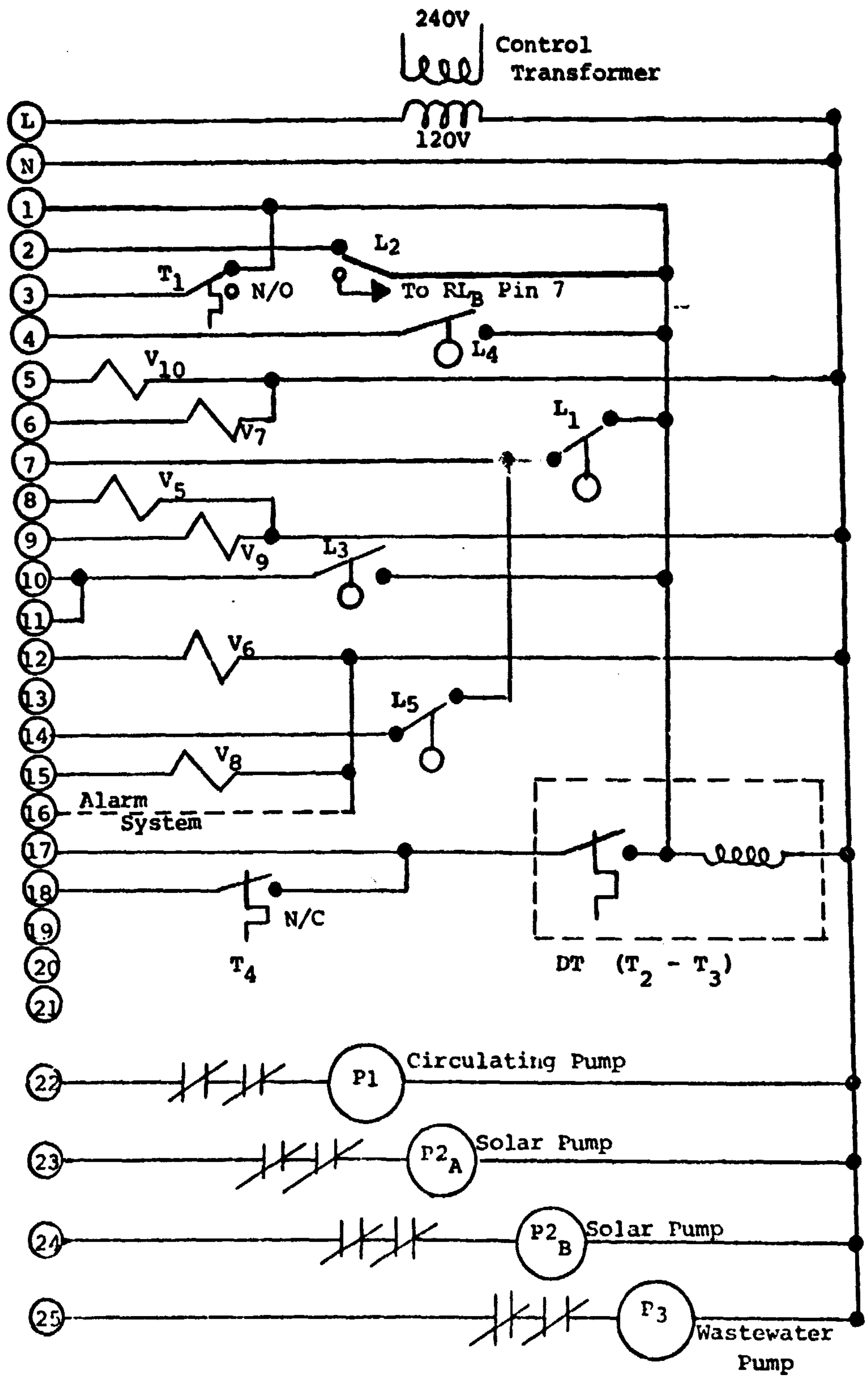


FIGURE 4-3 EXTERNAL ELECTRICAL INTERFACES TO CONTROL PANEL



SECTION 4.3 SYSTEM START-UP & PREVENTATIVE MAINTENANCE

Following pressure testing of each subsystem, level sensors L_1, L_2, L_3 and L_4 are calibrated, using the manometers on the solar storage and auxiliary (4,000 gallon) tanks. By-pass valves on each manometer are used to verify calibration of these sensors, including high and low settings for each sensor. Temperature sensors T_1 and T_4 are calibrated using a digital-readout precision thermometer and thermostatically controlled water bath prior to installation in the solar storage tank. The ΔT sensor is similarily calibrated prior to installation.

After conventional continuity and resistance checks, direction of rotation of pumps P_1, P_2, $P2_A$ and P_3 is checked in the "MANUAL" mode prior to activation of the "AUTO" mode of operation.

Start-up tests are completed by checking state and operation of each valve in the system in accordance with the sequences defined in Figure 4-1 and Tables 4-1 and 4-2.

Initial validation of systems performance and potential malfunctioning is performed by exercising each control subsystem manually, prior to activation of automatic modes. Thereafter, alarm circuits and the display board are used to indicate any system malfunction.

Routine, preventative maintenance is limited to the following:

- Cleaning of Solar Panels every week
- Check of wastewater heat recovery subsystem performance by reading chart recorders every day.
- Pneumatic feed system integrity and lubrication checks once per month
- Visual and audible checks of pump operation every month
- Visual checks of analog instrumentation for possible system malfunction once a week.

All major malfunctions are automatically identified and alarmed through the alarm and display system.

SECTION 5.0

PHOTOGRAPHS

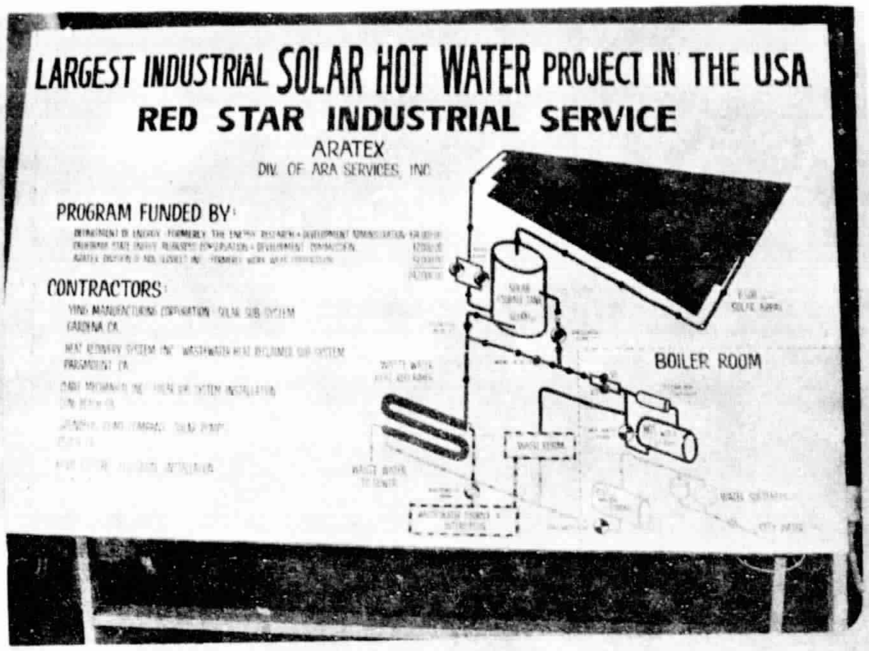


Figure 5.1

Diagnostic Display Board

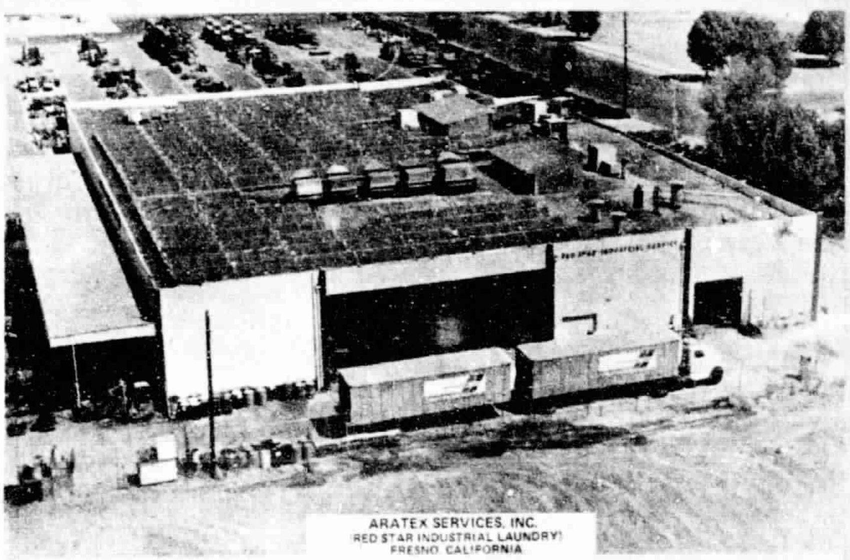


Figure 5.2

Aerial View of Solar Collector Array.

