SAN/1218-1

APPLICATION OF SOLAR ENERGY TO THE SUPPLY OF INDUSTRIAL PROCESS HOT WATER

Aerotherm Final Report, 77-235

MASTER

January 1977

Work Performed Under Contract No. EY-76-C-03-1218

Aerotherm Division
Acurex Corporation
Mountain View, California

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Division of Solar Energy

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Microfiche $3.00 (domestic)
$4.50 (foreign)

SAN/1218-1
Distribution Category UC-59b

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Contract E043-1218

CDRL/PA 10

APPLICATION OF SOLAR ENERGY TO THE SUPPLY OF INDUSTRIAL PROCESS HOT WATER

Prepared for

Energy Research and Development Administration
20 Massachusetts Avenue, NW
Washington, D.C. 20545

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SUMMARY

This report describes the work performed by Acurex/Aerotherm during Phase I of the Solar Industrial Hot Water Program. The period of performance was March 15, 1976 to December 15, 1976. The work was sponsored by the U.S. Energy Research and Development Administration under contract E043-1218.

The objectives of the Solar Industrial Process Hot Water Program are to design, test, and evaluate the application of solar energy to the generation and supply of industrial process hot water, and to provide an assessment of the economic and resource benefits to be gained. Other objectives are to stimulate and give impetus to the use of solar energy for supplying significant amounts of industrial process heat requirements.

The Solar Industrial Hot Water Programs are divided into three phases:

<u>Phase I</u> — Detailed design and analysis of the solar energy hot water system for incorporation into the selected industrial process.

<u>Phase II</u> — Assembly and installation of solar energy hot water system designed in Phase I on process line or machine.

<u>Phase III</u> — Operation, data acquisition, analysis, and reporting.

The body of this report has a brief overview of the different tasks performed during Phase I. Appendix A to this report is a copy of the Preliminary Design and Performance Report and Appendix B is a copy of the Energy Reduction and Economic Analysis Report; both of these reports have been updated since they were submitted in October 15, 1976. Detail drawings of the Solar System appear in Attachment 2.

The Solar System described in this report was designed for installation at the Campbell Soup plant in Sacramento, where the solar heated water will be used to wash empty and full soup cans on a soup filling line.

The National Canners Association (NCA) assisted in the design plan and the economic analysis of the system. NCA also assured that the design was approved by all required regulatory agencies.

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1. OBJECTIVES

The purpose of this program was to design a solar energy system for generating industrial process hot water for the canning industry, and to assure the potential savings in money and resources of such a system. Specific objectives of the program were to:

- Review the process hot water requirements of the selected company, formulate selection criteria, and then select the process hot water requirement to be met by the solar energy collection systems
- Select a process allowing a direct comparison between a solar energy augmented system and the existing system
- Analyze the selected process in detail to define the requirements for a solar energy system capable of providing significant quantities of process hot water
- Provide a conceptual design of the solar hot water system utilizing state-of-the-art solar energy components
- Provide a detail design of the solar hot water system using the conceptual design as a baseline
- Provide a cost breakdown and schedule for building and installing the solar hot water system at the selected plant
- Stimulate interest among members of the canning industry in using a solar energy supported process hot water system
- Perform an economic analysis and comparison of both the existing process and the proposed solar energy augmented system showing the potential benefits of using solar energy

2. PROCESS HOT WATER REVIEW

The plant selected for the design of a solar industrial process hot water system was the Campbell Soup facility in Sacramento, California. The total hot water demand for this plant varies between 500 and 800 gpm during regular production shifts, and hits a peak of over 1,000 gpm for approximately one hour during the cleanup shift. Most of the hot water is heated in the boiler room by a combination of waste heat recovery and low pressure (5 psi) steam-water heat exchangers. The hot water emerges from the boiler room at a temperature between 160°F and 180°F and is transported to the various process areas. Booster heaters in the process areas then use low pressure (5 psi) or medium pressure (20 psi) steam to raise the temperature of the water to the level required for each process (Figure 1).

Hot water is used primarily at the Campbell Soup plant in the following processes:

1. Vegetable Blanching. Rice and beans are blanched with water at 205°F. There are three blanchers in the plant with a total demand of 60 gpm of hot water. The process is seasonal and declines during summer months to make room for tomato processing.

2. Meat Preparation. Water at a temperature of 205°F and 210°F is used for the defrosting of meat. This is a batch process and requires about 300 gallons per hour (average 5 gpm).

3. As a Product Ingredient. Many products require hot water as one of their ingredients. These are also batch processes and the water demand varies greatly from process to process. It is estimated that between 100 gpm and 200 gpm of water are required on the average for this application.

4. Can Washing. This is a continuous year round operation which requires hot water at temperatures of 180°F and 190°F. There are 20 parallel can washing lines, with both converted lines requiring 10 gpm to 15 gpm and unconverted lines about double that amount. In converted lines, the hot water used for washing the empty cans is reused for washing the filled cans. In the unconverted lines, fresh hot water is used for both processes. The total demand for the can washing operation is approximately 300 gpm.

5. Hydrostatic Cookers. The hydrostatic cooker consists of two open columns of hot water that balance the steam pressure in an enclosed steam dome. The average temperature of water in the cooker is around 200°F and the total volume about 8,000 gallons. The unit is drained and refilled once a week. It is refilled with cold water and then heated by contact with the steam in the dome.

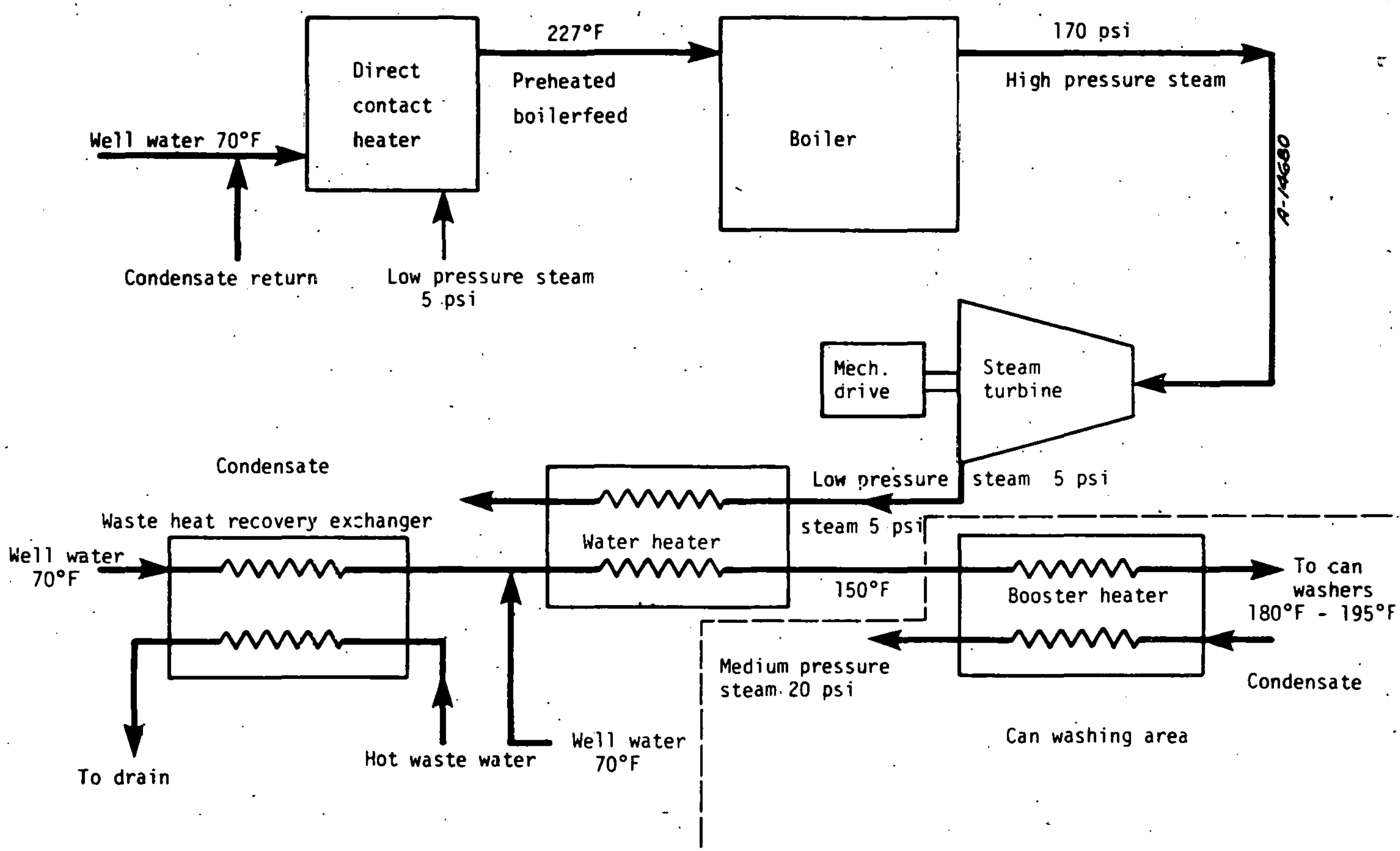

Figure 1. Water heating system at Campbell Sacramento plant.

6. Cleanup Operation. This operation demands the largest volume of hot water usage in the plant. Cleanup usually takes place during the third shift, when the hot water demand may be as high as 1,300 gpm for approximately an hour. The temperature of water drops to 150°F or lower during these periods. In addition to this major cleanup, there is a 4 to 5 minute cleanup period per machine every hour during the regular shifts.

Of all the uses of hot water listed above, can washing was best suited for a demonstration of the feasibility of a solar hot water system. Of the 20 can washing lines, lines U and V were particularly suited for this purpose. This was true for the following reasons:

- The can washing process is ideally suited for this experiment because it offers 20 parallel lines for comparison purposes. The performance of two similar lines, one of which has been converted to solar, can be carefully monitored and evaluated. The U line was selected for the solar demonstration and the V line, which is located nearby, as the comparison line.

- Can washing has one of the largest demands for hot water in the plant during the regular shifts. The demand for each line is 15 gpm, which is ideal for an experimental solar system to handle. Following a successful experiment, other lines can be converted simply without any need for major redesign of the basic solar collector system.

- Can washing is one of the few processes which requires a continuous supply of hot water. Batch processes, for which the demand is discontinuous, would require a larger storage system for the hot water. In addition, monitoring of flowrates, temperatures, etc. of batch processes would require more sophisticated equipment to measure and record the variations. Evaluation of results and comparisons would also be more difficult if the variations in demand for hot water were irregular.

- The location of the U and V lines in the plant is ideal for a solar application. The control system and data acquisition system can be installed in a stairwell directly outside the washdown area. The storage tank can be placed either in the courtyard or parking lot in the immediate vicinity.

- The temperature level required for can washing is lower than that required for many other processes. This tends to minimize problems of heat loss in the piping and the storage vessel. The efficiency of the solar collectors is also higher at lower fluid temperatures.
- The Campbell plant changes over to tomato processing during the harvesting months of August and September. When this happens, lines U and V change over to tomato soup and run identical products during these months. During the rest of the year, the can size and production rate is the same for both lines, but line U processes chicken noodle soup whereas line V processes beef noodle soup.

3. ANALYSIS OF SELECTED PROCESS

The can washing devices are quite simple in operation. Empty cans are conveyed through the washers on six metal rails which form a cage. The empty washer itself is a sheet metal enclosure approximately 8 feet long; a water supply tube with a series of eight nozzles is located along one lower corner. As the cans pass through the washer, the rail cage is twisted through an angle so that all surfaces of the cans are exposed to the fixed streams of hot water.

For the converted lines, the hot water which drains off from an empty can washer flows into a sump below a filled can washer. Part of this water is fed with detergent and sprayed into the first section of the washer through a bank of 18 nozzles. The remaining hot water from the sump is then used to rinse off the filled cans in the second section of the washer which is equipped with 19 nozzles. A schematic diagram of the can washing process is shown in Figure 2.

The hot water supplied to the can washing line must meet the following requirements:

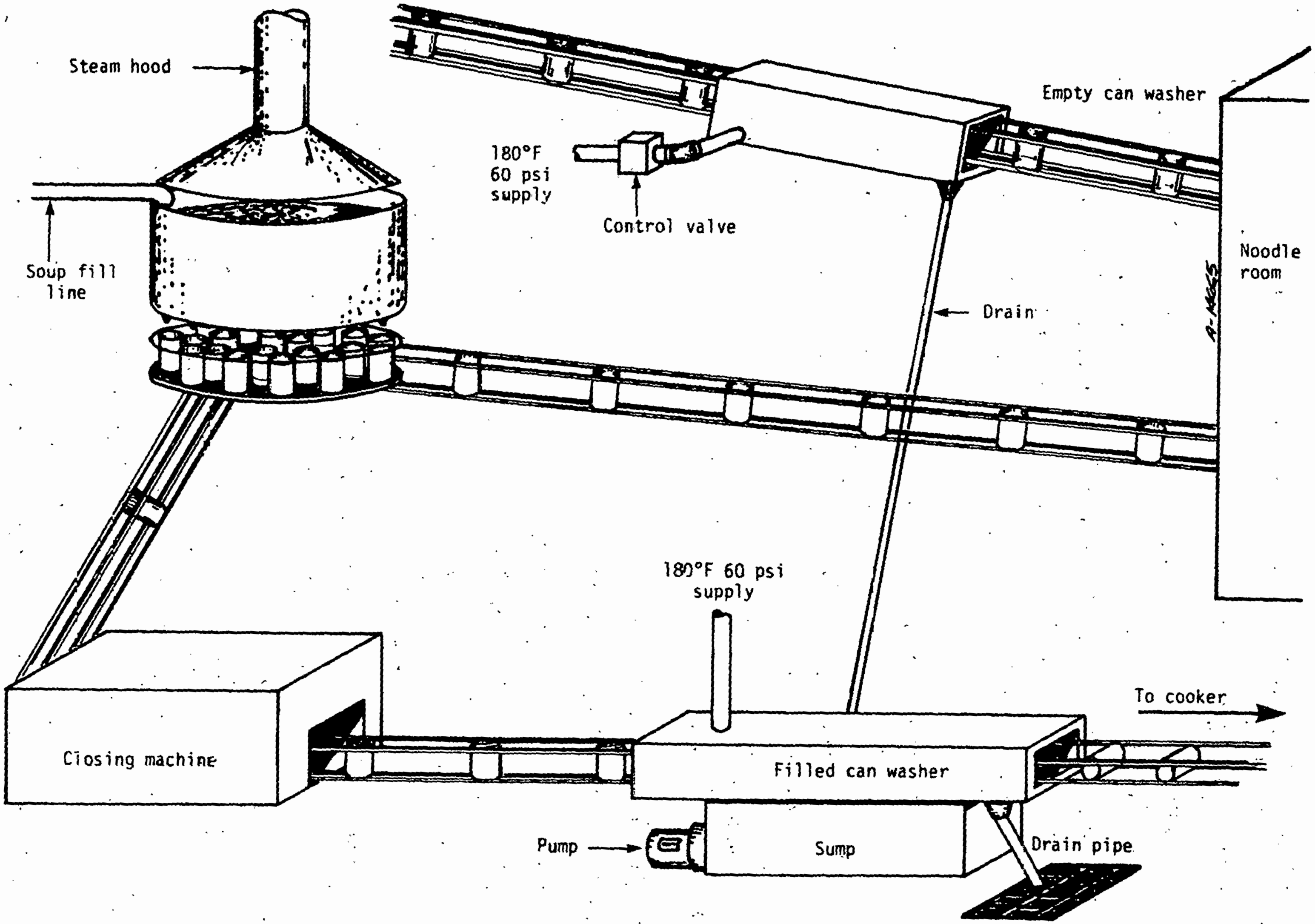

Figure 2. Can washer configuration.

- Flowrate: A continuous supply of hot water is required at the rate of 12.5 gpm
- Pressure: The supply pressure must be $\geq$60 psi
- Temperature: 180°F to 195°F

The can washer must be supplied with hot water during the first two shifts and partly during the cleanup shift, but not during the 4- to 5-minute cleanup period every hour. The plant normally operates 5 days a week, except during the harvest season, when for 4 to 6 weeks the plant operates 6 days a week. The plant is shutdown for 2 weeks beginning June 18th and for 1 week at Christmas.