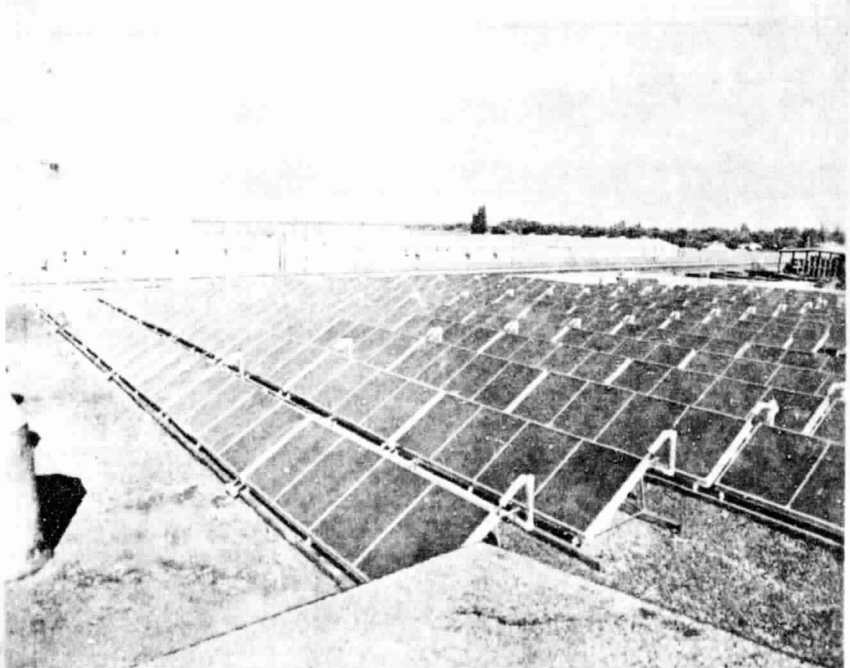


Figure 5.3

Close-up of Completed Collector Array.

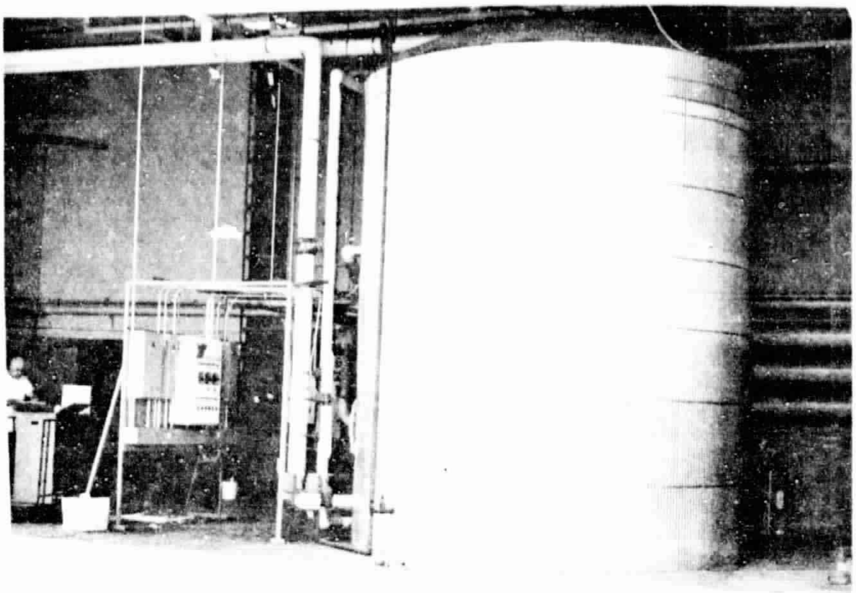


Figure 5.4

Solar Storage Tank and Control Panel.

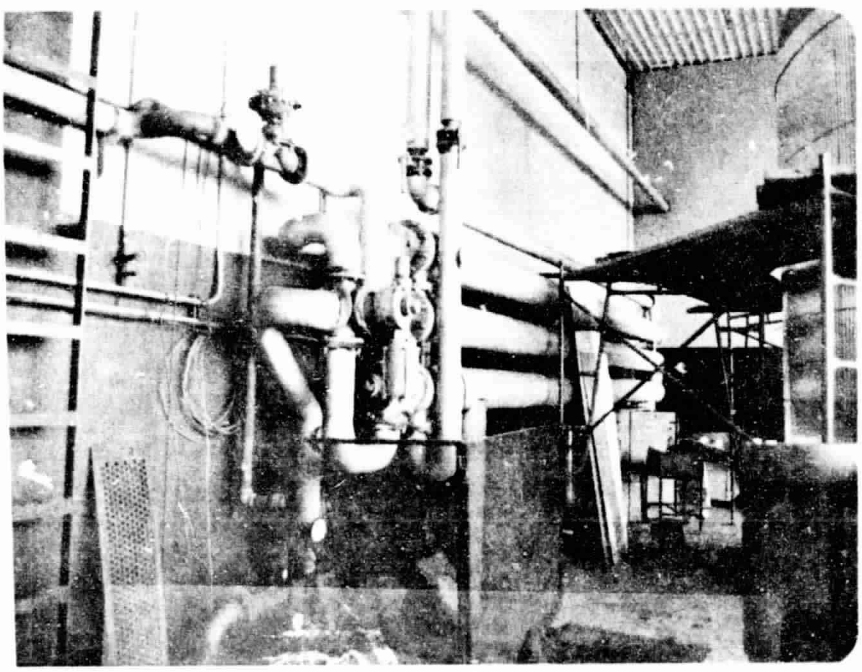


Figure 5.5

Close-up of Waste-water Heat Recovery System.

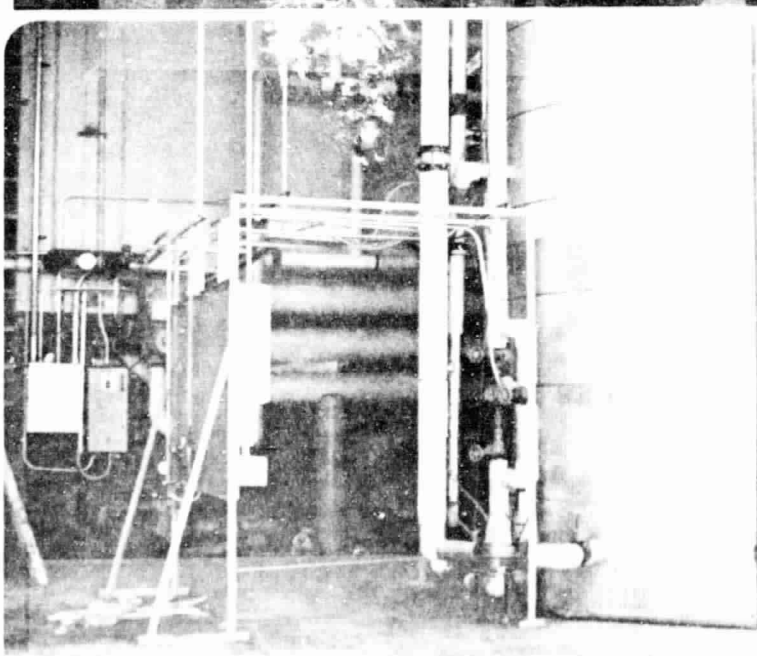


Figure 5.6

Close-up of Major Valves & Solar Pumps.