The design, construction and installation of machinery and equipment for the food industry is regulated by a number of agencies. The major regulatory agencies and standards which affect the design of a solar collector for hot water in the canning industry are listed below:

- Food and Drug Administration (FDA), Good Manufacturing Practice Regulation, Part 120 — Sanitation, April 21, 1969
- United States Department of Agriculture (USDA), Accepted Meat and Poultry Equipment, June 30, 1974
- American National Standards Institute (ANSI), Food, Drug, and Beverage Equipment, ANSI-ASME, F 2.1, 1975
- Environmental Protection Agency (EPA), National Interim Primary Drinking Water Regulations, December 24, 1975
- Codified Federal Regulation (CFR), Title 9, Chapter III — Animal, Plant Health Inspection Service, October 3, 1970
- OSHA

The regulations covering food processing equipment are quite detailed and complex. For the purposes of supplying hot water for the can washing operation, the important constraints can be summarized as follows:

- Material. Equipment in the food area must be constructed of materials which prevent deterioration from normal use and from chemicals, cleaning agents, and atmospheric exposure in the normal production environment. They must be smooth-surfaced, corrosion and abrasion resistant, shatterproof, nontoxic, nonabsorbent, and must not strain or migrate to the product.

- <u>Design and Construction</u>. All equipment in the food area must be designed and built to be readily cleanable. The design and construction of such equipment must prevent food from being contaminated with lubricants, fuel, metal fragments, glass, contaminated water, or any other foreign substances. Culinary steam, process air, and water are not excluded from this requirement.
- <u>Installation</u>. All parts of stationary or not readily removable equipment must be installed far enough away from floors, walls, and ceilings to provide access for cleaning and inspection. As an alternative, permanently mounted equipment may be sealed with a watertight seal to the adjacent structure. Wall-mounted cabinets and electrical connections must be installed at least 1 inch from the wall or sealed watertight to the wall.
- <u>General Safety Considerations</u>. All machines must be designed and built with materials which will provide adequate safety and protection for personnel.

USDA approval is required before any new equipment can be installed in the plant. Four copies of complete drawings and plans, including a list of materials, along with a letter requesting approval was submitted to USDA during Phase I of the program.

4. CONCEPTUAL DESIGN

After inspecting the Campbell Soup Sacramento plant, three potential locations for the collector field were identified (Figure 3). Area 1 is located on the roof of the finished product warehouse. The administration building and portion of the labeling building makeup area 2. Area 3 is a grass field.

In choosing between these three possible locations, four main criteria were used:

- Minimal collector field shading by buildings
- Cost of installation

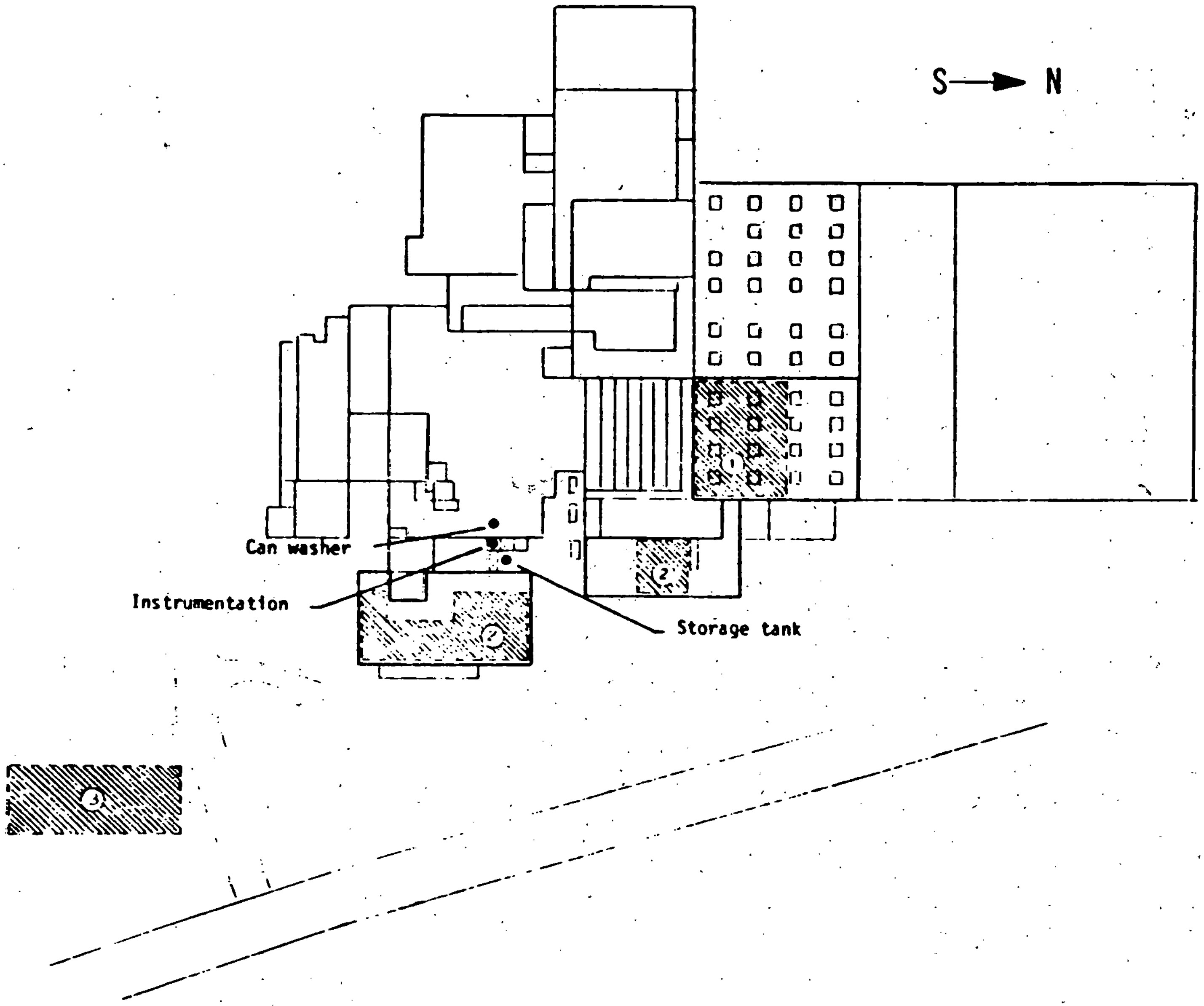

Figure 3. Candidate collector field locations at Campbell.

- Accessibility
- Campbell corporate approval

Table 1 summarizes the advantages and disadvantages of each of the potential locations. Both locations 1 and 3 are free of shading problems from buildings or other existing structures. A typical afternoon shading of area 2, however, shows that collector output in this location would be affected by shade from the surrounding buildings (Figure 4).

When cost of installing the collector field in each of the candidate locations was estimated, it was found that the cost would be lowest in location 1. This, along with the many other advantages, resulted in the selection of location 1. This choice has been approved by Campbell.

Once area 1 was chosen, a study was made of the various ways of installing the collector field to minimize mutual shading effects. A typical sun path diagram for each month of the year was made for the different concentrator mounting arrangements in order to determine times of the day in which mutual shading reduces the incident energy by either 0 to 50 percent or 50 to 100 percent. As shown in Figure 5, a mounting configuration was chosen in which mutual shading of the collectors occurs only early in the morning or late in the afternoon. At these times, the useful energy loss is negligible. The effect of finite through length (end loss) upon the collectable energy was incorporated into these evaluations.

Once the optimum mounting arrangement had been determined, a collector field analysis was performed to identify the field size and mix of concentrators and flat plate collectors which would be required for Sacramento weather conditions. Weather data from both Fresno and Davis,* California were obtained from the National Oceanic and Atmospheric Administration (NOAA). These data were compared to the statistical correlation procedure of Liu and Jordan (Reference 1) and good agreement was obtained. Statistical clearness parameters (Reference 2) and collector performance specifications were then used to figure the hourly useful collected energy for selective flat plates,

*Davis is about 15 miles from Sacramento, California.

TABLE 1. COLLECTOR FIELD LOCATION ASSESSMENT

Location	Advantages	Disadvantages
1. Finished Products Warehouse	• Skylights provide some of required support structure • Expansion area available • Minimal building shading • Maintenance • Lowest installation cost	• Slightly longer pipe run than location 2 • Roof leakage
2. Office and Labeling Buildings	• Shortest pipe run	• Building shading • Multiple roof locations are required • Roof leakage
3. Corner Lot	• No building shading problems • Ease of maintenance • Roof leakage is not a problem • Readily accessible for visitors	• Expensive and time consuming installation • Requires fence — vandalism • Dust from passing traffic • Future parking lot

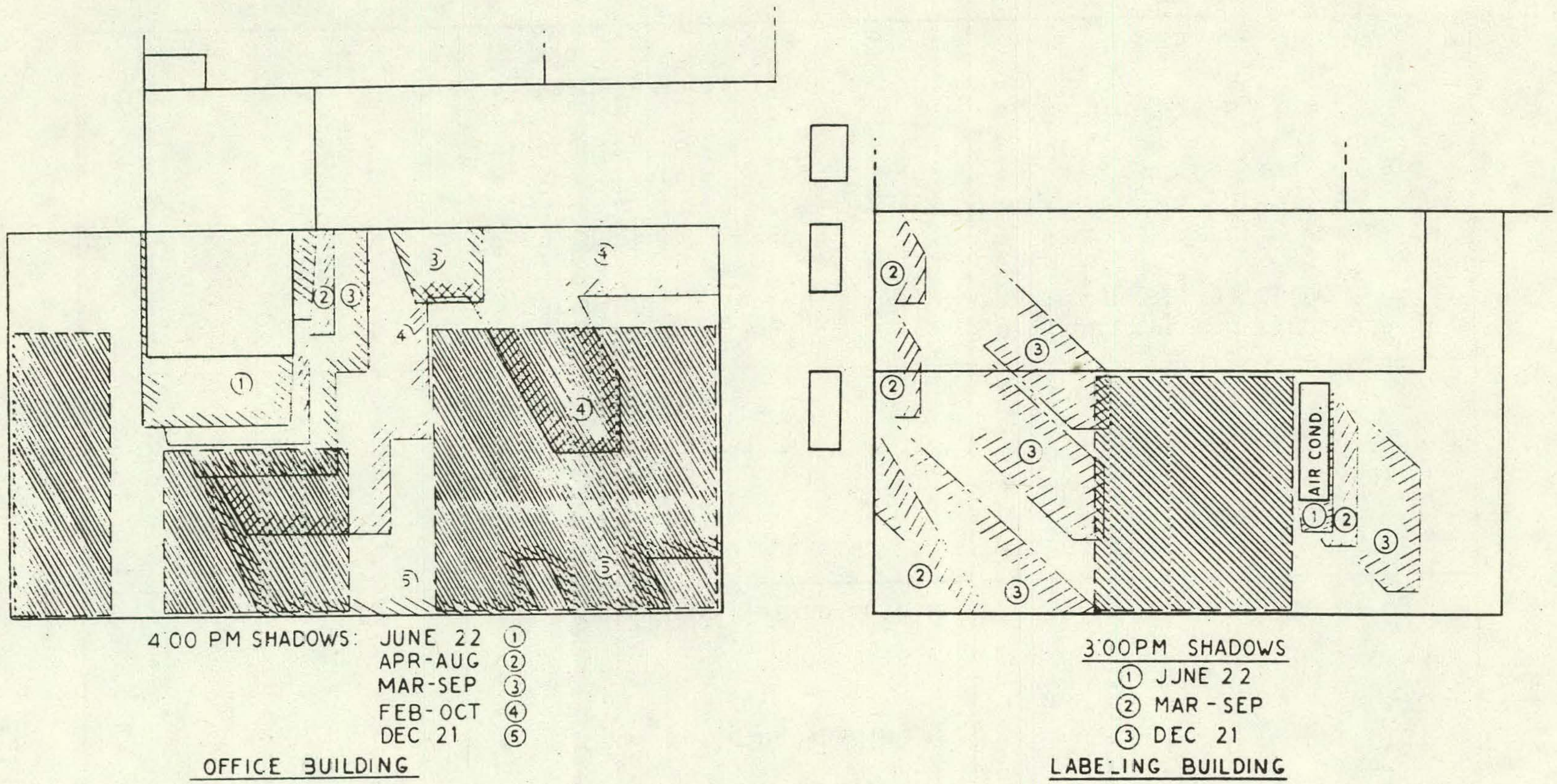

Figure 4. Location 2 afternoon shading.

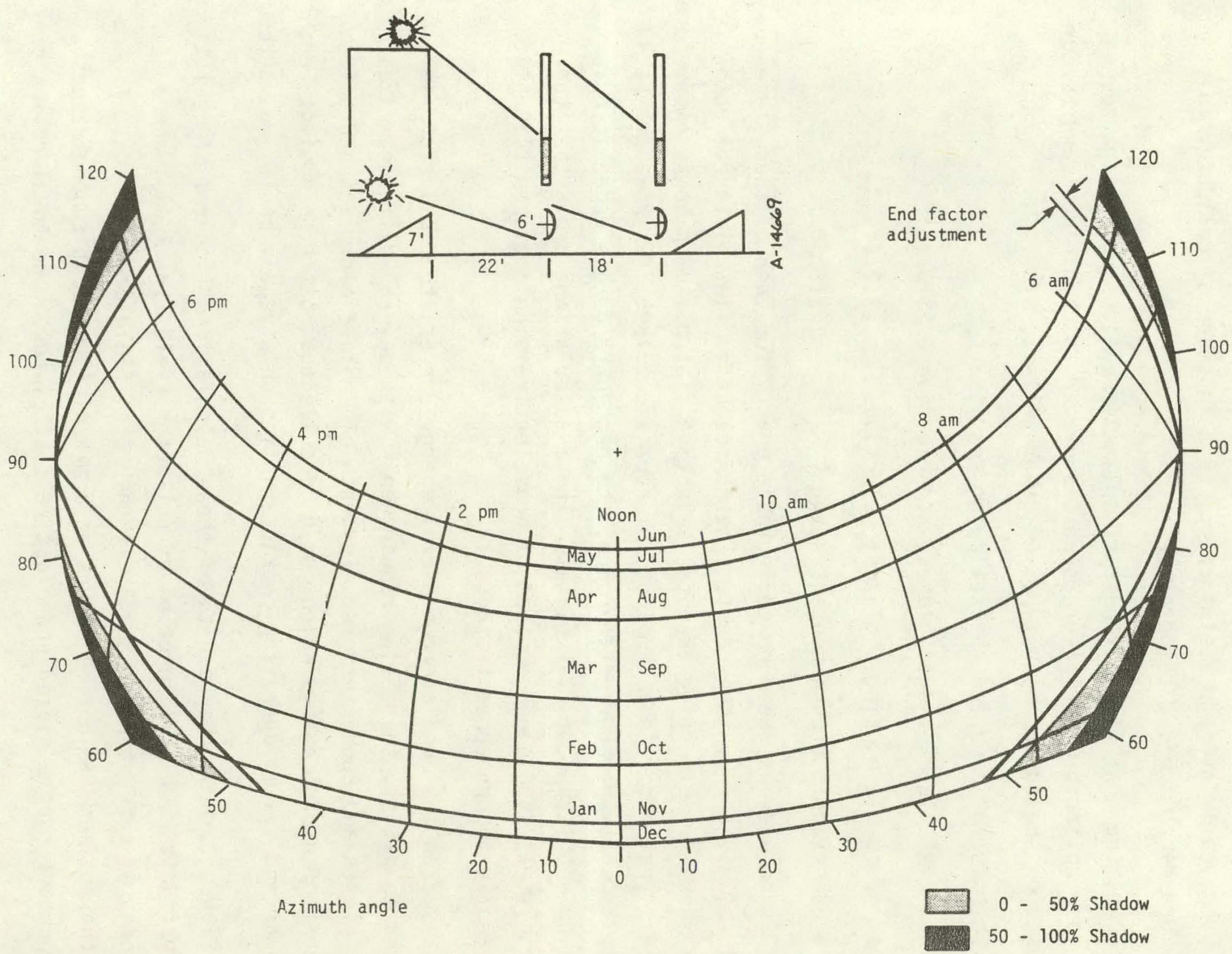

Figure 5. Relative collector shading.

nonselective flat plates, and east-west axis tracking concentrating collectors.* This combination of statistical data was then averaged to obtain monthly and yearly average useful energy as a function of collector inlet temperature minus ambient temperature.

Next, the cost effectiveness of collector options was evaluated. Seventy-one collector manufacturers were surveyed to obtain cost and performance data on the three major types of solar collectors.

This survey produced the following results:

- Flat plate, single glazed, nonselective = >$10/ft^2
- Flat plate, single glazed, selective = >$12/ft^2
- Parabolic trough concentrating = >$12.50/ft^2

Figure 6 shows the June collectable energy for each of these types of collectors, divided by their cost. The nonselective flat plate collector is clearly more cost effective than the selective flat plate up to a temperature difference (collector inlet-ambient) of approximately 67°F. However, at a slightly lower temperature difference, the concentrator has economic advantages over both types of flat plates. These calculations prove that the collector field should be composed of nonselective single glazed flat plates and parabolic trough concentrators.

Based on the June average useful energy curves, the collector field was sized to satisfy the design requirements with several different mixes of flat plates and concentrators. For each of these field mixes and sizes, the amount of useful energy which could be collected, based on ambient weather conditions and system operation characteristics on a yearly basis, was determined.

Figure 7 shows the results of these calculations in terms of useful energy per unit cost as a function of collector field mix, A_C/A_T, where A_C is the area of concentrators and A_T is the total field area. As this figure shows, the optimum field size occurs at a mix of 40-percent concentrators and 60-percent single glazed nonselective flat plates. The total collector

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*By using existing skylights (25° tilt angle, south facing) as a support structure for flat plates, the installation cost for the flat plate collectors could be reduced. Even though this tilt is not optimum, performance loss is minimal.

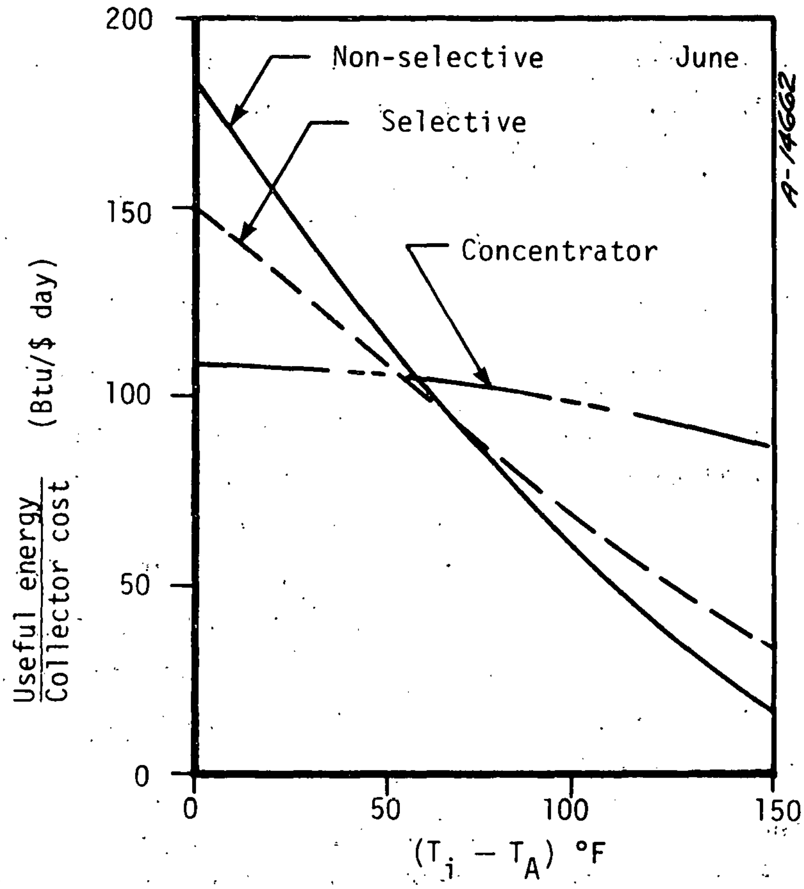


Figure 6. Economic comparison of flat plate and concentrating collectors for June.

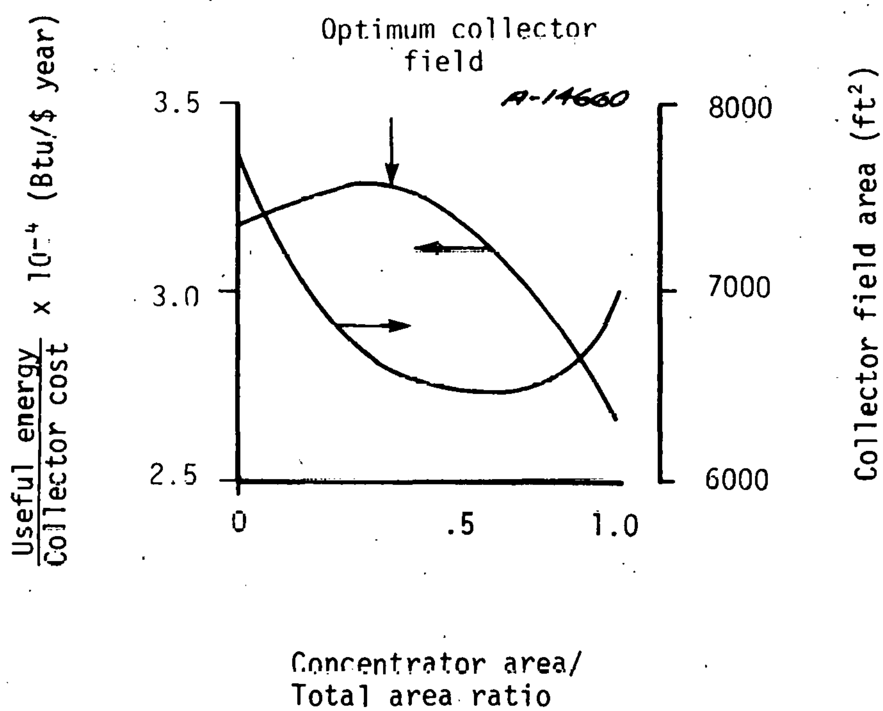


Figure 7. Economic optimization of collector field mix.

area needed to supply the plant's hot water requirements on a typical June day is about 6,620 ft^2 according to the efficiency curves assumed for the study. It should be noted that as the ratio of concentrators to total field area varies, the total collection area required to supply a fixed amount of energy also varies. This is due to the efficiency differences between the flat plate and the concentrating collectors.

The TRNSYS computer code (Reference 3) was substantially modified to more accurately simulate the performance of the process hot water system for the Campbell Soup plant. System simulations were performed using actual weather data for Fresno adjusted to reflect the daily total radiation levels and ambient temperatures for Davis, California. The results of these simulations substantiated the fact that the collector field size and mix identified in the above analysis is the optimum for this application.

4.1 Storage

Two basic types of controls were evaluated for the storage tank: stratified and accumulator. With stratified control, fluid is removed from the bottom of the storage tank, circulated through the field, and returned to the top of the tank. Hot water for can washing would be supplied from the top of the tank, and makeup well water would enter the bottom of the tank.

With accumulator control, cold well water enters the collector field directly, passes through the field once and enters the top of the tank. A floating suction removes water for can washing from the top of the tank. In order to collect energy 7 days a week an accumulator volume of 20,000 gallons is required. For this control option, the flowrate through the field is a programmed function approximating the daily insolation profile. The integrated mass flux is equal to 5/7ths of the total weekly can washer demand, which allows weekends to be used for replenishing the water in the accumulator tank (Figure 8). The profiled flowrate maintains the collector field outlet temperature at 195°F on a peak June day throughout the entire daily collection period.

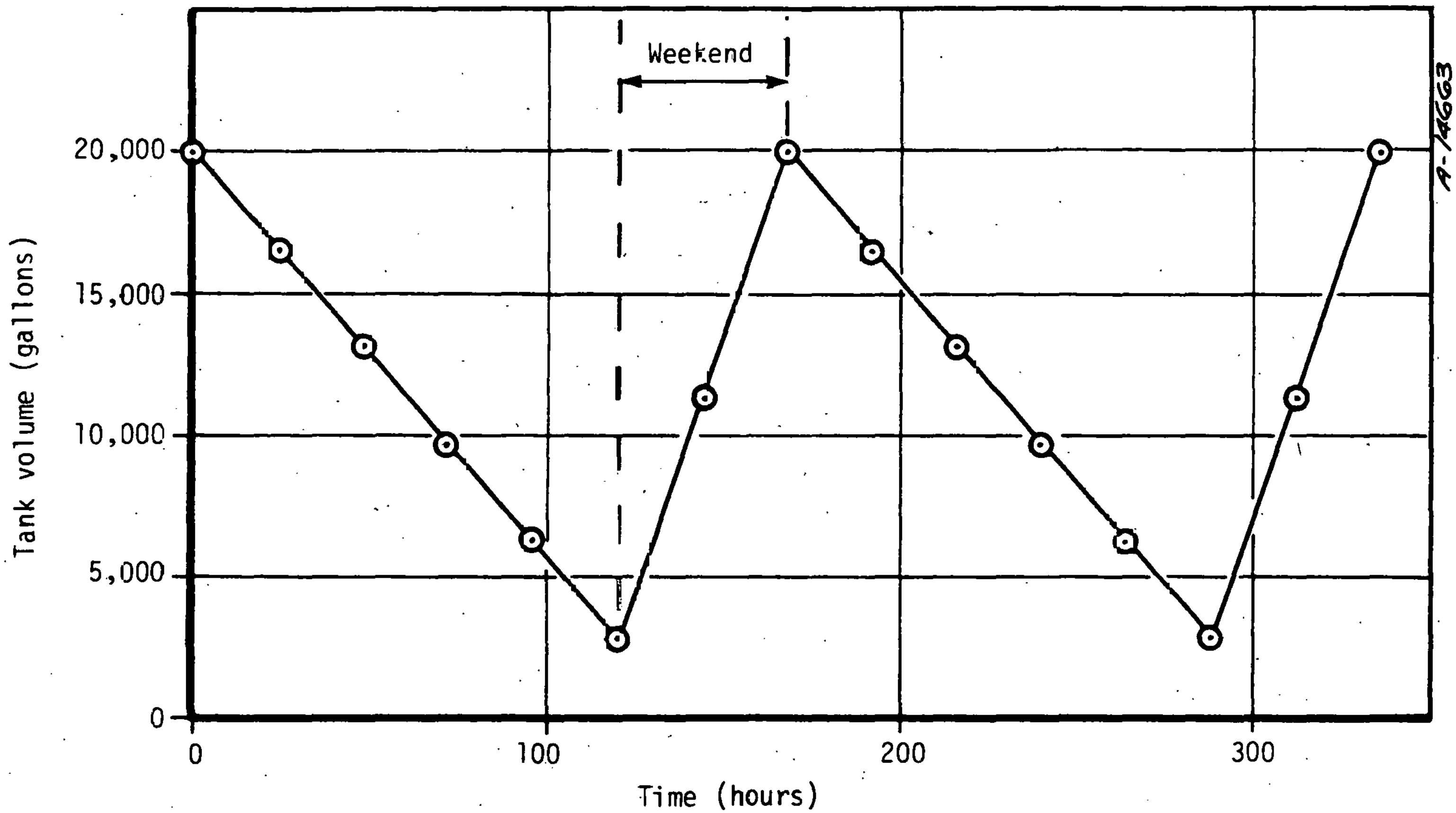


Figure 8. Accumulator tank volume history.

To determine which type of control provides the most useful energy to the can washer, transient system simulations were performed for three different stratified tank sizes and a 20,000 gallon accumulator tank. The results of these simulations, presented in Figure 9, show that for a given field size and mix, the accumulator is most cost effective. For this reason, a 20,000 gallon accumulator storage tank was selected.

A location for the storage tank was chosen near the can washing line, where it will be easy to install and maintain. Because of the short distance from the tank to the can washer, water temperature and pressure drops are minimal. Figure 10 shows the location of equipment in the Campbell Soup plant. Figure 11 is a schematic of the system.

4.2 Control Philosophy

The decision to use accumulator control was made on the basis of the results of collector field and storage tank optimizations. Since the can washing line only operates 5 days a week and useful energy will usually be collected for all 7 days, a storage tank will be used. The tank will be virtually empty after Friday's second shift and will be filled with hot water by Sunday evening (Figure 8).

The flowrate through the collector field will vary throughout the day. A programmable controller will adjust the flowrate in a predetermined manner to approximate the incident energy. The total integrated daily mass flow will be equal to 5/7ths of the weekly washer demand. This program will be changed monthly to account for changes in the length of the day.

4.3 Annual System Performance

A transient computer simulation of the entire solar process hot water system was made. A modified version of TRNSYS (Reference 3) was used in this analysis, with weather data from NOAA for Fresno, California adjusted for differences in daily total radiation between Fresno and Davis, California. Since neither Fresno nor Davis record beam radiation, the methods of Liu and Jordan (Reference 2) were used to estimate the beam component from the total radiation data. The percentage of the hot water for the can washer which will be supplied each month by solar system is shown in Figure 12. This simulation shows that approximately a 70-percent solar substitution will result from the baseline system design.

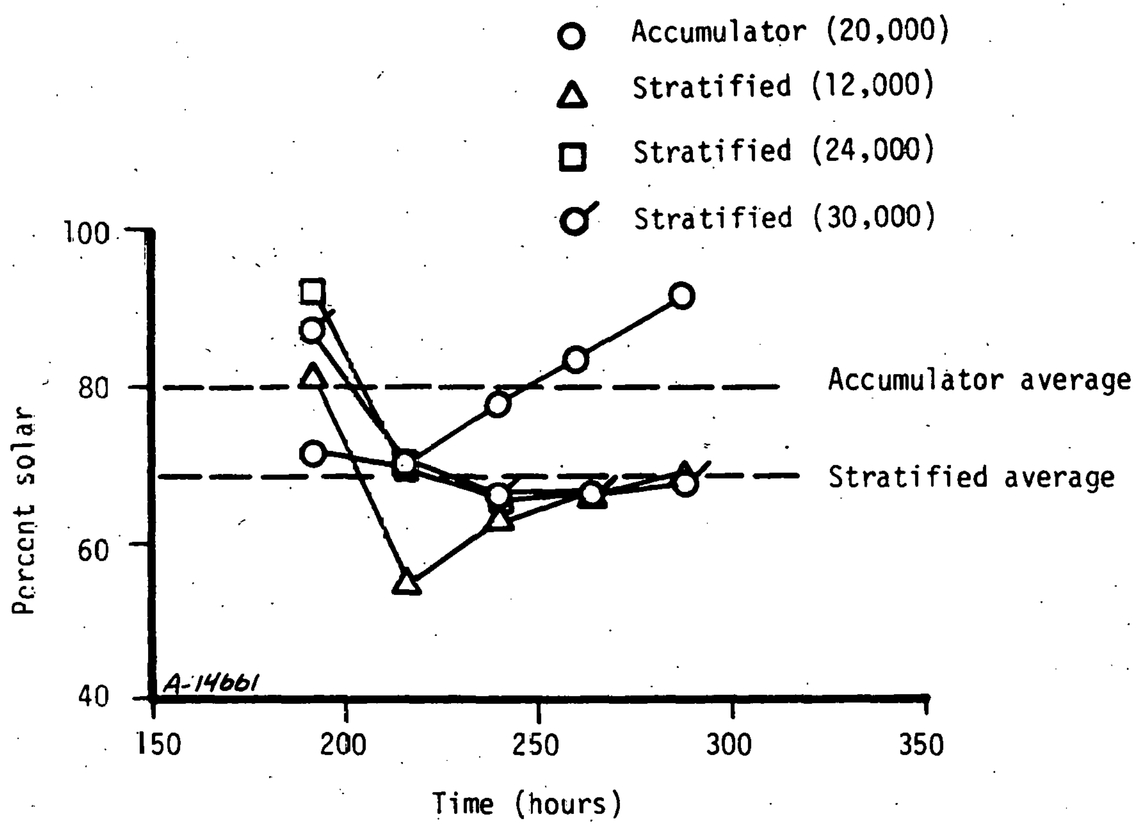


Figure 9. Effect of tank size and control mode on solar contribution.