SECTION 6.0

PERFORMANCE PREDICTIONS AND RESULTS TO-DATE

SECTION 6.0 PERFORMANCE PREDICTIONS

In this section of the final report, thermal balance analyses and performance predictions, originally submitted to NASA/MSFC on January 17, 1977 as a part of Progress Report No. 3, are reproduced for completeness and self-consistency. Comparison with data gathered by the National Solar Data Network is still incomplete at this time, due to problems with the sensor calibration. However, there is some indication that degradation of the solar panels due to stagnation and unusual weather problems has caused a shortfall in performance, which can only be corrected if the panels are resurfaced and re-glazed (see Section 7.0 of this report). Thermal balance analyses and other theoretical performance data are presented below, based on the original design criteria used at the start of the project.

SECTION 6.1 THERMAL BALANCE ANALYSES

In deriving the thermal balance for the hot water system at Red Star Industrial Service Laundry, 3333 No. Sabre Avenue, Fresno, Ca., it was necessary to make certain assumptions which could only be fully validated after the site was instrumented by IBM. Changes in processes and equipment which had occurred during the last three years made it difficult to compare data acquired in 1975 with current data. Nevertheless, by using a normalized Figure-of-Merit (FM), which related the gallons of hot water generated under standardized temperature conditions to therms of natural gas consumed by the hot water system, it was possible to project system performance under three different sets of conditions:

- Auxiliary system only (235 BHP Babcock & Wilcox Steam Boiler)
- Auxiliary system plus wastewater heat reclamation subsystem
- Auxiliary system plus wastewater heat reclamation and solar subsystems

Assumptions made in this analysis were as follows:

- Hot water accounts for 75% of the total water usage in the plant. (Recently reduced to 50% of total water usage by in-process conservation)

- Boiler thermal efficiency was assumed to be 75%, discounting other system losses such as evaporation, etc.[1]
- Incoming water temperature is 65°F.[2]; hot water temperature is 180°F.
- Total number of hours of operation/year = 2,080.

Figure 6-1 shows the flow diagram for water and steam in the plant, including existing heat conservation systems using steam condensate.

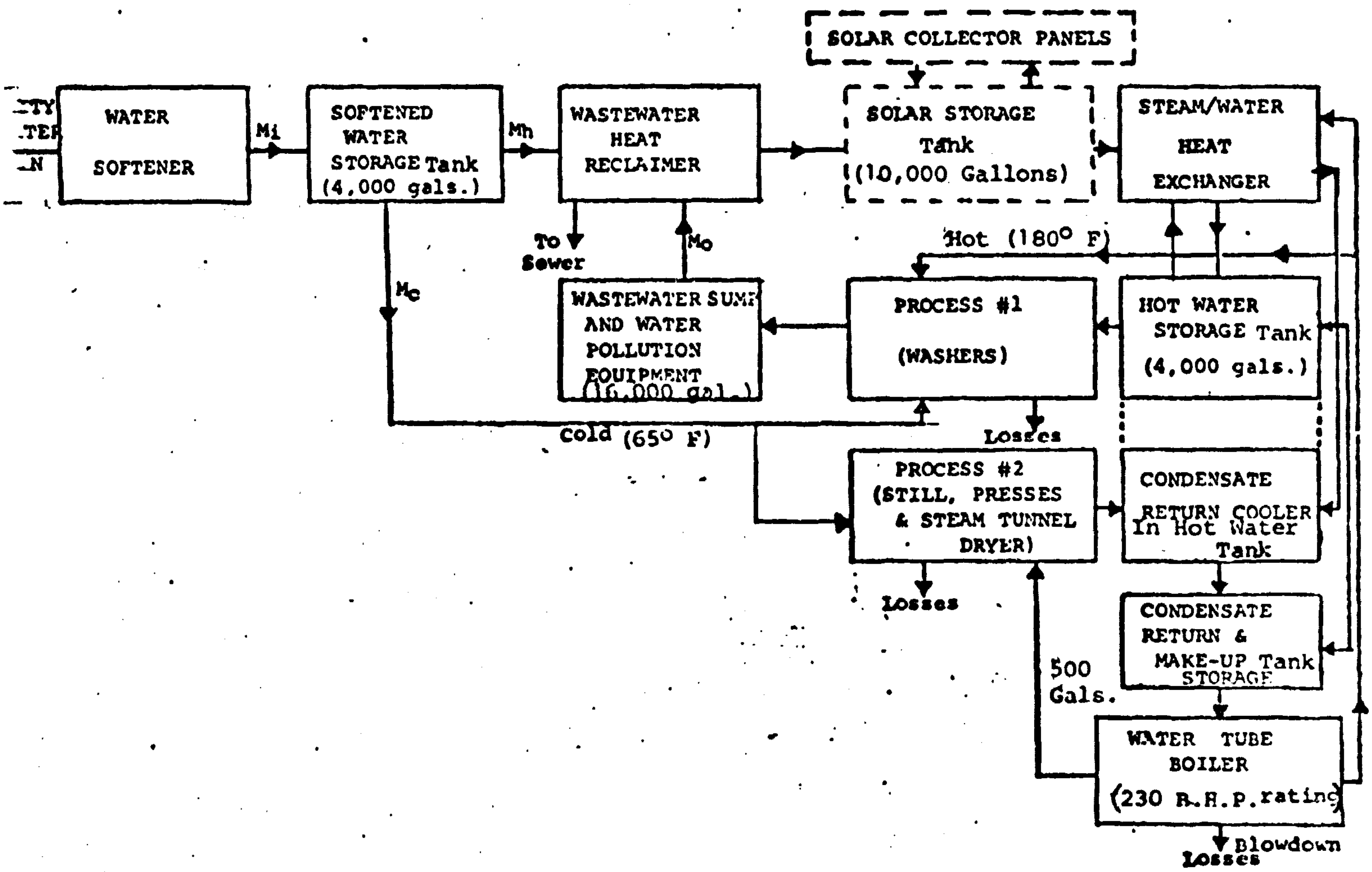
1 National Solar Data Network (IBM) analyses assume 60%.

2 Average incoming temperature is actually 75°F.

FIGURE 6-1

THERMAL BALANCE FLOW DIAGRAM FOR

RED STAR INDUSTRIAL SERVICE



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CASE 1 - NO WASTEWATER HEAT RECLAMATION OR SOLAR HEAT SUBSYSTEMS

A. Based on data acquired from January 1975 to June 1975 inclusive (before installation of wastewater heat recovery system and steam drying tunnel),

Estimated 1975 water consumption = 13.938Mg/year = 6,700gph

Estimated 1975 gas consumption = 274,750 Therms/yr = 132 Therms/hr.

Assume a boiler efficiency (η) of 75%

Then thermal input = 0.4463 Therms/BHP
and thermal output = 33,472 BTU/BHP.

Considering hourly flow and thermal transfer, based on above assumptions.

$$\text{Hot water flow} = \frac{13.938 \times 10^6}{2,080} \times 0.75 \text{ gallons/hr.}$$

$$= 5,026 \text{ gallons/hour}$$

Heat required to heat from 65°F. to 180°F.

$$Q_H = 5,026 \times 8.33 \times (180-65) \text{ BTU/hour}$$

$$= 4,815,000 \text{ BTU/hour}$$

At 75% boiler efficiency, energy input to boiler

$$Q_H = \frac{48.15}{0.75} \text{ Therms/hour}$$

$$= 64.2 \text{ Therms/hour (\% of total = 48.64)}$$

Process steam for stills & presses in this example (no steam tunnel) requires an additional thermal input to the boiler (Q'_P)

$$Q'_P = 15.0 \text{ Therms/hours (\% of total = 11.36)}$$

Similarily, the gas tumbler dryers are assumed to consume 30% of the total gas consumption, with the remainder being made up by evaporation and other losses.

i.e. Q'TD = 39.6 Therms/hour (% of total = 30.00)

Q'L = 13.2 Therms/hour (% of total = 10.00)

Where $Q'_H + Q'_P + Q'_T + Q'_L = 132$ Therms/hour

In this example, the Figure-of-Merit (FM) for hot water heating only, defined as gallons of hot water/therm of natural gas is:

$$FM = \frac{5,026}{64.2} = 78.3 \text{ gallons of hot water/therm}$$

B. Based on water consumption for period January 1976 through June 1976 and equipment changes during the period June 1975 to December 1975,

Estimated 1976 annual water consumption	= 23.244 Mg/yr. = 11,175 gals/hr.
Estimated 1976 annual hot water consumption	= 17.433 Mg/yr. = 8,381 gals/hr.

Corresponding values for hourly gas consumption, without wastewater heat reclamation or solar heat would theoretically be:

Q'_H	= 107 Therms/hour	(% of total 62.2)
Q'_P	= 15 Therms/hour	(% of total 8.7)
Q'_{TD}	= 39 Therms/hour	(% of total 22.7)
Q'_L	= 11 Therms/hour	(% of total 6.4)

Then $Q'_T = Q'_H + Q'_P + Q'_{TD} + Q'_L$ = 172 Therms/hour

and $FM = \frac{8,381}{107} = 78.3$ gallons/Therm

This value will be used to derive the actual energy savings attributable to the wastewater heat reclaimer, based on data taken during the same period, i.e. January 1976 through June 1976.

CASE 2 - AUXILIARY SYSTEM WITH WASTEWATER HEAT RECLAMATION

Estimated 1976 water consumption = 23.244 Mg/yr. = 11,175 gals/hr.

Estimated 1976 gas consumption = 264,340 Therms/yr = 127 Therms/hr.

From Case 1 (B.) above, assuming that the net reduction in energy input due wastewater heat recovery is reflected in reductions in values of Q'_H only:

$$Q'_{WR} = \frac{\text{Hot Water flow/hour (gph)} \times 8.33 \times (155 - 65^{\circ}F)}{}$$

$$= \frac{8,381 \times 8.33 \times (115 - 65)}{0.75}$$

$$= 46.5 \text{ Therms/hour}$$

Since 172 Q'_{WR} = 125.5 Therms/hour.

New value of Q'_H is 107-46.5 = 60.5 Therms/hour.

The new value of the Figure-of-Merit (FM) is given by:

$FM = \frac{8,381}{60.5} = 138.5$ gallons of hot water/therm.

CASE 3 - AUXILIARY SYSTEM WITH WASTEWATER HEAT RECLAMATION & SOLAR HEAT

From Section 2.0 of this report the nominal energy output from the solar subsystem is 2.0×10^9 BTU/year.

Equivalent hourly average output

$$Q_S = \underline{2 \times 10^9} \times 10^{-5} \text{ Therms/hour}$$

$$= 9.6 \text{ Therms/hour}$$

Equivalent hourly energy savings, factored for boiler efficiency (= 0.75)

$$Q'_S = 12.8 \text{ Therms/hour}$$

i.e. Q''_H is reduced to $(60.5 - 12.8) = 47.7$ Therms/hour

The Figure-of-Merit for the auxiliary source now becomes:

$$FM = \frac{8,381}{47.7} = 175.7 \text{ gallons of hot water/therm.}$$

The results of this analysis are summarized below in Table 6-1. It should be emphasized that the results presented are estimates only, based on limited available data. Normal variations in laundry processes and merchandise mix, including seasonal variations, can result in wide variations in diurnal energy demands. These can only be accurately determined after the installation of adequate instrumentation, to be supplied by ERDA/NASA as a part of solar demonstration contract.

TABLE 6-1 - COMPARATIVE PERFORMANCE OF HOT WATER

SYSTEM AT RED STAR INDUSTRIAL SERVICE, FRESNO, CALIF.

WITH ALTERNATE CONSERVATION SYSTEMS

SYSTEM	Figure-of-merit (Gals. Hot Water/ Therms	Estimated Energy Consumption for Hot Water (Therms) by Boiler	Estimated Energy Savings (Therms)
1 Boiler only	78.3	224,644	-
2 Boiler & Wastewater Heat Reclamation Subsystem	138.5	125,870	98,774 Therms/yr.
3 Boiler & Wastewater Heat Reclamation and Solar Sub-System	175.7	99,220	125,424 Therms/yr.

SECTION 6.1.2 SOLAR SUBSYSTEM PERFORMANCE

Predicted Solar Collector Subsystem performance was originally calculated using the very limited data submitted by Desert Sunshine Exposure Test, Inc., in a letter report dated November 18, 1976. The results are given in Table 6.2. Solar insolation data used in the computation was derived from the NASA/MSFC computer printout provided by Ray Spink at a meeting held in Huntsville, Alabama on September 15, 1976, factored by % sunshine data supplied by NOAA. Solar insolation data is reproduced in Table 6.3.

Figure 6.2 shows the predicted efficiency curve for the Ying SP4120 collector with single Lexan III cover and Dunn-Edwards W201-20 Flat Back Coating. The efficiency curve is superimposed on the NASA Lewis Research Center Solar Simulator data in Figure 6.3.

TABLE 6.2 PREDICTED SOLAR COLLECTOR SUBSYSTEM PERFORMANCE

MONTH	Incident Daily Insolation at 30^{o} tilt angle (BTU/Ft^2)	Ambient Temp. T_a	$120 - T_a$	ΔT	Hourly Avg. Insolation Q (BTU/Ft^2)	Fluid Factor $\Delta T/Q$	η	% of Sunshine P	Net Daily Insolation ($\bar{I} = I \times \eta \times P$) BTU/Ft^2
JAN	1750	50	70	73	260	0.280	0.52	46	418.6
FEB	2076	60	60	65	275	0.236	0.56	63	732.4
MAR	2291	75	55	62	305	0.203	0.58	72	956.7
APR	2321	85	35	45	305	0.148	0.63	83	1213.7
MAY	2269	90	30	40	300	0.133	0.64	89	1292.4
JUN	2225	95	25	37	290	0.128	0.65	96	1388.4
JUL	2228	95	25	37	290	0.128	0.65	96	1390.7
AUG	2238*	90	30	40	300	0.133	0.64	89	1274.8
SEP	2190	85	35	45	305	0.148	0.63	83	1145.1
OCT	1992	75	45*3	54*3	305	0.203	0.58	72	831.9
NOV	1712	60	60	65	275	0.236	0.56	63	604.0
DEC	1595	50	70	73	260	0.280	0.52	46	381.5
							SUB-TOTAL		11,630.2

Annual Energy Output/Square Foot $= \frac{11,630.2 \times 365}{12}$ BTU/Ft^2

$= 353,752$ BTU/Ft^2

Net Array area A $= 6,280$ Ft^2

∴ Total Energy Output $= 2.222 \times 10^9$ BTU/year

Less 10% losses $= 2.0 \times 10^9$ BTU/year

Notes: 1. Insolation data from NASA-MSFC - computer Print-out dated 9/15/76

2. % Sunshine data from NOAA Fresno, California

3. Efficiency (η) based on DSET data

TABLE 6.3

SOLAR INSOLATION DATA FOR FRESNO, CA.