Campbell Soup Company
SACRAMENTO PLANT
Collector field area
Can washing building
Pipe run
Instrumentaticn area
Storage tank

Figure 10

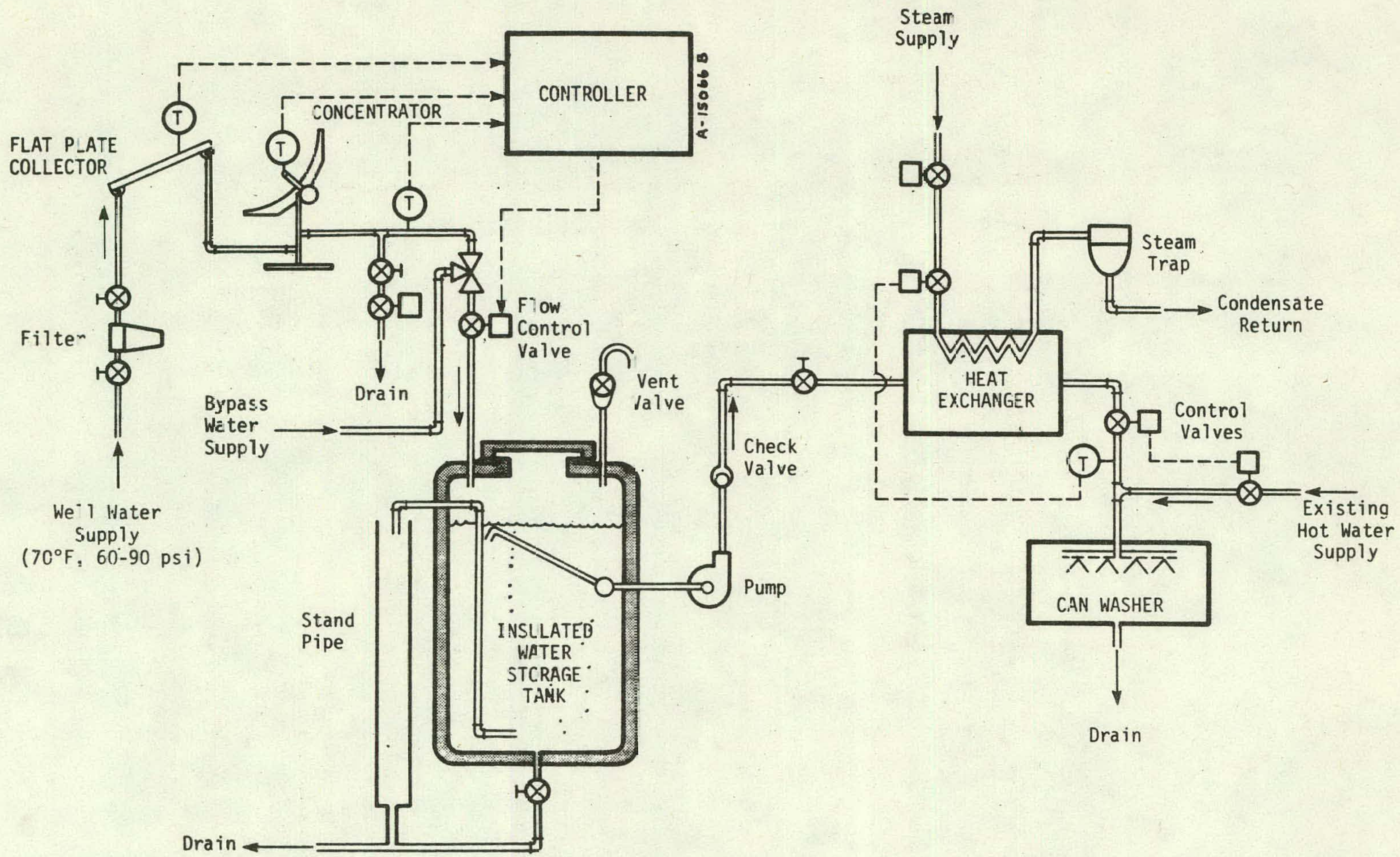


Figure 11. Solar water heating system for can washing.

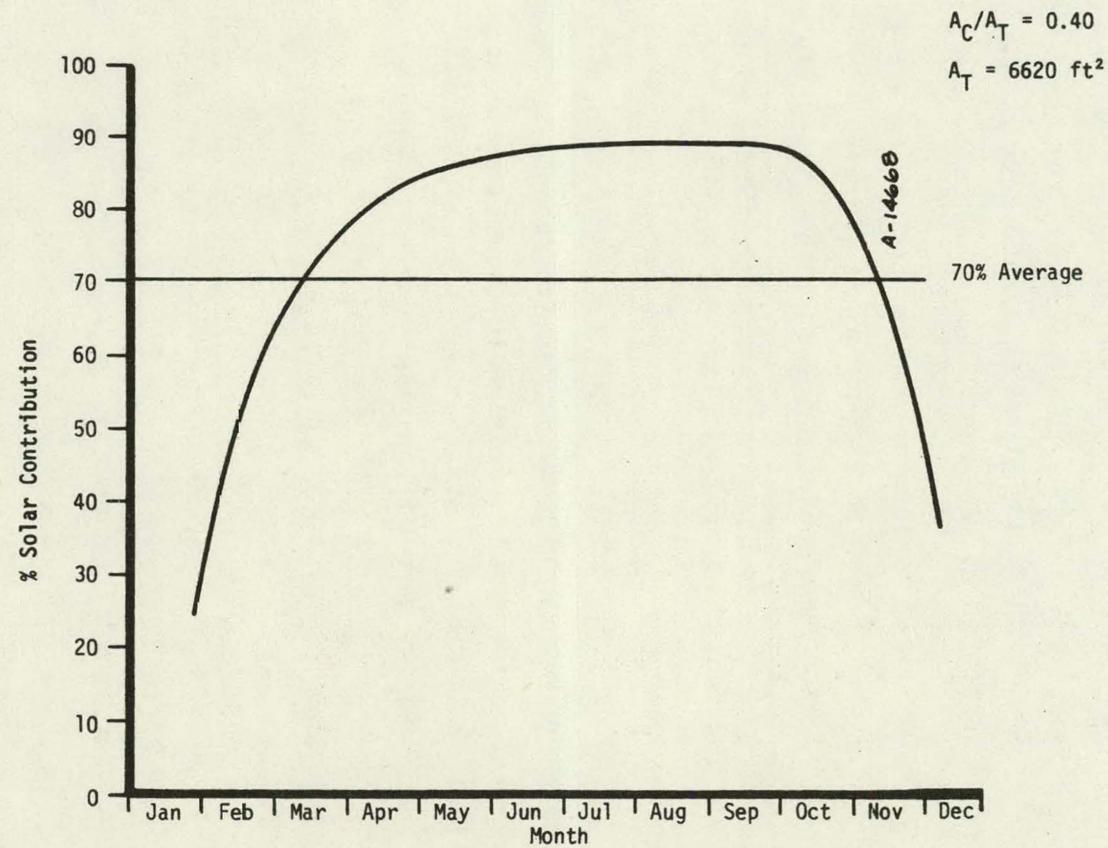


Figure 12. Transient system performance simulation.

5. DETAIL DESIGN

A detail design was developed to integrate the subsystem components selected in the conceptual design into a final design for supplying solar-heated hot water to can washing line V. The detail design package was generated: (1) to provide specifications for installing the system at the Campbell Soup Company's Sacramento Plant with approval from Campbell Soup Company and ERDA; (2) to obtain USDA approval for the design; (3) to generate fixed price cost estimates for the installation of the system (Phase II); and (4) to estimate the operating and maintenance cost of the system (Phase III). A brief description of the overall solar water-heating system follows.

The collector field is located on the roof of the finished products warehouse of the Campbell Soup Sacramento plant (Figure 13). Water is supplied from a 1-1/2-inch supply line which is located directly below an existing roof access hatch. A supply pipe will be brought up through that hatch to supply the dual rows of flat plate collectors.

The water preheated by the flat plates is then passed into six sets of parallel connected concentrators. Each set consists of eight 6 x 10 foot modules connected in series. The water from these units is gathered in a 1-1/2-inch insulated pipe and transported to the storage tank. This pipe will be attached to an existing pipe run until it reaches the can washing building. From there the pipe will follow the can washing building around to the storage tank. Figure 14 gives the details of the field layout. Figures 15 and 16 show a typical installation of a concentrating collector and a flat plate collector.

The storage tank is a 19,200 gallon steel tank which is coated internally with a USDA approved phenolic liner. The outside of the tank is insulated. A 3-hp motor is used to pump the stored water from the tank into the can washing line.

The pipe carrying solar-heated water from the storage tank will pass into the can washing building through a plastic windowpane. The water will go through a steam heat exchanger to be brought up to its required use temperature. In order not to waste energy from the solar collector system, the collector field has been sized to supply exactly the required amount on a peak June day. The heat exchanger will therefore be used most of the year

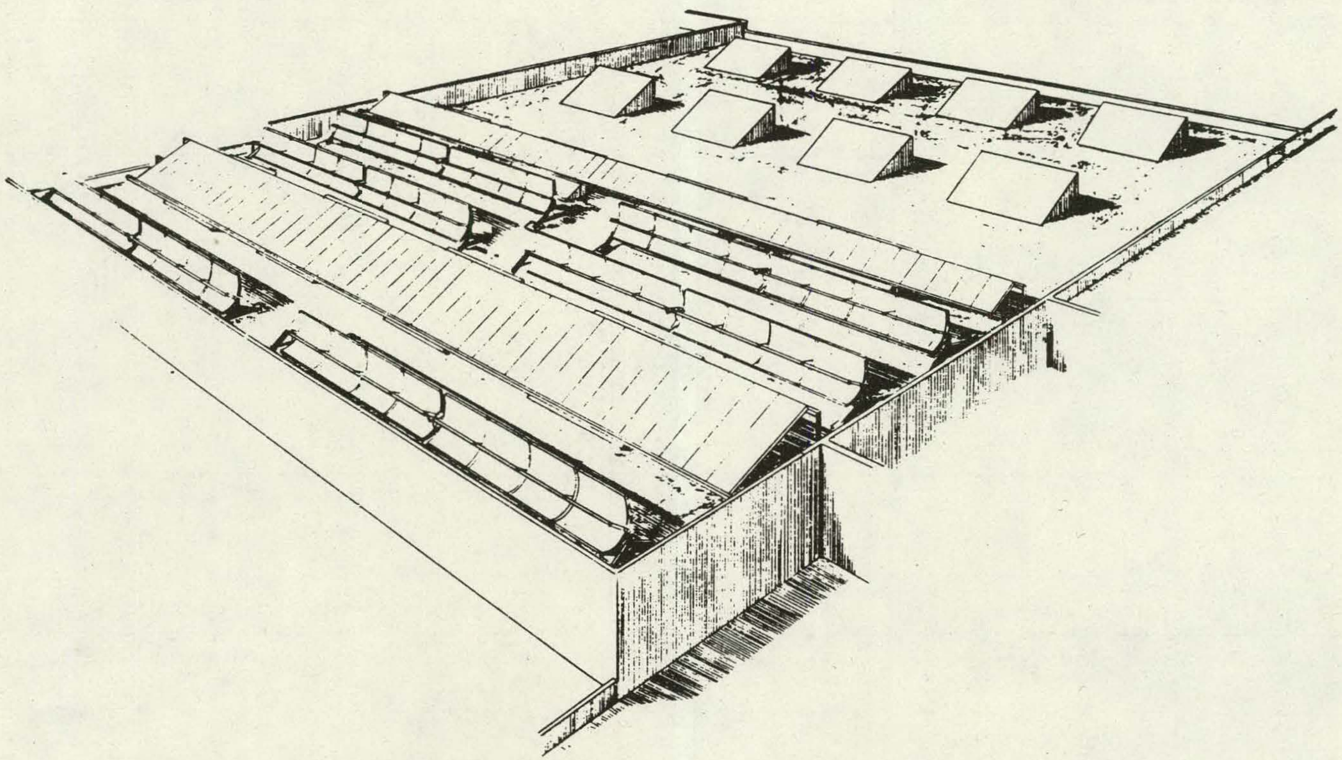
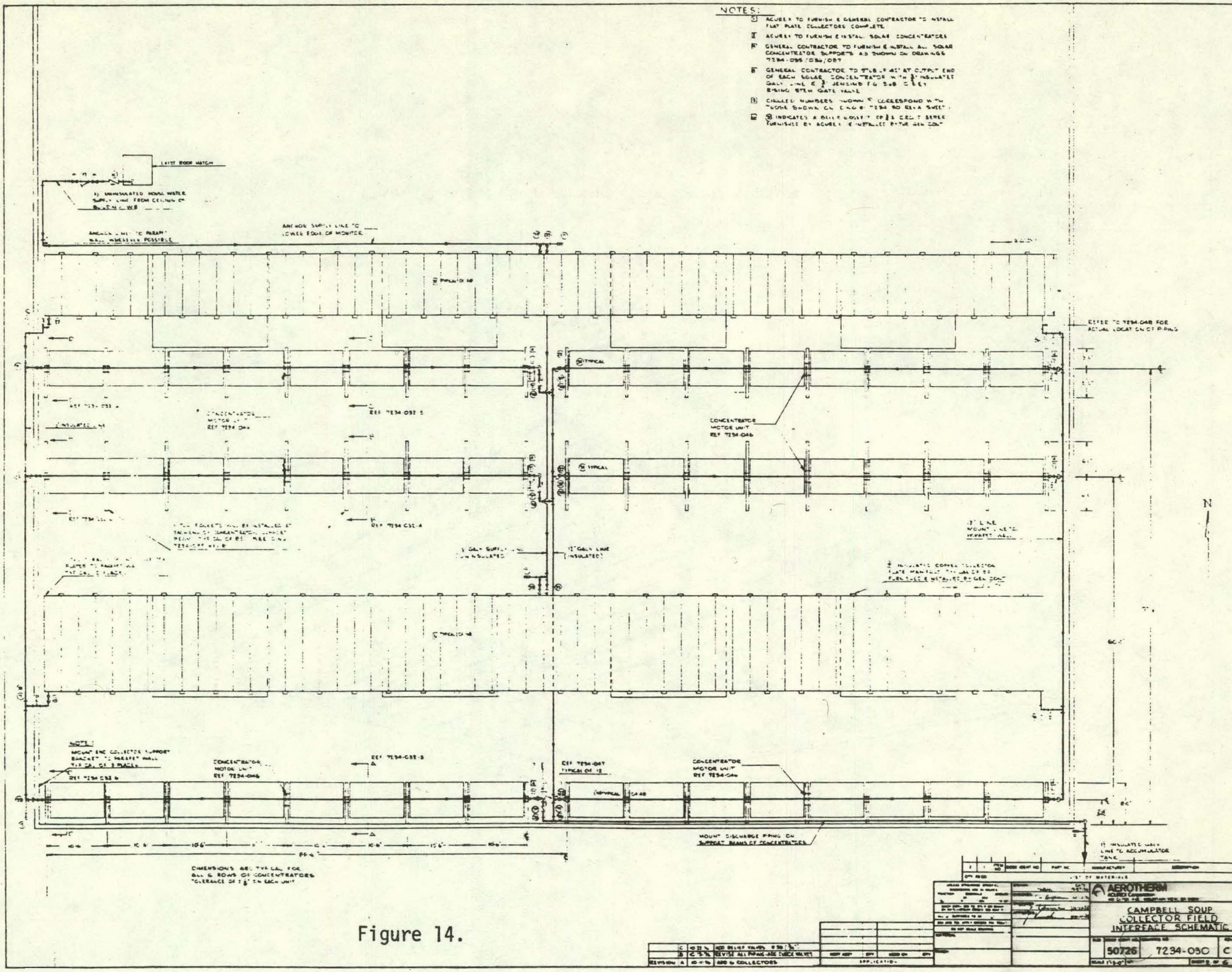


Figure 13. Flat plate and concentrating collectors on selected roof site.


NOTES:
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CAMPBELL SOUP
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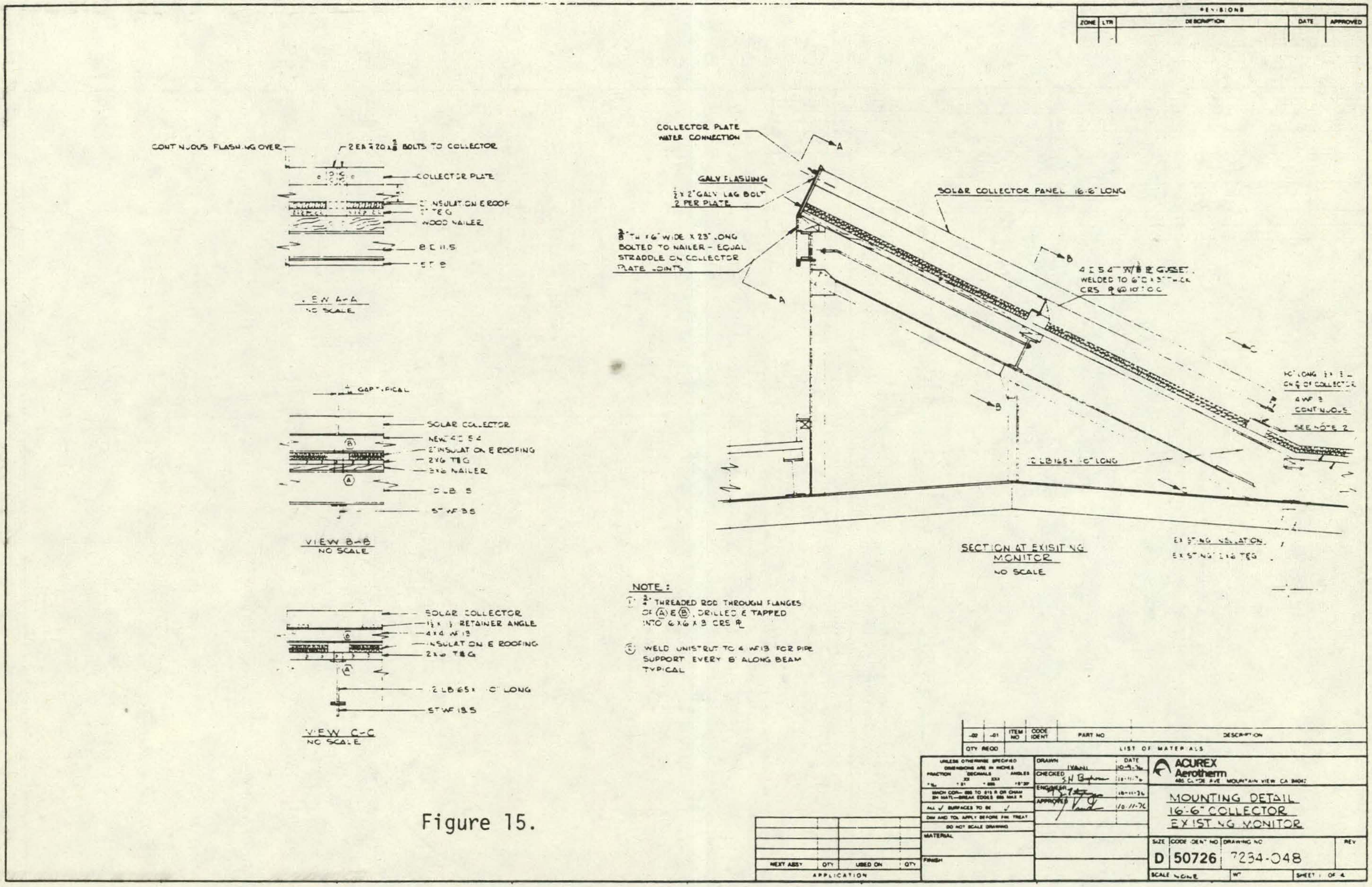
Figure 14.



REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
COLLECTOR PLATE
WATER CONNECTION
GALV FLASHING
SOLAR COLLECTOR PANEL 16'-6" LONG
2 PER PLATE
BOLTED TO NAILER - EQUAL
STRADDLE ON COLLECTOR
PLATE JOINTS
SECTION AT EXISITING
MONITOR
NO SCALE
VIEW B-B
NO SCALE
VIEW C-C
NO SCALE
SOLAR COLLECTOR
2X6 T&G
WOOD NAILER
COLLECTOR PLATE
NOTE:
WELD UNISTRUT TO 4 WF13 FOR PIPE
SUPPORT EVERY 8' ALONG BEAM
TYPICAL
LIST OF MATERIALS
ACUREX
Aerotherm
MOUNTING DETAIL
16'-6" COLLECTOR
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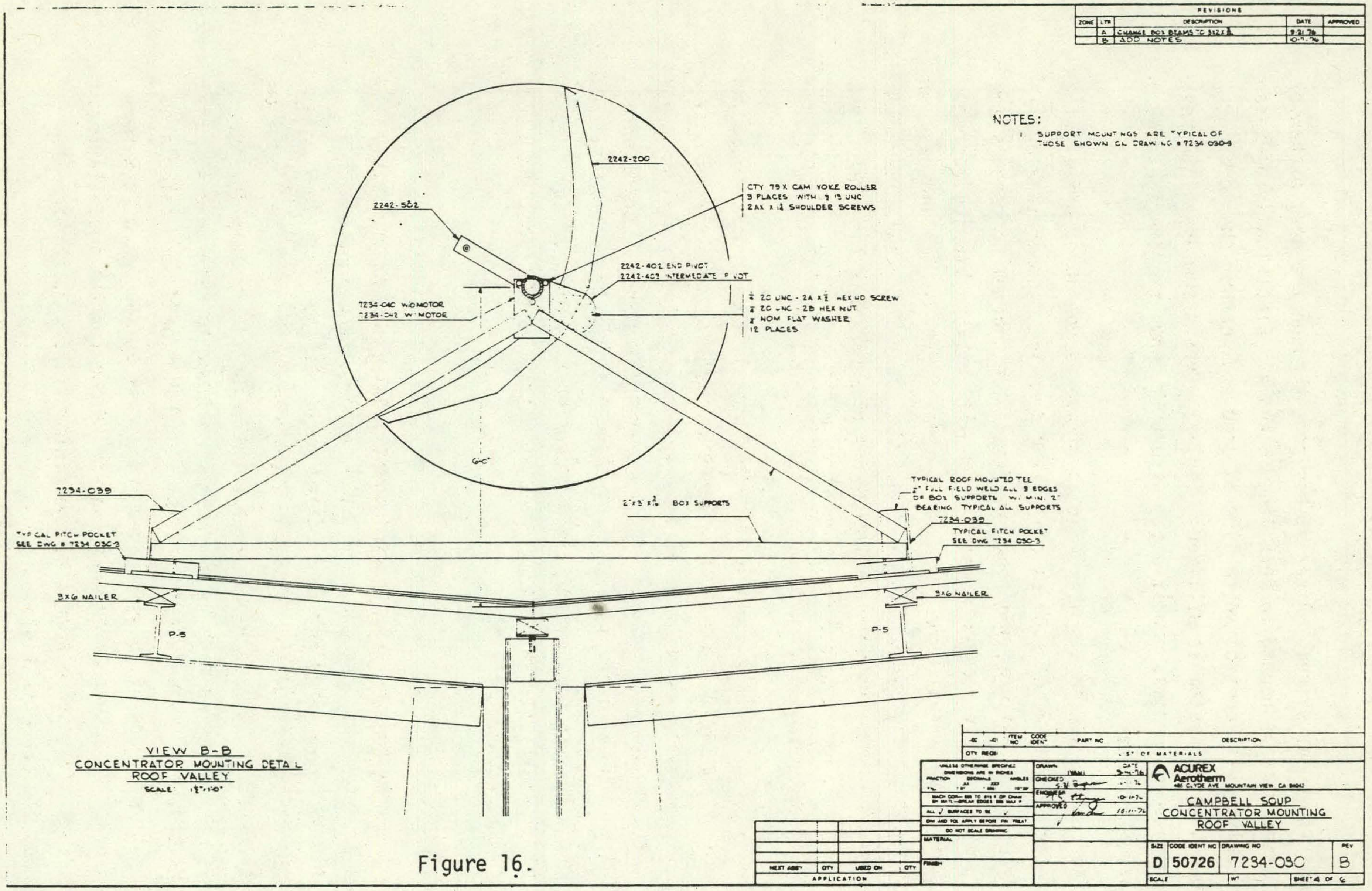
D
50726
7234-048
APPLICATION

Figure 15.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A CHANGE BOX BEAMS TO
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NOTES:
1. SUPPORT MOUNTINGS ARE TYPICAL OF THOSE SHOWN ON DRAWING # 7234-030-3
2242-200
2242-502
2242-402 END PIVOT
2242-403 INTERMEDIATE PIVOT
7234-040 W/O MOTOR
7234-042 W/MOTOR
12 PLACES
BOX SUPPORTS
7234-039
TYPICAL PITCH POCKET SEE DWG # 7234-030-3
3X6 NAILER
P-5
VIEW B-B
CONCENTRATOR MOUNTING DETAIL
ROOF VALLEY
LIST OF MATERIALS
ACUREX Aerotherm
CAMPBELL SOUP
CONCENTRATOR MOUNTING
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Figure 16.

to augment the solar system. After it has gone through the heat exchanger, the hot water will be routed to both lines U and V. Electrically operated solenoid valves will control which line is used and whether the solar or existing hot water system is utilized. Table 2 gives a summary of the system components and process conditions. Figure 17 shows the storage tank and can washer interface.

The control system has been kept as simple as possible, while still allowing for contingencies such as can filler downtime, temperature overheat, frost, power failure, and tank overflow. The control components are standard, commercially available parts which will be assembled to perform the required control functions. Special control functions will be based on temperature inputs from measuring points in the system. Normal flowrate will be controlled by a cam-operated program based on a variable flow value. This program will be changed each month. Figure 18 shows the control system schematic.

Data will be collected and handled in several ways. First, data will be collected at the site and stored on magnetic tape for computer reduction, plotting, and analysis at Acurex. In addition, selected data will be available for the IBM data storage unit and transmitted by phone to the central data facility at Huntsville, Alabama. Finally, data can be printed out in real-time at the site for use in making field adjustments. Also, all abnormalities in the system will be recorded on the written record so that they may be given immediate attention.

5.1 Roof Loads

An analysis was made of the roof support structure of the Campbell Soup plant to make sure that the roof could support the weight of the collector field and associated hardware on the roof. The analysis took into account both the weight of the collector field components and the load from the wind expected in the Sacramento area. The velocity pressure for the installation was determined using the method outlined in Reference 4. The actual windloads are shown in Tables 3 and 4. These loads were calculated using velocity pressure of 25 psf instead of 15 psf as specified in Reference 4, in order to insure an adequate safety factor for the installation. Based on this wind pressure analysis, the minimum safety factor for the Campbell Soup structure is 1.67.

TABLE 2. SYSTEM COMPONENTS AND PROCESS CONDITIONS

T-60

Equipment

- Flat Plate Collectors

Total Area	4698 sq. ft.
Absorber Area	4134 sq. ft.
Area Ratio Absorber/Total	0.88

Absorber Coating — nonselective, 3M brand Nextel black velvet coating.

Absorber Plate — 0.040 aluminum plates swage fitted over copper tubing.

Glazing — low iron-tempered glass 0.125-inch thick.

Insulation — bottom, one layer of 1.0-inch thick fiberglass insulation and one layer of 1.25-inch thick isocynate foam.
— sides, one layer of 1.0-inch thick fiberglass insulation

Housing — extruded aluminum sides with bottom plate.

- Concentrating Collectors

Total Area	2880 sq. ft.
Type	Tracking
Concentration Ratio	35
Rim Angle	90°
Aperture	6 ft.
Length Per Unit	10 ft.
Slew Rate	90° in 15 min.
Receiver Tube	
Coating	black chrome over nickel plate
Size	1.250-inch o.d.
Material	copper tubing
Cover	pyrex glazing

- Accumulator Tank

Total Volume	19,200 gal.
Height	24 ft.
Diameter	12 ft.
Material	steel with PLACITE 3055 baked phenolic lining.
Insulation	fiberglass 6 inches thick with aluminum cover.

- Transfer Pump

Head	200 ft.
Capacity	15 gpm
Material	bronze fitted
Type	regenerative turbine

TABLE 2. Continued

T-60

	Model		Wesco CK610
	Manufacturer		Fairbanke Morse
	Motor		3 horsepower
• Heat Exchanger			
	Service		heating potable water
	Temperature Rise		70°F to 200°F
	Flowrate		15 gpm
	Tube Side		potable water
	Shell side		steam @ 20 psig
	Heat Transfer Surface Area		41 sq. ft.
	Fouling Resistance		0.0005 shell side 0.001 tube side
	Material		
	Tube		Admiralty
	Shell		Red Brass
	Bonnet		Cast Iron
	Size		9-3/4-inch o.d. x 19-inches long
	Model		HCF-C 08024
	Manufacturer		American Standard, Heat Transfer Div.
• Piping			
	Material		Sch 40 galvanized steel
	Size		
	Field inlet		1-1/2 inch
	Field outlet to Accumulator Tank		2 inch
	Concentrator inlet and outlet		1 inch
	Flate Plate Collectors		1 inch
	Accumulator Tank to canning lines		1-1/2 inch
	Connection to canning lines		3/4 inch
• Flowrates		Normal	Augmented
	Field Total		
	June Var.	1-21 gpm	28 gpm max.
	December	5-22 gpm	28 gpm max.
	Concentrator Array		4.7 gpm max.

TABLE 2. Concluded

T-60

Flat Plate Array	
10.5 ft. Array	5.3 gpm max.
16.5 ft. Array	8.8 gpm max.
• Pressure Drop	
Field — Overall	35 psi max.
Field Outlet to Accumulator Tank	17 psi max.
Concentrator Array	15 psi max.
Flat Plate Array	
16.5 ft. length	18 psi max.
10.5 ft. length	18 psi max.
Accumulator Tank to Can Washer	30 psi max.
Pressure Drop Across Nozzle at Can Washer	60 psi max.

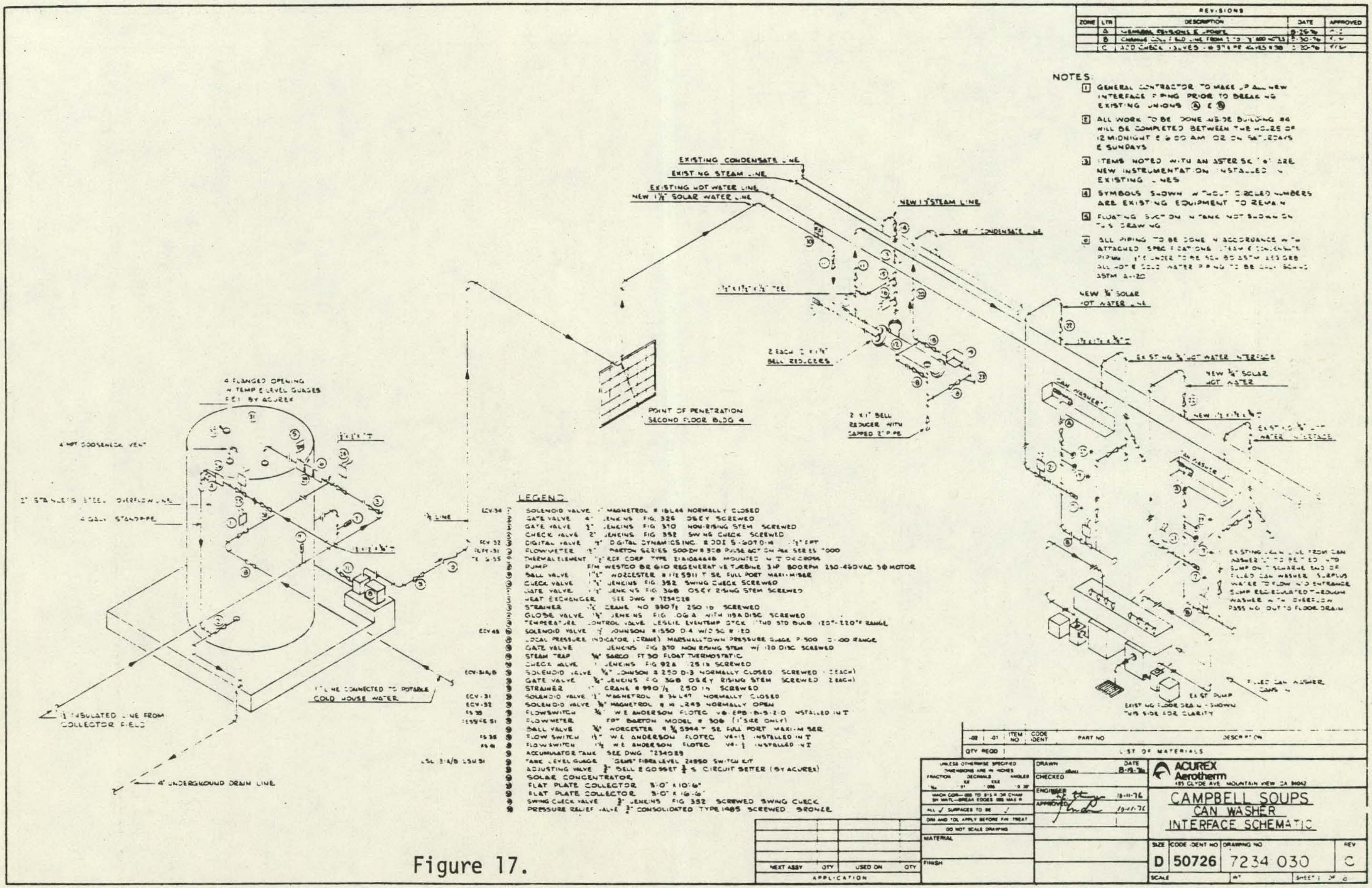
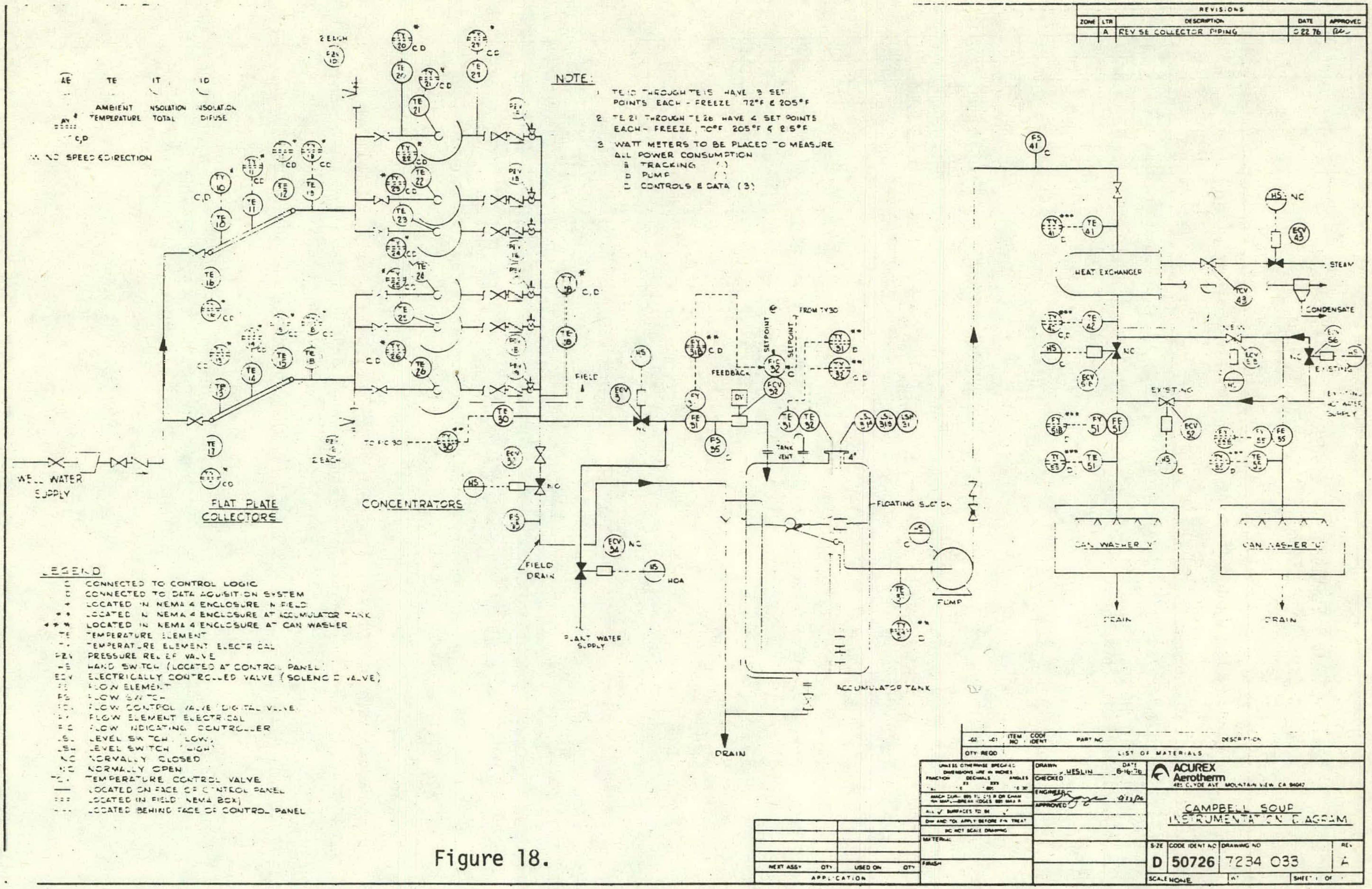

REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
NOTES:
1 GENERAL CONTRACTOR TO MAKE UP ALL NEW INTERFACE PIPING PRIOR TO BREAKING EXISTING UNIONS A & B
2 ALL WORK TO BE DONE INSIDE BUILDING #4 WILL BE COMPLETED BETWEEN THE HOURS OF 12 MIDNIGHT & 6:00 AM OR ON SATURDAYS & SUNDAYS
3 ITEMS NOTED WITH AN ASTERISK ARE NEW INSTRUMENTATION INSTALLED IN EXISTING LINES
4 SYMBOLS SHOWN WITHOUT CIRCLED NUMBERS ARE EXISTING EQUIPMENT TO REMAIN
EXISTING CONDENSATE LINE
EXISTING STEAM LINE
EXISTING HOT WATER LINE
NEW 1½" SOLAR WATER LINE
NEW 1½" STEAM LINE
NEW ¾" SOLAR HOT WATER LINE
NEW ¾" SOLAR HOT WATER
POINT OF PENETRATION SECOND FLOOR BLDG 4
2 EACH 2 x 1½" BELL REDUCERS
2 x 1" BELL REDUCER WITH CAPPED 2" PIPE
CAN WASHER
EXIST PUMP
4" UNDERGROUND DRAIN LINE
LEGEND
SOLENOID VALVE MAGNETROL # 16L44 NORMALLY CLOSED
GATE VALVE 4" JENKINS FIG. 326 OS&Y SCREWED
GATE VALVE JENKINS FIG 370 NON-RISING STEM SCREWED
CHECK VALVE 2" JENKINS FIG 352 SWING CHECK SCREWED
PUMP F/M WESTCO BR 610 REGENERATIVE TURBINE 3HP 800RPM 230-460VAC 3Φ MOTOR
HEAT EXCHANGER SEE DWG # 7234028
STRAINER CRANE NO 990½ 250 lb SCREWED
STEAM TRAP ¾" SARCO FT 30 FLOAT THERMOSTATIC
STRAINER 1" CRANE # 990½ 250 lb SCREWED
FLOWMETER BARTON MODEL # 306 (1" SIZE ONLY)
ACCUMULATOR TANK SEE DWG 7234029
SOLAR CONCENTRATOR
FLAT PLATE COLLECTOR 3'-0" x 10'-6"
FLAT PLATE COLLECTOR 3'-0" x 16'-6"
SWING CHECK VALVE ¾" JENKINS FIG 352 SCREWED SWING CHECK
PRESSURE RELIEF VALVE ¾" CONSOLIDATED TYPE 1485 SCREWED BRONZE
NEXT ASSY QTY USED ON QTY
APPLICATION
QTY REQD
LIST OF MATERIALS
PART NO DESCRIPTION
DRAWN CHECKED ENGINEER APPROVED
MATERIAL
FINISH
DO NOT SCALE DRAWING
ACUREX Aerotherm
485 CLYDE AVE MOUNTAIN VIEW CA 94042
CAMPBELL SOUPS
CAN WASHER
INTERFACE SCHEMATIC
SIZE CODE IDENT NO DRAWING NO REV
D 50726 7234 030 C
SCALE

Figure 17.



REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
A | REVISE COLLECTOR PIPING
NOTE:
1. TE 10 THROUGH TE 15 HAVE 3 SET POINTS EACH - FREEZE 72°F & 205°F
2. TE 21 THROUGH TE 26 HAVE 4 SET POINTS EACH - FREEZE, 70°F, 205°F & 215°F
3. WATT METERS TO BE PLACED TO MEASURE ALL POWER CONSUMPTION
a. TRACKING
b. PUMP
c. CONTROLS & DATA (3)
AMBIENT TEMPERATURE
INSOLATION TOTAL
INSOLATION DIFUSE
WIND SPEED & DIRECTION
WELL WATER SUPPLY
FLAT PLATE COLLECTORS
CONCENTRATORS
FIELD DRAIN
PLANT WATER SUPPLY
FEEDBACK
SETPOINT
FROM TY30
TANK VENT
FLOATING SUCTION
PUMP
ACCUMULATOR TANK
DRAIN
HEAT EXCHANGER
STEAM
CONDENSATE
EXISTING
EXISTING HOT WATER SUPPLY
CAN WASHER
LEGEND
C CONNECTED TO CONTROL LOGIC
D CONNECTED TO DATA ACQUISITION SYSTEM
* LOCATED IN NEMA 4 ENCLOSURE IN FIELD
** LOCATED IN NEMA 4 ENCLOSURE AT ACCUMULATOR TANK
*** LOCATED IN NEMA 4 ENCLOSURE AT CAN WASHER
TE TEMPERATURE ELEMENT
TY TEMPERATURE ELEMENT ELECTRICAL
PRV PRESSURE RELIEF VALVE
HS HAND SWITCH (LOCATED AT CONTROL PANEL)
ECV ELECTRICALLY CONTROLLED VALVE (SOLENOID VALVE)
FE FLOW ELEMENT
FS FLOW SWITCH
FCV FLOW CONTROL VALVE (DIGITAL VALVE)
FY FLOW ELEMENT ELECTRICAL
FIC FLOW INDICATING CONTROLLER
LSL LEVEL SWITCH (LOW)
LSH LEVEL SWITCH (HIGH)
NC NORMALLY CLOSED
NO NORMALLY OPEN
TCV TEMPERATURE CONTROL VALVE
LOCATED ON FACE OF CONTROL PANEL
LOCATED IN FIELD (NEMA BOX)
LOCATED BEHIND FACE OF CONTROL PANEL
LIST OF MATERIALS
DRAWN MESLIN
CHECKED
ENGINEER
APPROVED
ACUREX Aerotherm
485 CLYDE AVE MOUNTAIN VIEW, CA 94042
CAMPBELL SOUP INSTRUMENTATION DIAGRAM
SIZE D
CODE IDENT NO 50726
DRAWING NO 7234 033
REV A
SCALE NONE
NEXT ASSY
USED ON
APPLICATION

Figure 18.

TABLE 3. SUMMARY OR LOADS FOR FLAT PLATE COLLECTORS MOUNTED ON ROOF

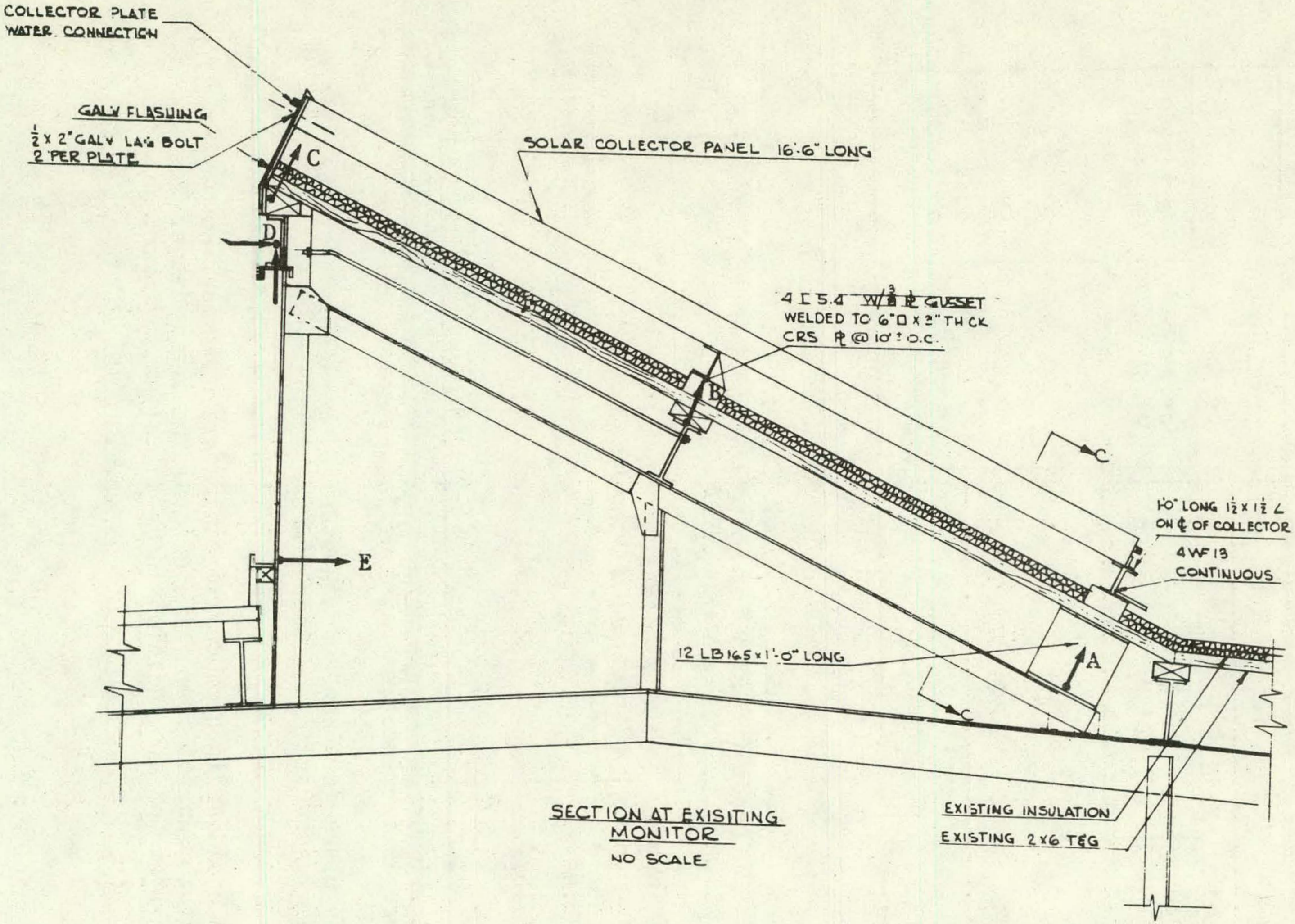
Item (a): Loads for 16.5 ft. collector mounted on typical monitor				
Point[a]	Deadload Acting Down	Windloads (Directions as shown)	Horizontal Windload	Vertical Windload
A	900 lb	1300 lb		
B	1760 lb	3145 lb		
C	28 lb/ft	93.3 lb/ft		
D	800		1736 lb	1691 lb
E	144	948 lb		

- Item (b): Loads for 10.5 ft. collector mounted on typical monitor			
Point[a]	Deadload Acting Down	Windloads (Directions as Shown)	Horizontal Load
B	1810 lb	1510 lb	883 lb
C	35.2 lb/ft	151 lb/ft	
D	900	1510 lb	667 lb

[a]Refer to Figure 19 for location point of loads.

[b]All loads take place in plane on both sides of monitor except for point C which gives distributed load along existing monitor for reference.

[c]Deadloads are additional loads due to collectors and mounting structure. Windloads for Item (a) are total for the monitor. Windloads for Item (b) are additional due to collectors mounted between monitors.



NOTE: Points A thru E represent centers for deadweight and windloads.

Figure 19. Force diagram for 16.5-foot long flat plate collector mounted on monitor.

TABLE 4. SUMMARY OF FORCES ON CONCENTRATING COLLECTORS MOUNTED ON ROOF

T-61

Condition		Sawtooth Position[a,d]			Roof Valley[b]			Parapet Wall[c]		
		R_{A_Y}	R_{B_Y}	$R_{B_Y} = R_{B_X}$	R_{A_Y}	R_{B_Y}	$R_{A_X} = R_{B_X}$	R_{A_Y}	R_{B_Y}	$R_{A_X} = R_{B_X}$
$(R_{B_Y})_{max}$	Wind	1062	2079	137	560	2058	806	2909	-1270	1195
$(R_{A_Y})_{min}$	From	-1563	175	894	-1518	-20	806	-2653	1654	1065
$R_{A_Y} = R_{B_Y}$ = Max.	South	-856±192	1828±192	1315	-873	1413	1315	1497	-2139	1315
$(R_{B_Y})_{min}$	Wind	-1485	-576	-137	-20	-1518	-806	-2485	1926	-1195
$(R_{A_Y})_{max}$	From	2049	419	-894	2058	560	-806	3309	-1230	-1065
$R_{A_X} = R_{B_X}$ = Min.	North	1342±192	1828±192	-1315	1413	-873	-1315	2542±253	-2002±253	-1315
Maximum Total Upward Force		-940±192	-1150±192	0	-1045±126	-1045±126	0	-1270±253	-820±253	0
Maximum Total Downward Force		1426±192	1744±192	0	1585±126	1585±126	0	1926±253	1244±253	0