SITE NO. = FRSNO   LATITUDE = 36.75   TILT = 30.00   AZIMUTH = .0   PAGE 1 OF 1

INSOLATION VALUES INCLUDE DIRECT AND DIFFUSE COMPONENTS EXCEPT FOR 0.00 VALUES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
5AM	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6AM	.00	.00	.00	2.05	5.98	7.59	5.99	1.31	.00	.00	.00	.00
7AM	.09	18.82	43.15	62.04	67.10	67.57	65.43	58.38	43.10	16.61	.09	.00
8AM	74.39	112.31	134.28	141.39	140.40	138.56	137.51	134.77	126.09	105.43	72.04	53.27
9AM	163.46	195.12	232.57	214.32	208.56	203.99	204.66	206.52	203.20	186.76	159.51	146.76
10AM	220.42	253.14	274.63	271.66	262.16	256.13	257.50	262.94	263.45	248.92	223.12	212.28
11AM	268.28	293.05	313.13	300.45	296.62	290.62	291.49	298.87	301.76	287.85	263.30	252.32
12PM	231.57	311.43	320.31	321.24	303.36	300.44	303.07	311.37	315.21	301.31	276.42	265.30
1PM	268.28	293.05	313.13	300.45	296.62	286.62	291.49	298.87	301.76	287.85	263.30	252.32
2PM	223.42	250.14	274.60	271.66	262.16	256.13	257.50	262.94	263.45	248.92	223.12	212.28
3PM	163.46	195.12	232.57	214.32	208.56	203.99	204.66	206.52	203.20	186.76	159.51	146.76
4PM	74.33	112.31	134.28	141.39	140.40	138.56	137.51	134.77	126.09	105.43	72.04	53.27
5PM	.09	18.82	43.15	62.04	67.10	67.57	65.43	58.38	43.10	16.61	.09	.00
6PM	.00	.00	.00	2.05	5.99	7.59	5.89	1.91	.00	.00	.00	.00
7PM	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
D. SUM	1750	2076	2291	2321	2269	2225	2228	2238	2190	1992	1712	1595

FIGURE 6.2

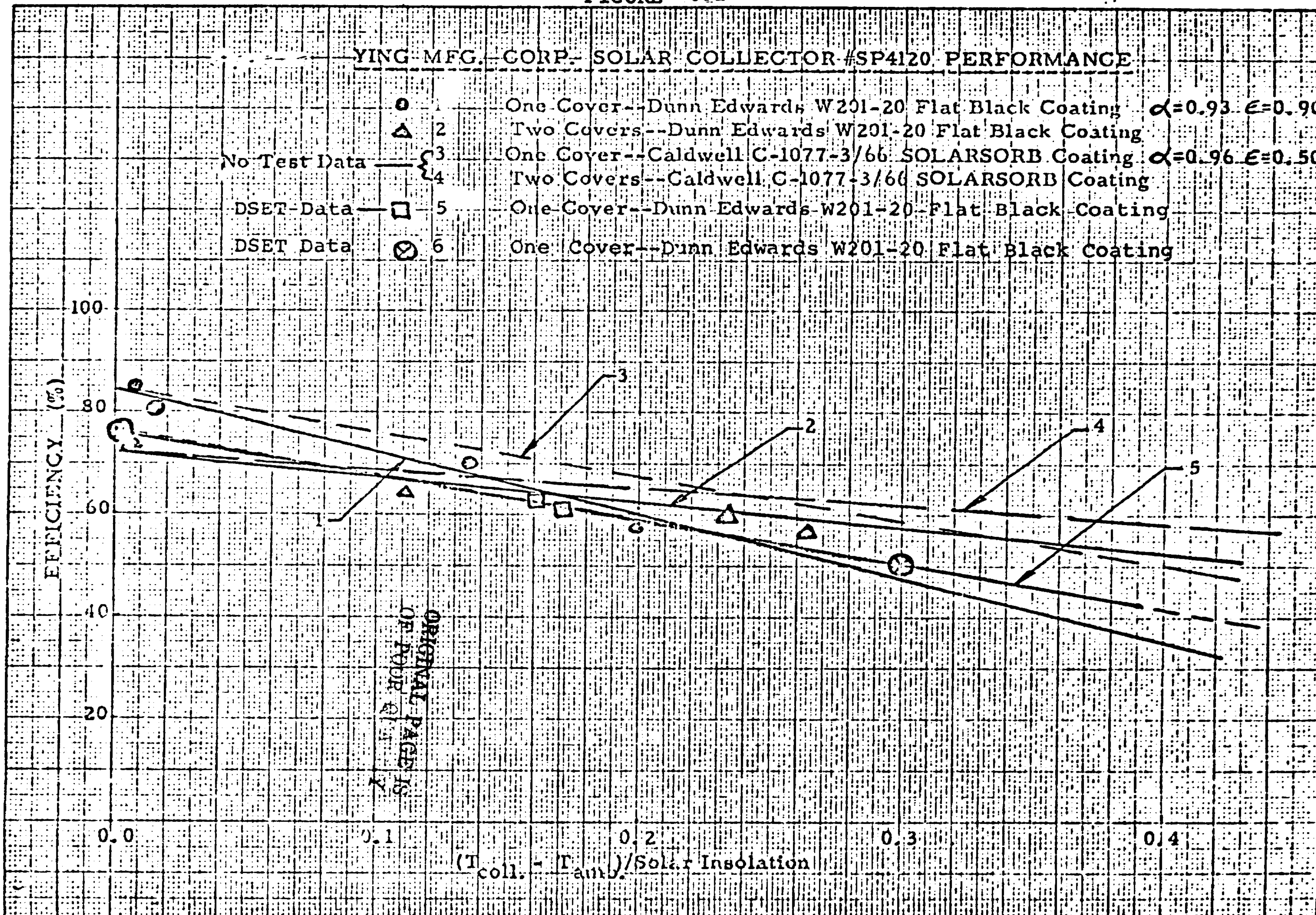
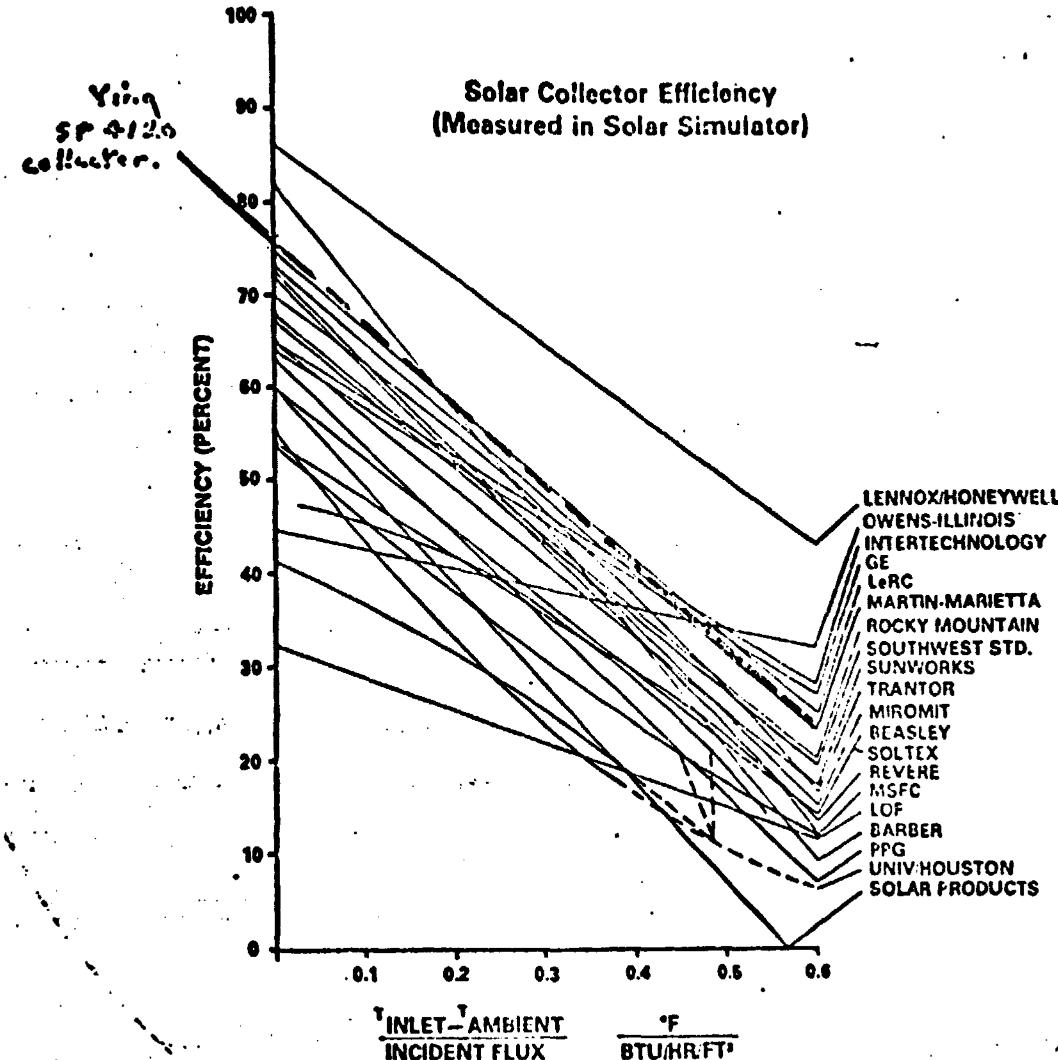

YING MFG. CORP. SOLAR COLLECTOR #SP4120 PERFORMANCE
1 One Cover--Dunn Edwards W201-20 Flat Black Coating α=0.93 ε=0.90
2 Two Covers--Dunn Edwards W201-20 Flat Black Coating
No Test Data 3 One Cover--Caldwell C-1077-3/66 SOLARSORB Coating α=0.96 ε=0.50
4 Two Covers--Caldwell C-1077-3/66 SOLARSORB Coating
DSET Data 5 One Cover--Dunn Edwards W201-20 Flat Black Coating
DSET Data 6 One Cover--Dunn Edwards W201-20 Flat Black Coating
EFFICIENCY (%)
100
80
60
40
20
0.0
0.1
0.2
0.3
0.4
(T coll. - T amb.)/Solar Insolation
1
2
3
4
5

FIGURE 6.3 - COMPARATIVE EFFICIENCY OF ALTERNATE SOLAR COLLECTOR CONFIGURATIONS MEASURED IN THE NASA-LRC SOLAR SIMULATOR



(Ying SP4120 Single Glazed Collector data superimposed for comparison, based on latest Desert Sunshine test data)

References:

1. NASA Lewis Research Center Technical Memorandum NASA TMX-71793 dated 7/28/76 entitled "Flat-Plate Solar Collector Performance Evaluation with a Solar Simulator as a basis for Collector Selection & Performance prediction".
2. Diagram reproduced from Appliance Manufacturer, November 1976.
3. Ying SP4120 Efficiency Curve based on Desert Sunshine test in December 1976.

SECTION 6.2 COMPUTED DATA FOR PERIOD FROM MARCH TO MAY 1978

Data, derived from the D.O.E. report entitled "Solar Energy System Performance Evaluation; Fresno, California: November 1977 through May 1978", authored by Henry L. Armstrong, et al. of IBM is repeated, together with more recent data for the months of June, July and August 1978, extracted from the National Solar Data Program Monthly Performance Reports.

TABLE IV - 2.1
THERMAL PERFORMANCE WITH HEAT RECOVERY ENERGY

MONTH	Total System Load* (Million BTU)	Energy Supplied By Heat Recovery (Million BTU)	Energy Supplied By Solar System (Million BTU)	Energy Supplied By Aux. System (Million BTU)	Solar Fraction %	Fossil Savings (Solar Only) (Million BTU)
March 1978	562	225	52	285	16	87
April 1978	490	182	59	249	19	99
May 1978	526	200	77	248	24	76
June 1978	411	190	99	304	24	165
July 1978	408	172	113	285	28	189
August 1978	435	203	109	320	25	181

* Excluding Wastewater Heat Recovery Input

Analysis of water bills and IBM data for recent months indicates that an average of 36,000 gpd of hot water was used in the facility during the period under review. It was similarily determined from gas meter readings that the total auxiliary load for hot water supply was somewhat higher than the IBM data would indicate.

For comparison, calculated data for the six month period was averaged to give the following results, based on an assumed boiler efficiency of 60%.

Total Hot Water Load including Heat Recovery & 10% Losses	640×10^6 BTU/month
Heat Recovery System (HRS') Input	188×10^6 BTU/month
Hot Water Load excluding Heat Recovery	490×10^6 BTU/month
Solar Input	107×10^6 BTU/month
Auxiliary Energy Supplied	345×10^6 BTU/month
Auxiliary Fossil Fuel	575×10^6 BTU/month
Fossil Energy Savings (HRS' Only)	313×10^6 BTU/month
Fossil Energy Savings (Solar)	178×10^6 BTU/month
Total Fossil Fuel Use without (HRS' or Solar)	$1{,}066 \times 10^6$ BTU/month
% Savings due to HRS'	29%
% Savings due to Solar	17%

Deriving the Figure-of-Merit (Gallons of Hot Water/Therm of Natural Gas or equivalent) the following figures are obtained:

System	Computed Figure-of-Merit (Hot Water/Therm)	Predicted Figure-of-Merit (Hot Water/Therm)
BOILER ONLY	72.6	78.3
BOILER & HRS'	103	138.5
BOILER, HRS' & SOLAR	135	175.7

More accurate data from the National Solar Data Program in the coming months should enable these figures to be refined. It is, however, apparent that there is a significant loss in the efficiency of the Solar Subsystem for reasons previously stated, and also a loss of 6% to 10% in Wastewater Heat Recovery Subsystem efficiency compared with predicted performance. The latter is partly attributable to greater use of low temperature washroom processes, reflecting in lower than optimum U-values in the heat exchanger.

NOTE: HRS' - Wastewater Heat Recovery Subsystem

At the present cost (as of March 1980) of natural gas in California ($4.043/McF), annual savings are estimated at:

Wastewater Heat Recovery Subsystem		$15,187.00	
Solar Subsystem		3,516.00	
	TOTAL	$18,703.00	per annum

FOOTNOTE: Assumptions made in deriving the Figures-of-Merit quoted above were as follows:

- Gas consumption for Boiler - 65% of total gas consumed
- Steam for water heating - 50% of total steam
- Gas consumption (Total) 23,000 Therms/mo.
- Water consumption (Total) 774,000 Gallons/mo.
- Hot Water consumption - 50% of total water used
- Boiler Efficiency (per IBM) - 60%
- Incoming Water Temperature (Average) - 75°F.
- Outgoing Water Temperature (Average) - 172°F.

SECTION 7.0

MAJOR PROBLEMS

SECTION 7.0 MAJOR PROBLEMS

Initially, immediately following award of the contract, it appeared that the whole project would be in jeopardy due to a disagreement between ERDA (now DOE) and ARATEX (formerly Work Wear Corporation) with respect to the required level of funding. This problem was only resolved after the California State Energy Resources Conservation and Development Commission (now the California Energy Commission) agreed to provide additional funding in the amount of $17,000.00, to supplement the DOE grant of $165,000.00

A further factor contributing to the initial delay in actually starting fabrication and construction on the project was the difficulty in selecting a solar collector contractor who could provide the necessary performance data, and could guarantee delivery of the number of panels required for this installation. The problem was further compounded by the realization that a lightweight panel would be required if the structural limitations, inherent in the design of the building, were to be overcome. This problem is discussed below in Section 7.1.

The time from submittal of the proposal in response to PON-1 to the signing of the sub-contracts was almost one year. Thereafter, work proceeded smoothly on the project and the system first went on line in July 1977. These and other minor problems are discussed in the following sub-sections of this report.

SECTION 7.1 SOLAR COLLECTOR SELECTION

After it became apparent that the solar collector designer who had been originally named in the proposal, Truman Temple and Associates, did not have the production capability to manufacture the required number of panels, other contractors were approached for quotations. Negotiations with one of the potential contractors, Piper Hydro, Inc., were terminated when it became apparent that performance data relating to the Piper Hydro collectors was not going to be made available to ARATEX Services, Inc. At the same time, following stress analysis of the roof structure in Fresno, it became apparent that a roof loading of no more than two (2) pounds per square foot attributable to the solar collectors would have to be realized, if additional structure modifications to the roof were to be avoided. This limitation, together with a lack of performance data, eliminated many of the potential contractors, leaving Ying Manufacturing Corporation as the only contractor capable of meeting the requirements of this particular project. This was considered to be a major break-through in the initiation of the project hardware phase, notwithstanding the fact that very limited performance data was available at this time (November 1976).