[a]Drawing 7234-030 Sheet 5

[b]Drawing 7234-030 Sheet 4

[c]Drawing 7234-030 Sheet 3

[d]See Figure 20 for application point of load

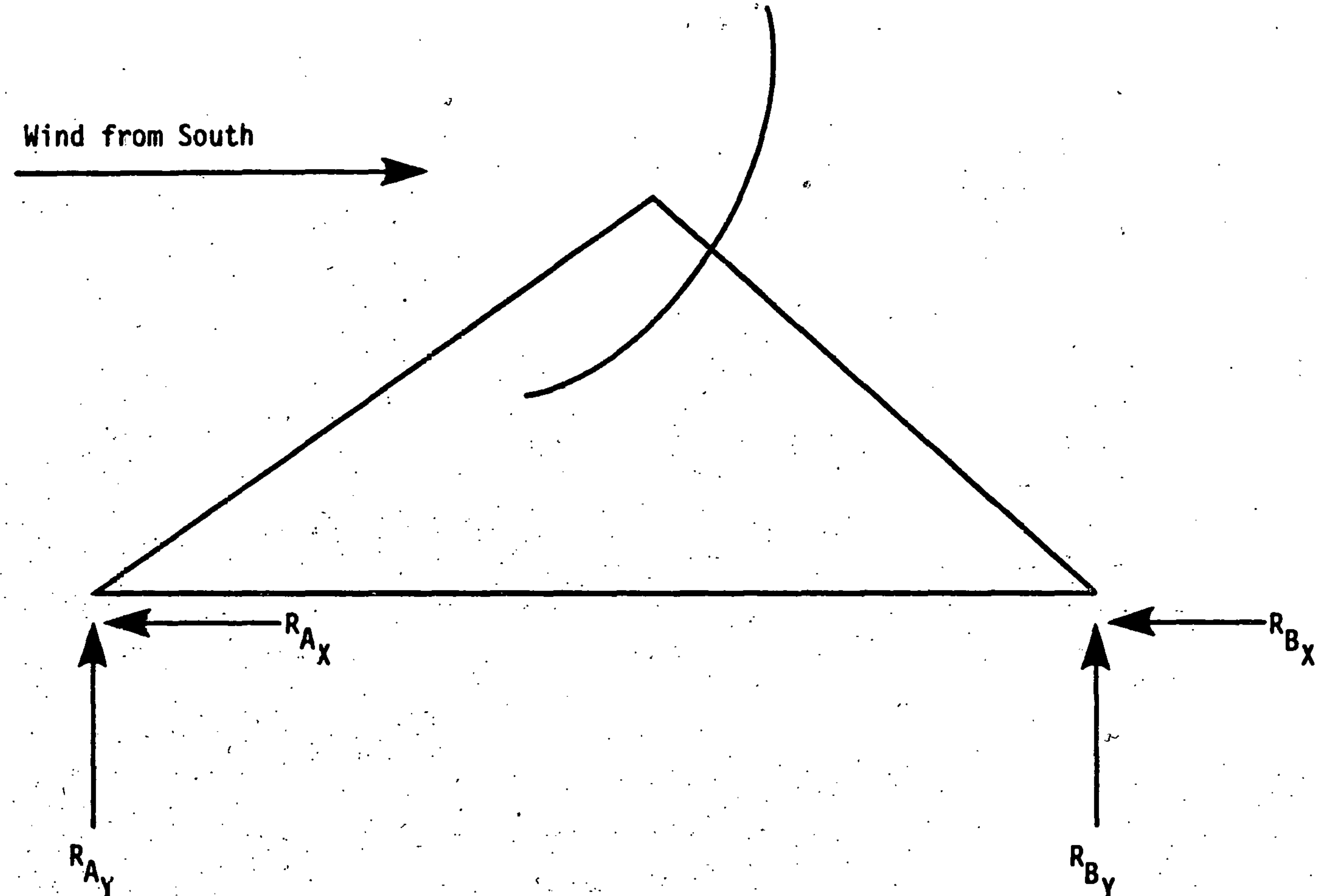


Figure 20. Force diagram for concentrating collectors mounted on roof.

After all windloads and deadweight loads were tablulated, Aerotherm employed the structural consulting firm, of Buehler, Cole, Yee & Schubert (as specified by Campbell Soup) to analyze the roof structure to determine its capability to handle the added loads. The consulting firm verified the adequacy of the warehouse roof structure, as shown in Attachment 1.

6. ECONOMIC ANALYSIS

An economic analysis was performed to compare the energy cost before taxes of the Acurex solar hot water system to a conventional fossil fuel system. The method outlined in the Lawrence Livermore Laboratory memorandum of 10 August 1976 (Reference 5) was used for the analysis, except that a value of 0.65 rather than 0.7 was used for boiler/end-use efficiency. The Acurex FPS computer code was used to perform the economic analysis for the Campbell Soup Sacramento, California plant and two "fiducial" locations (Albuquerque, N.M. and Omaha, Nebraska) as delineated in Reference 2. The analysis was made twice — once using no fuel cost escalation, and once using a five percent annual fuel cost escalation for all three locations.

The results of the analysis (Table 5) show that with no fuel cost escalation, the payback is in excess of 20 years and the rate of return is negative for all three locations. Furthermore, using a 5 percent fuel cost escalation does not significantly affect the payback period or the rate of return.

In addition to this analysis, the economics of the Sacramento Campbell Soup installation were further examined using canning industry guidelines and anticipated component cost reductions to determine the effect of these factors on the payback period and rate of return. Factors taken into account included anticipated reduction in component costs, estimated fuel cost escalations for California, an increased Federal investment tax credit, and an accelerated depreciation method. It was assumed that these factors will apply by 1980 and that they represent a realistic estimate of the economic conditions which will affect the proposed solar hot water system in the near future. Table 6 is a summary of the results.

The analysis showed that the results obtained using industry assumptions do not differ significantly from the results obtained with ERDA guidelines. The payback period is still greater than 20 years and the rate of

TABLE 5. ECONOMICS OF CAMPBELL SOLAR HOT WATER SYSTEM: ERDA ANALYSIS

T-62

Location	Total Investment, $	% Total Energy[a] Supplied by Solar	Before Tax Costs $/1000 MJ ($/MBtu)			Payback[b] Years	ROR[c] %
			Conventional	Solar	Solar Only		
No fuel cost escalation:							
Albuquerque	260,951	85	(4.18)	(16.38)	(18.16)	>20	-1.0
Omaha	260,951	58	(4.18)	(17.45)	(26.61)	>20	-2.4
Sacramento	299,733	77	(4.18)	(18.93)	(22.95)	>20	-1.8
With 5 percent fuel cost escalation compounded annually:							
Albuquerque	260,951	85	(5.87)	(16.83)	(18.16)	17.9	1.3
Omaha	260,951	58	(5.87)	(18.16)	(26.61)	>20	-0.5
Sacramento	299,733	77	(5.87)	(19.32)	(22.95)	19.6	0.2

[a] Total annual energy requirement at the can washer = 2.56×10^{12} megajoules (2.8×10^{9} Btu)

[b] Payback is based on net cash flow after taxes

[c] ROR — minimum rate of return on the net cash flow after taxes for 20 years

TABLE 6. ECONOMIC ANALYSIS: SACRAMENTO, BASED ON ANTICIPATED COST REDUCTIONS AND INDUSTRY ASSUMPTIONS

T-63

Location	Total Investment, $	% Total Energy[a] Supplied by Solar	Before Tax Costs $/1000 MJ ($MBtu)			Payback,[b] Years	ROR[c] %
			Conventional	Solar	Solar Only		
• Industry Assumptions:							
Sacramento with 0.51 tax rate, accelerated depreciation, and California fuel cost escalation of 3.4%	299,733	77	5.13	18.19	21.88	>20	-1.3
• Anticipated Cost Reduction:							
Sacramento	188,220	77	5.55	10.72	11.88	15.1	2.8
Sacramento	112,920[e]	77	5.55	7.22	7.33	11.2	6.5

[a] Total annual energy requirement at the can washer = 2.8 x 10^9 Btu

[b] Payback is based on net cash flow after taxes

[c] ROR — minimum rate of return on the net cash flow after taxes for 20 years

[d] An installed cost of $25/ft^2 based on 7578 ft^2

[e] An installed cost of $15/ft^2 based on 704 m^2 (7578 ft^2)

return is slightly negative. On the other hand, adding realistic system cost reductions to the analysis shifts the results in favor of the solar energy system. Table 6 shows that reducing the system cost has a significant effect on both the payback period and the rate-of-return. Reducing the system cost to $188,200 (a 40-percent reduction) reduces the payback period to 15 years and gives a positive 2.8-percent rate-of-return as compared to a payback period exceeding 20 years and a negative rate-of-return for the prototype system.

7. TECHNICAL TRANSFER TO INDUSTRY

The dedicated support Acurex has received during Phase I of the program from the Campbell Soup Company, both the Sacramento Plant engineering staff and their Corporate Headquarter staff at Camden, New Jersey, and the National Canners Association (NCA) has stimulated interest in the canning industry in the use of solar process hot water systems. Campbell Soup Company has already begun an internal program to cut down energy consumption, and is enthusiastic at both the corporate and regional plant levels about the possibilities for solar process hot water.

The National Canners Association brings to the project a direct link to an entire industry which is a potential user of solar hot water processes. The canning industry is a major consumer of process hot water, and is an aggressive industry seeking ways to reduce its energy consumption. NCA represents nearly 600 member companies in the business of canning food for human consumption. Participation of NCA personnel in every phase of the project — and particularly in process design, process economics, and information dissemination — will guarantee that the experiment is relevant to the industry and that the industry will learn about the results.

REFERENCES

1. Liu, B. Y. H. and Jordan, R. C., "The Long-Term Average Performance of Flat-Plate Solar-Energy Collectors," Solar Energy, Vol. 7, No. 2, 1963.

2. Liu, B. Y. H. and Jordan, R. E., "The Interrelationship and Characteristic Distribution of Direct, Diffuse, and Total Solar Radiation," Solar Energy, July 1960, pp. 1-19.

3. Klein, S. A., "TRNSYS, A Transient Simulation Program," Engineering Experiment Station Report 38, Solar Energy Laboratory, University of Wisconsin, March 1976.

4. ANSI A 58.1 - 1972, American National Standard Building Code Requirements for Minimum Design Loads in Buildings and other Structures.

5. Lawrence Livermore Laboratory Memorandum, "Method of Economic Analysis for Comparison of Solar Process Heat Systems," from W. C. Dickenson to Contractors, Ltd., August 10, 1976.

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ATTACHMENT 1

STRUCTURAL CONSULTANT ROOF APPROVAL

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BUEHLER, COLE, YEE & SCHUBERT

STRUCTURAL ENGINEERS, INC.

718 Alhambra Boulevard ■ Sacramento, California 95816 ■ 443-6766

October 13, 1976

Donald R. McCullough
Contracts Administrator
Acurex Corporation
485 Clyde Avenue
Mountian View, California 94042

Subject: Building W-8, Campbell Soup Company
Sacramento, California
BCYS Job No. 173-76

Dear Don:

This office has reviewed the drawings submitted by you as listed on your letter dated September 27, 1976. We have analyzed the plans for existing loads in addition to the proposed new loads applied as a result of installing solar collectors on the roof. This is to certify that under the conditions as described in the listed drawings, that the existing framing will be adequate to handle the loads.

Very truly yours,

Jimmie R. Yee

Jimmie R. Yee
BUEHLER, COLE, YEE & SCHUBERT
Structural Engineers, Inc.

JRY/jb

cc: J. Vindum
G. Litzinger

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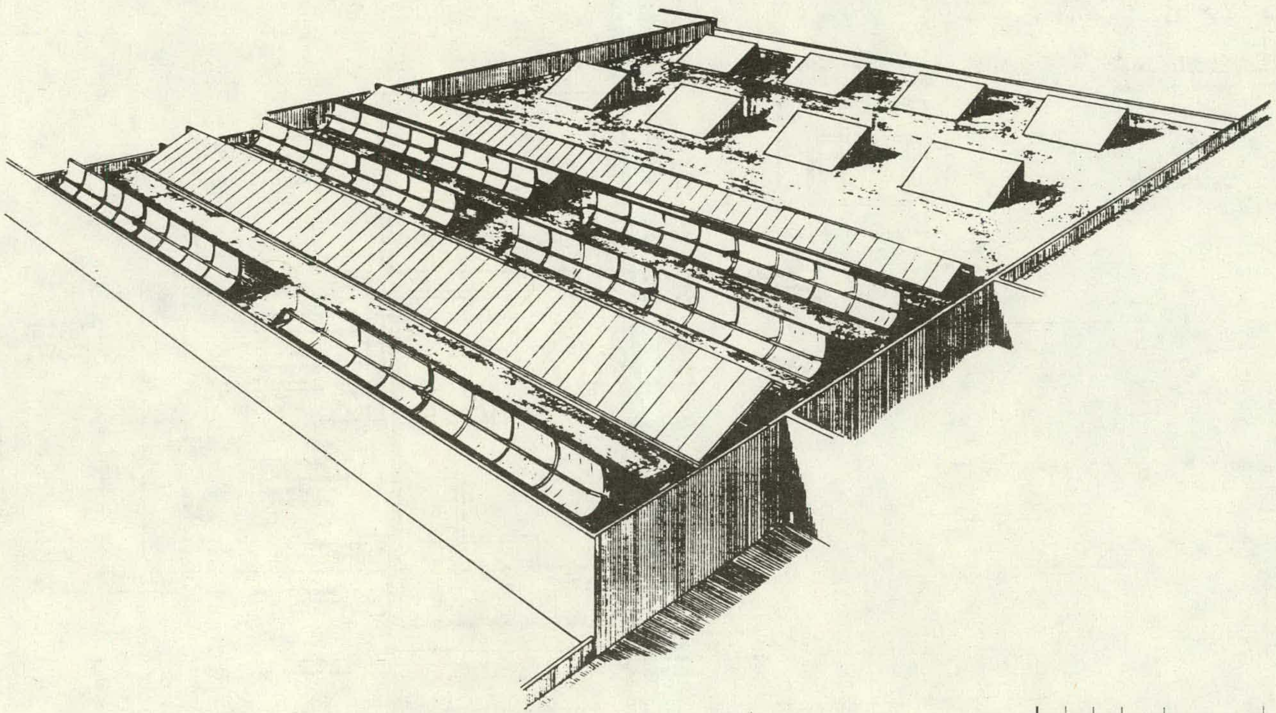
ATTACHMENT 2

INSTALLATION AND DETAIL DRAWINGS

INDEX

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	REVISED & REDRAWN	24 JUNE 197?	Staiger



-02	-01	ITEM NO.	CODE IDENT	PART NO.	DESCRIPTION
QTY. REQD.		LIST OF MATERIALS			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
FRACTION ±1/64 DECIMALS .XX ±.01 .XXX ±.005 ANGLES ±0°30'
MACH COR—.005 TO .015 R OR CHAM
BH MATL—BREAK EDGES .005 MAX R
ALL ✓ SURFACES TO BE ✓
DIM AND TOL APPLY BEFORE FIN TREAT
DO NOT SCALE DRAWING
MATERIAL
FINISH

NEXT ASSY	QTY	USED ON	QTY
APPLICATION			

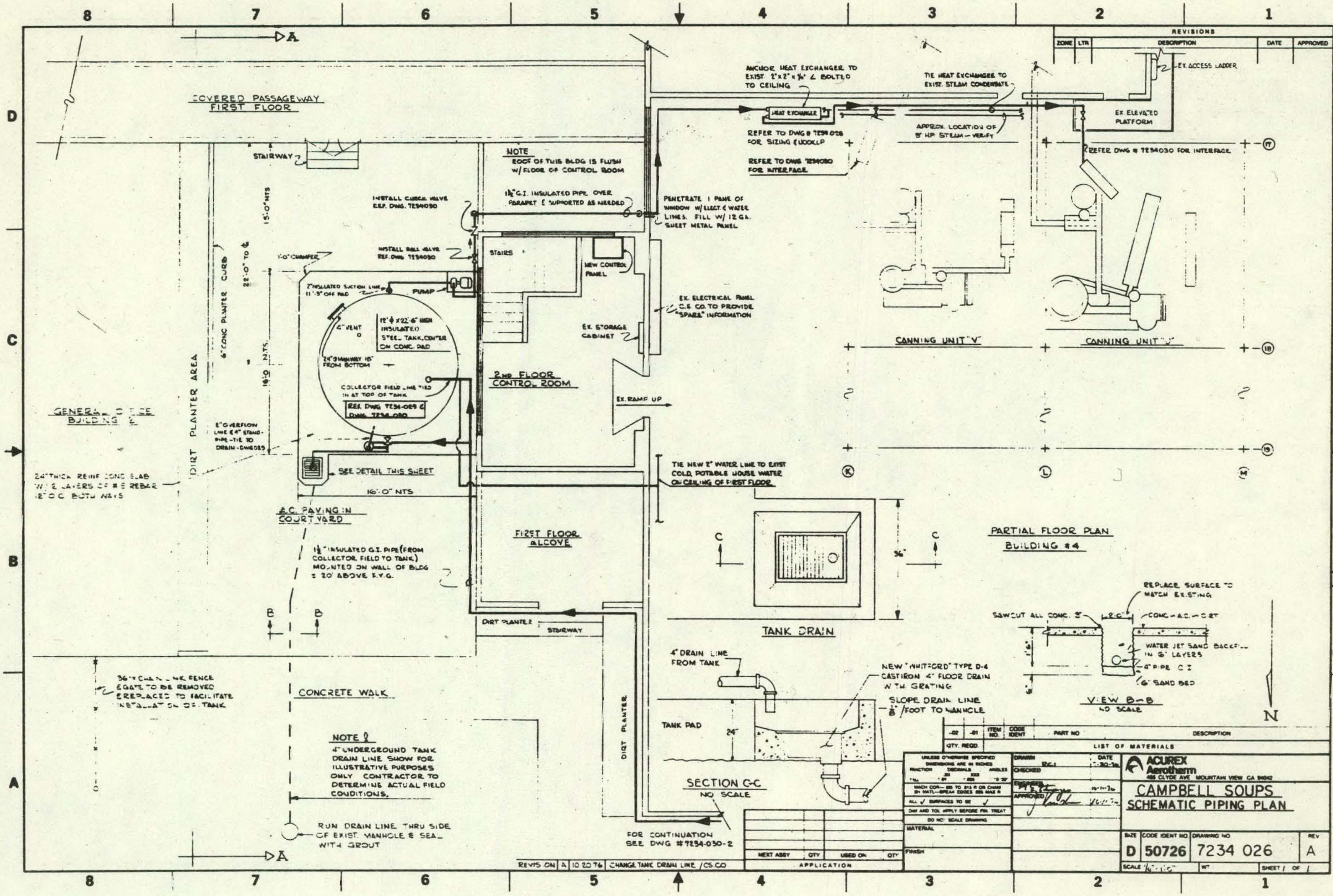
DRAWN W. Staiger DATE 24 June 7?
CHECKED
ENGINEER
APPROVED