SECTION 7.2 STRUCTURAL PROBLEMS

Configuration studies and stress analysis had revealed the criticality of roof loading at the Fresno site. After resurfacing the roof (a necessary pre-requisite to installation of the solar array), available roof loading for the solar array was limited to approximately 2.5 pounds per square foot. Because this loading factor was considered to be marginal, the decision was made to reduce the amount of gravel actually applied to the roof during the resurfacing operation.

A further problem which arose during the construction phase was the difficulty encountered in sealing the attachment bolts which secured the supporting framework for the solar collectors to the roof. This has resulted in some roof leaks during the rainy season, which are a serious problem in this particular facility because of potential damage to the many garments being processed and stored beneath the roof area. Corrective action is presently being taken to overcome this problem.

These problems underscored the difficulty of retrofitting a large solar installation to an existing structure.

SECTION 7.3 STAGNATION CONDITIONS

After installation of the solar collectors in April 1976, the collectors were allowed to stagnate with no fluid in the collectors and no protective covers. This resulted in collector temperatures of 400°F., with resultant damage to the selective coating and to the glazing which only became apparent after the system had been put into operation and formally dedicated in September 1977. Prior to this time, there was no apparent damage. However, it has now become apparent that there is quite a serious loss in performance attributable to the damage incurred during the stagnation period, exacerbated by unusually adverse weather conditions during the winter of 1976/77. Supplemental funding was requested from D.O.E. to rectify this problem, which was initially denied. Subsequently, $11,000.00 was made available to the project, enabling the contractor to remove ninety (90) of the collector panels for re-surfacing, replacement of the damaged Lexan glazing with Tedlar, and re-installation of the collectors. If sufficient additional funding is made available by D.O.E., the remaining fifty (50) panels will be reworked. Due to climatic conditions in Fresno, this work will have to be performed in the late Fall of 1980, or Spring of 1981.

SECTION 7.4 DUST ACCRETION

While low relative humidity and agricultural activities in the Fresno area result in high dust concentrations in the atmosphere during the summer months, the amount of dust which collects on the Lexan covers of the solar collectors appears to be excessive. This results in a requirement to clean the panels with water and a non-ionic detergent every week. This is considered to be an unacceptable maintenance burden on the facility. A possible mechanism for this excessive dust accumulation would appear to be electrostatic attraction, due to the fact that the panels are electrically insulated from a ground plane by the connecting hoses between the header and return lines. Once again, supplemental funding to investigate and solve this problem has so far been denied by D.O.E. This phenomena is believed to contribute to some of the degradation in performance which has been observed, based on the latest IBM data.

SECTION 7.5 ALARM AND DISPLAY SYSTEMS

During the integration and test phase of the solar sub-system, it was determined that there was one particular failure mode which could result in a potentially dangerous condition, which could go unnoticed without observation of the control panel light indicators. This arose because of the requirement that a common-control voltage be used for controlling not only the solar sub-system functions, but also the auxiliary hot water storage tank level control functions in the boiler room. Accordingly, it was decided to put in an auxiliary relay and alarm circuit to provide warning of a loss of control voltage to the operators in the boiler room. At the same time, additional alarms were added to the system - including both visual and audible indicators - to provide for a warning in the event of the failure of any of the pumps in the system. While these alarms monitor non-critical functions, they do serve as diagnostic tools in the event of a failure of any of the pump circuits.

SECTION 7.6 CONSTANT FLOW REGULATORS

During evaluation of the initial systems design, it was determined that each of the 140 solar collector panels would require an independent constant flow regulator to ensure that the flow rate through each panel was optimized at 2 gpm. Unfortunately, the type of flow regulator chosen proved to have excessive head loss at the required flow rate. Modifications to the units resulted in a reduction of the back-pressure to 2 psi, which was considered to be acceptable, notwithstanding the fact that this resulted in a requirement to operate both circulating pumps to attain the desired flow. Since the initiation of this project, better flow regulators with a lower head loss have become available and would be used in future installations.

SECTION 7.7 IBM INSTRUMENTATION AND PERFORMANCE DATA

Recurrent difficulties with the sensors chosen for this project and the need to replace many of the sensors has resulted in many delays in obtaining reliable data. As late as August 1978 sensors were still being replaced and calibrated. In consequence, it would appear that the earliest data upon any reliance could be placed, for purposes of system performance assessment, is the data which was accumulated during the month of September 1978. Since this problem has been common to many of the DOE Solar Energy projects, there is no need to elaborate further on this problem.

SECTION 7.8 PROGRAM MANAGEMENT

The level of effort required to satisfy contractual requirements - both financial and in terms of man-power - was grossly underestimated at the start of this project. Specifically, man-power and financial committments to program management were significantly greater than had been expected, while the continuing demands for non-contractual involvement in other related DOE programs has resulted in significant expenditure of effort in order to meet these requirements. This problem essentially precludes small companies from taking part in the PON programs, since smaller companies cannot afford the man-power and costs related to the contractual and non-contractual requirements of such programs.

SECTION 8.0

LESSONS LEARNED AND RECOMMENDATIONS

SECTION 8.0 LESSONS LEARNED AND RECOMMENDATIONS

In retrospect, it is unlikely that a commercial organization such as ARATEX Services, Inc. (formerly Work Wear Corporation) would embark on a project of this magnitude without a better definition of the contractual and cost requirements for such a program. Bearing in mind the very low return on investment of such programs, it is unlikely that Corporate management could be induced to embark on similar programs unless more flexible financial arrangements could be set up at the start of the project. There is little incentive to embark on high-risk projects without improved financial incentives.

Many of the frustrations on this project were - and still are - related to the method of monitoring the project and providing information to enable the contractor to assess the performance of the system in order to take whatever corrective action may be required to improve system performance. Furthermore, the cost of providing additional instrumentation for use by the contractor was not reflected in the fixed cost of the project when the initial negotiations took place. It is recommended that either additional funds be allocated to the project for on-site instrumentation, or better arrangements be made with the data analysis group, to provide data in a timely fashion to the contractor.

"Out of Sight - Out of Mind" is a characteristic of solar energy projects. Solar systems for industrial applications need to be fully automated, with adequate allowance provided to prevent catastrophic failure. More attention also needs to be paid to the problem of maintaining performance through routine cleaning procedures for the solar collectors. This problem has been grossly underestimated in many projects.

Finally, there is a need on the part of DOE to recognize that, in the commercial world, "Time is Money". If follow-up activities by DOE sponsored contractors and laboratories are required, then compensation should be provided to the prime contractor for time spent in supporting these activities.

SECTION 9.0

CERTIFICATION

INTERIM PERFORMANCE CRITERIA

CERTIFICATION

CONTRACT NUMBER	EX-76-C-01-2384
DEMONSTRATION CONTRACTOR	ARATEX Services, Inc. (Formerly Work Wear Corporation)
SYSTEM LOCATION	Fresno, California
SYSTEM TYPE	Hot Water (Industrial Laundry)

CERTIFIED BY: Eric S. Burnett
Project Manager

DATE: 7/29/77

APPENDIX A

INSTRUMENTATION SENSOR/J-BOX INTERCONNECTION TABLES

APPENDIX A - Instrumentation Sensor/J-Box Interconnections Tables

Site: ARATEX/Red Star **Wire List:** 7933721 **Page:** 1 **of** 4

FROM SENSOR		TO JUNCTION BOX				
Sensor Number	Sensor Connection /Color	Sensor/J-Box Wire Color	External Cable Number	Terminal Strip Number	SDAS Channel	Level
T001	R	R	#33	TB6-1	16	
"	W*	B	"	TB6-2	16	
"	W*	C	"	TB6-4	16	
"		S	"	TB6-3		S
T100	R	R	# 9	TB4-11	12	
"	W*	B	"	TB4-12	12	
"	W*	C	"	TB4-14	12	
"		S		TB4-13		S
T150	R	R	#11	TB5-6	14	
"	W*	B	"	TB5-7	14	
"	W*	C	"	TB5-9	14	
"		S		TB5-8		S
T101	R	R	#17	TB8-6	23	
"	W*	B	"	TB8-14	23	
"	W*	C	"	TB8-7	23	
"		S		TB8-8		S
T151	R	R	#16	TB6-11	18	
"	W*	B	"	TB6-12	18	
"	W*	C	"	TB6-14	18	
"		S		TB6-13		S
T102	Y*	R	#34	TB3-11	9	
"	Y*	B	"	TB3-12	9	
"	**	C	"	TB3-10	9	
"		S	"	TB3-13		S
T200	R	R	#15	TB7-6	20	
"	W*	B	"	TB7-7	20	
"	W*	C	"	TB7-9	20	
"		S		TB7-8		S
T201	R	R	#14	TB9-6	26	
"	W*	B	"	TB9-7	26	
"	W*	C	"	TB9-9	26	

Wire Color Code: B = Black, C = Clear, R = Red, S = Shield, W = White, Y = Yellow.

NOTE: *=Either Wire

**=Yellow, Black & Clear Connected

APPENDIX A - Instrumentation Sensor/J-Box Interconnections Tables

Site: ARATEX/Red Star Wire List: 7933721

FROM SENSOR		TO JUNCTION BOX				
Sensor Number	Sensor Connection /Color	Sensor/J-Box Wire Color	External Cable Number	Terminal Strip Number	SDAS Channel	Level
T201		S		TB9-8		S
T202	R	R	#12	TB10-1	28	
"	W*	B	"	TB10-2	28	
"	W*	C	"	TB10-4	28	
"		S		TB10-3		S
T300	R	R	# 7	TB3-6	8	
"	W*	B	"	TB3-7	8	
"	W*	C	"	TB3-9	8	
"		S		TB3-8		S
T350	W*	B	# 8	TB1-7	02	
"	W*	C	"	TB1-9	02	
"	R	R	"	TB1-6	02	
"		S		TB1-8		S
T351	R	R	#51	TB2-1	4	
"	W*	B	"	TB2-2	4	
"	W*	C	"	TB2-4	4	
"		S		TB2-3		S
T302	R	R	#52	TB11-6	32	
"	W*	B	"	TB11-7	32	
"	W*	C	"	TB11-9	32	
"		S		TB11-8		S
T352	R	R	#54	TB2-11	6	
"	W*	B	"	TB2-12	6	
"	W*	C	"	TB2-14	6	
"		S		TB2-13		S
T303	R	R	#25	TB10-11	30	
"	W*	B	"	TB10-12	30	
"	W*	C	"	TB10-14	30	
"		S		TB10-13		S
T304	R	R	#23	TB4-1	10	
"	W*	B	"	TB4-2	10	

Wire Color Code: B = Black, C = Clear, R = Red, S = Shield, W = White, Y = Yellow.

NOTE: * = Either Wire

** = Yellow, Black & Clear Connected

Site: ARATEX/Red Star   Wire List: 7933721

FROM SENSOR		TO JUNCTION BOX				
Sensor Number	Sensor Connection /Color	Sensor/J-Box Wire Color	External Cable Number	Terminal Strip Number	SDAS Channel	Level
T304	W*	C	#23	TB4-4	10	
"		S		TB4-3		S
T354	R	R	#26	TB9-1	22	
"	W*	B	"	TB8-2	22	
	W*	C	"	TB8-4	22	
"		S		TB8-3		S
W100	1	R	#21	TB4-10	11	+5 VDC
"	2	C	"	TB4-7	11	Hi
"	3	B	"	TB4-6	11	Lo
"	4	B	#22	TB4-9	11	Ground
"		S		TB4-8		S
W300	1	R	#19	TB1-15	3	+5 VDC
"	2	C	"	TB1-12	3	Hi
"	3	B	"	TB1-11	3	Lo
"	4	B	#20	TB1-14	3	Ground
"		S		TB1-13		S
W301	1	R	#56	TB2-10	5	+5 VDC
"	2	C	"	TB2-7	5	Hi
"	3	B	"	TB2-6	5	Lo
"	4	B	#57	TB2-9	5	Ground
"		S		TB2-8		S
W302	3	B	#55	TB9-11	27	
"	2	W	#53	TB9-12	27	
"		S		TB9-13		S
"	4	B	#53	TB9-14	27	
"	1	R	"	TB9-15	27	
W303	3	B	#10	TB11-1	31	
"	2	W	#18	TB11-2	31	
"		S		TB11-3		
"	4	B	#18	TB11-4	31	
"	1	R	"	TB11-5	31	

Wire Color Code: B = Black, C = Clear, R = Red, S = Shield, W = White, Y = Yellow.

NOTE: * = Either Wire

** = Yellow, Black & Clear Connected

APPENDIX A - Instrumentation Sensor/J-Box Interconnections Tables

Site: ARATEX/Red Star   Wire List: 7933721

FROM SENSOR		TO JUNCTION BOX				
Sensor Number	Sensor Connection /Color	Sensor/J-Box Wire Color	External Cable Number	Terminal Strip Number	SDAS Channel	Level
EP101	1	B	#27	TB9-1	25	Lo
"	2	R	"	TB9-2	25	Hi
"		S		TB9-3		S
EP301	1	B	#28	TB5-1	13	Lo
"	2	R	"	TB5-2	13	Hi
"		S		TB5-3		S
EP302	1	B	#59	TB6-6	17	Lo
"	2	R	"	TB6-7	17	Hi
"		S		TB6-8		S
EP303	1	B	#29	TB7-1	19	Lo
"	2	R	"	TB7-2	19	Hi
"		S		TB7-3		S
EP304	1	B	#30	TB7-11	21	Lo
"	2	R	"	TB7-12	21	Hi
"		S		TB7-13		S
I001	A	B	#35	TB3-1	7	Lo
"	B	R	"	TB3-2	7	Hi
"		S		TB3-3		S
D001	G	R	#36	TB5-15	15	+5 VDC
"	E	C	"	TB5-12	15	Hi
"	F	B	"	TB5-11	15	Lo
"			"	TB5-14	15	Ground
"		S		TB5-13		S
V001	A	R	#37	TB10-7	29	Hi
"	B	B	"	TB10-6	29	Lo
"		S		TB10-8		S

Wire Color Code: B = Black, C = Clear, R = Red, S = Shield, W = White, Y = Yellow.

NOTE: * = Either Wire

** = Yellow, Black & Clear Connected

APPENDIX B

LIST OF MANUFACTURERS

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COMPONENT	MANUFACTURER
Solar Collectors & Control System	Ying Manufacturing Corporation 1940 West 144th Street Gardena, CA. 90249 (213) 770-1756
Solar Hot Water Tank	Century Plastics, Inc. 1210 North Tustin Avenue Anaheim, CA. (714) 582-7806
Solar Pumps ($P2_A$ & $P2_B$)	Grundfos Pump Corporation 2555 Clovis Avenue Clovis, CA. (209) 299-9741
Circulating (Feed) Pump (P1)	Pacific Pumping Company of Canada 35 Sinclair Avenue Georgetown, Ontario, Canada
Wastewater Pump (P3)	Hydr-O-Matic Pump Division P.O. Box 327 Ashland, OH. 44805
Heat Reclaimer	Heat Recovery Systems 15925 Minnesota Street Paramount, CA. 90723 (213) 979-0505
Diaphragm Control Valves (V_1, V_2, V_B)	ITT Grinnell Valve Division Specialty Valve Group 225 North Front Street Wrightsville, PA. 17638
Pneumatic Control Valves (V_A, V_3, V_4)	DeZurik Sartell, Minnesota
*Electric Control Valve (V_S)	Automatic Switch Company (ASCO) 50-56 Hanover Road Florham Park, N.J. 07932 (201) 966-2000
* Level Controls (L_1, L_2, L_3, L_4)	ASCO
* Temperature Controls (T_1 & T_2)	ASCO

* All supplied at no cost to the contract.

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