ACUREX Aerotherm
485 CLYDE AVE, MOUNTAIN VIEW CA 94042

SOLAR COLLECTOR PERSPECTIVE LAYOUT - BUILDING W-8
CAMPBELL SOUP Co., SACRAMENTO

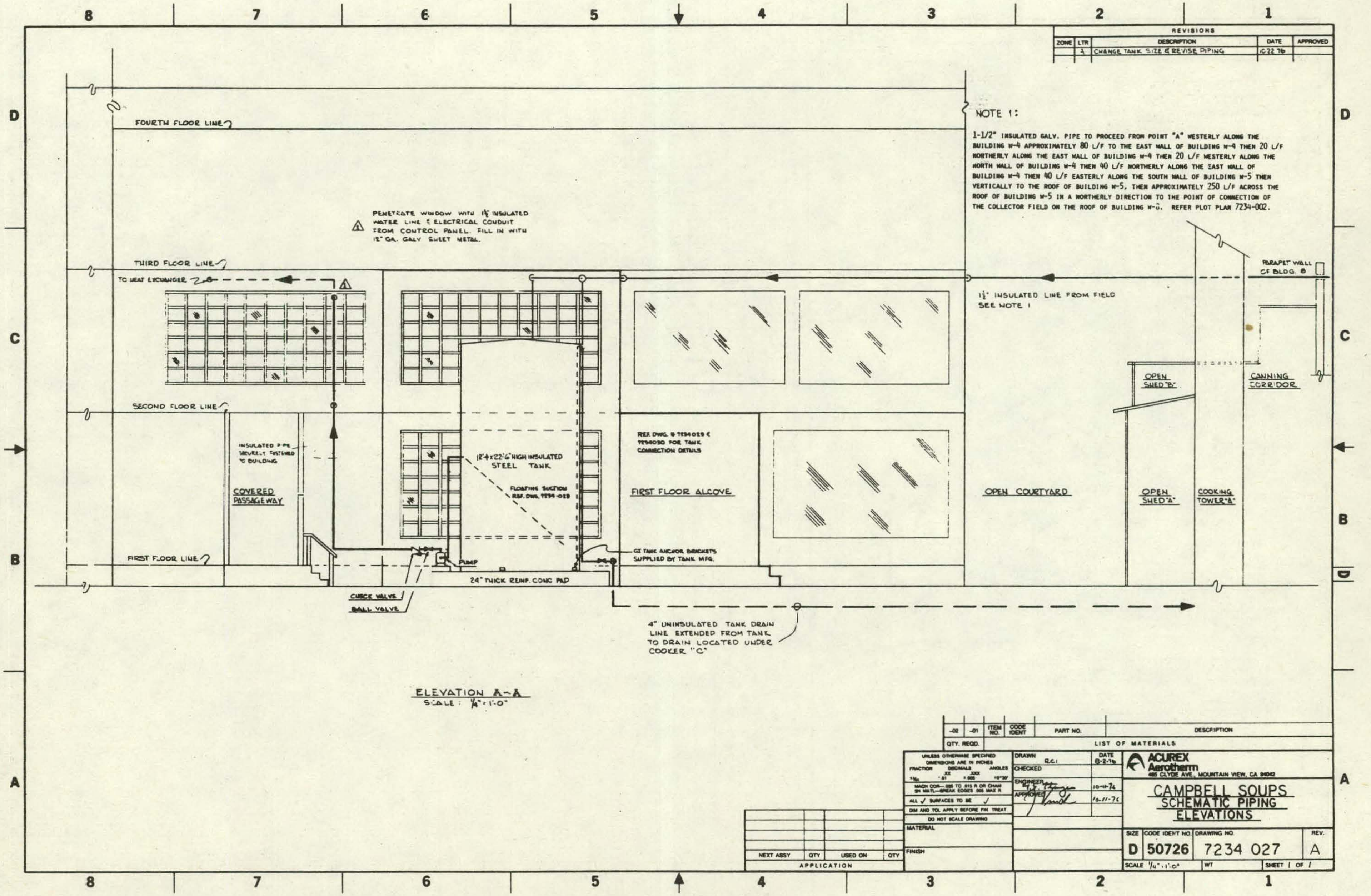
SIZE	CODE IDENT NO	DRAWING NO.	REV
D	50726	7234-015	A

SCALE ~ WT SHEET 1 OF 1



COVERED PASSAGEWAY FIRST FLOOR
STAIRWAY
NOTE
ROOF OF THIS BLDG IS FLUSH W/ FLOOR OF CONTROL ROOM
INSTALL CHECK VALVE REF. DWG. 7234030
1½" G.I. INSULATED PIPE OVER PARAPET & SUPPORTED AS NEEDED
PENETRATE 1 PANE OF WINDOW W/ ELECT. & WATER LINES. FILL W/ 12 GA. SHEET METAL PANEL
ANCHOR HEAT EXCHANGER TO EXIST. 2"x2"x¼" ∠ BOLTED TO CEILING
HEAT EXCHANGER
REFER TO DWG # 7234028 FOR SIZING & HOOKUP
REFER TO DWG 7234030 FOR INTERFACE
TIE HEAT EXCHANGER TO EXIST. STEAM CONDENSATE
APPROX. LOCATION OF 5" HP STEAM — VERIFY
EX. ACCESS LADDER
EX. ELEVATED PLATFORM
REFER DWG # 7234030 FOR INTERFACE
INSTALL BALL VALVE REF. DWG 7234030
STAIRS
NEW CONTROL PANEL
1'-0" CHAMFER
PUMP
12'φ x 22'-6" HIGH INSULATED STEEL TANK, CENTER ON CONC. PAD
4" VENT
EX. ELECTRICAL PANEL C.S. CO. TO PROVIDE "SPARE" INFORMATION
EX. STORAGE CABINET
2ND FLOOR CONTROL ROOM
EX. RAMP UP
COLLECTOR FIELD LINE TIED IN AT TOP OF TANK
REF. DWG 7234-029 & DWG 7234-030
CANNING UNIT "V"
CANNING UNIT "U"
GENERAL OFFICE BUILDING 2
DIRT PLANTER AREA
6" CONC PLANTER CURB
SEE DETAIL THIS SHEET
16'-0" NTS
THE NEW 2" WATER LINE TO EXIST COLD, POTABLE HOUSE WATER ON CEILING OF FIRST FLOOR
A.C. PAVING IN COURTYARD
1½" INSULATED G.I. PIPE (FROM COLLECTOR FIELD TO TANK) MOUNTED ON WALL OF BLDG ± 20' ABOVE F.Y.G.
FIRST FLOOR ALCOVE
DIRT PLANTER
STAIRWAY
TANK DRAIN
PARTIAL FLOOR PLAN BUILDING #4
REPLACE SURFACE TO MATCH EXISTING
SAWCUT ALL CONC.
WATER JET SAND BACKFILL IN 6" LAYERS
6" SAND BED
VIEW B-B NO SCALE
4" DRAIN LINE FROM TANK
NEW "WHITFORD" TYPE D-4 CASTIRON 4" FLOOR DRAIN WITH GRATING
SLOPE DRAIN LINE ⅛"/FOOT TO MANHOLE
TANK PAD
SECTION C-C NO SCALE
CONCRETE WALK
NOTE 2
4" UNDERGROUND TANK DRAIN LINE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. CONTRACTOR TO DETERMINE ACTUAL FIELD CONDITIONS.
RUN DRAIN LINE THRU SIDE OF EXIST. MANHOLE & SEAL WITH GROUT
FOR CONTINUATION SEE DWG # 7234-030-2
REVIS ON A 10.20.76 CHANGE TANK DRAIN LINE /CS.CO
LIST OF MATERIALS
ACUREX Aerotherm 485 CLYDE AVE MOUNTAIN VIEW CA 94042
CAMPBELL SOUPS
SCHEMATIC PIPING PLAN
D 50726 7234 026 A
N

52


REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
A | CHANGE TANK SIZE & REVISE PIPING | 10-22-76
FOURTH FLOOR LINE
NOTE 1:
1-1/2" INSULATED GALV. PIPE TO PROCEED FROM POINT "A" WESTERLY ALONG THE BUILDING W-4 APPROXIMATELY 80 L/F TO THE EAST WALL OF BUILDING W-4 THEN 20 L/F NORTHERLY ALONG THE EAST WALL OF BUILDING W-4 THEN 20 L/F WESTERLY ALONG THE NORTH WALL OF BUILDING W-4 THEN 40 L/F NORTHERLY ALONG THE EAST WALL OF BUILDING W-4 THEN 40 L/F EASTERLY ALONG THE SOUTH WALL OF BUILDING W-5 THEN VERTICALLY TO THE ROOF OF BUILDING W-5, THEN APPROXIMATELY 250 L/F ACROSS THE ROOF OF BUILDING W-5 IN A NORTHERLY DIRECTION TO THE POINT OF CONNECTION OF THE COLLECTOR FIELD ON THE ROOF OF BUILDING W-3. REFER PLOT PLAN 7234-002.
PENETRATE WINDOW WITH 1½" INSULATED WATER LINE & ELECTRICAL CONDUIT FROM CONTROL PANEL. FILL IN WITH 12" GA. GALV SHEET METAL.
THIRD FLOOR LINE
TO HEAT EXCHANGER
PARAPET WALL OF BLDG. 8
1½" INSULATED LINE FROM FIELD SEE NOTE 1
OPEN SHED "B"
CANNING CORRIDOR
SECOND FLOOR LINE
INSULATED PIPE SECURELY FASTENED TO BUILDING
12'Ø x 22'6" HIGH INSULATED STEEL TANK
FLOATING SUCTION REF. DWG. 7234-029
REF. DWG. 7234029 & 7234030 FOR TANK CONNECTION DETAILS
COVERED PASSAGEWAY
FIRST FLOOR ALCOVE
OPEN COURTYARD
OPEN SHED "A"
COOKING TOWER "A"
FIRST FLOOR LINE
PUMP
(3) TANK ANCHOR BRACKETS SUPPLIED BY TANK MFG.
24" THICK REINF. CONC PAD
CHECK VALVE
BALL VALVE
4" UNINSULATED TANK DRAIN LINE EXTENDED FROM TANK TO DRAIN LOCATED UNDER COOKER "C"
ELEVATION A-A
SCALE: ¼" = 1'-0"
-02 | -01 | ITEM NO. | CODE IDENT | PART NO. | DESCRIPTION
QTY. REQD. | LIST OF MATERIALS
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
MATERIAL
FINISH
NEXT ASSY | QTY | USED ON | QTY
APPLICATION
DRAWN R.C.I DATE 8-2-76
CHECKED
ENGINEER 10-11-76
APPROVED 10-11-76
ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042
CAMPBELL SOUPS
SCHEMATIC PIPING
ELEVATIONS
SIZE D | CODE IDENT NO. 50726 | DRAWING NO. 7234 027 | REV. A
SCALE ¼" = 1'-0" | WT | SHEET 1 OF 1

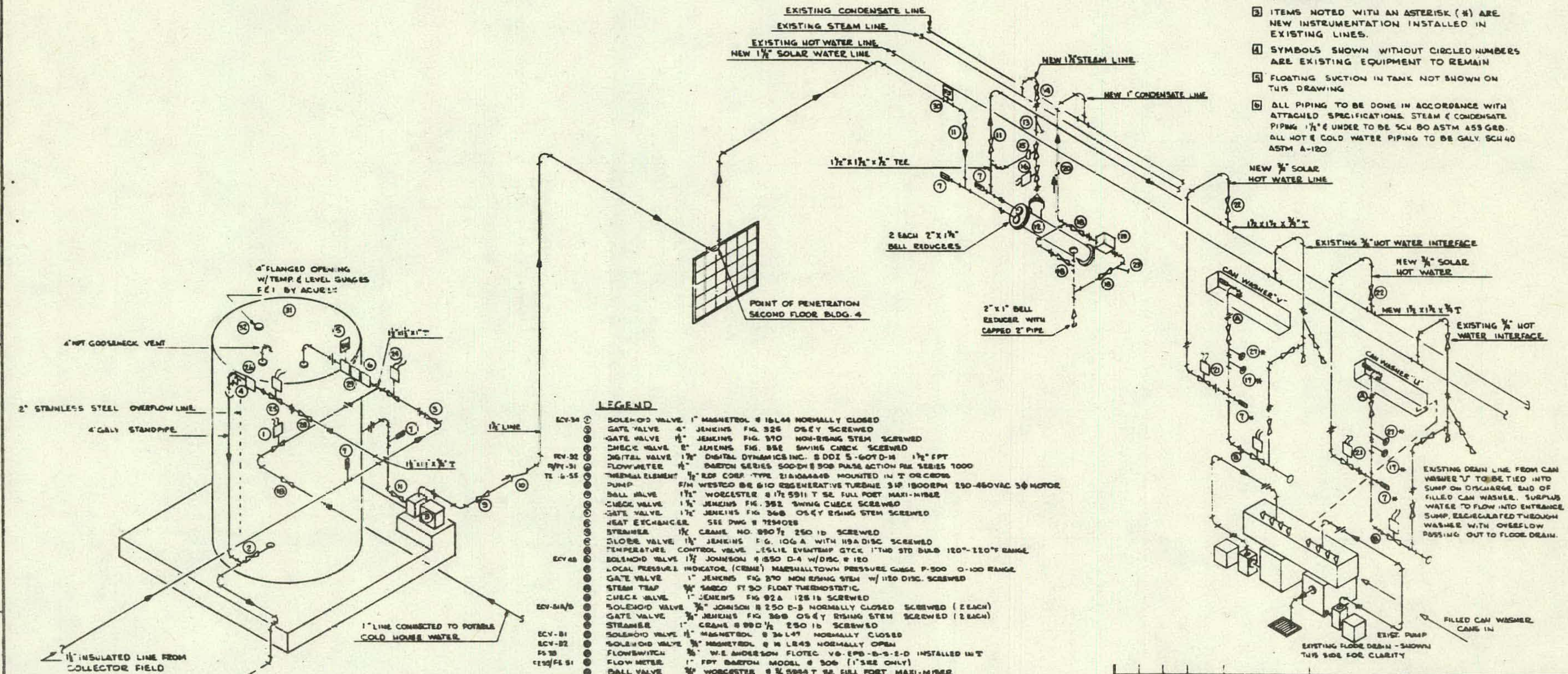
54

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	GENERAL REVISIONS & UPDATE	8-26-76	
	B	CHANGE COLL FIELD LINE FROM 2" TO 1½" ADD NOTES	9-30-76	
	C	ADD CHECK VALVES - # 37 & PR. VALVES # 38	10-20-76	

REVISIONS

NOTES:

1. GENERAL CONTRACTOR TO MAKE UP ALL NEW INTERFACE PIPING PRIOR TO BREAKING EXISTING UNIONS Ⓐ & Ⓑ.
2. ALL WORK TO BE DONE INSIDE BUILDING #4 WILL BE COMPLETED BETWEEN THE HOURS OF 12 MIDNIGHT & 6:00 AM OR ON SATURDAYS & SUNDAYS
3. ITEMS NOTED WITH AN ASTERISK (*) ARE NEW INSTRUMENTATION INSTALLED IN EXISTING LINES.
4. SYMBOLS SHOWN WITHOUT CIRCLED NUMBERS ARE EXISTING EQUIPMENT TO REMAIN
5. FLOATING SUCTION IN TANK NOT SHOWN ON THIS DRAWING
6. ALL PIPING TO BE DONE IN ACCORDANCE WITH ATTACHED SPECIFICATIONS. STEAM & CONDENSATE PIPING 1½" & UNDER TO BE SCH 80 ASTM A53 GRB. ALL HOT & COLD WATER PIPING TO BE GALV. SCH 40 ASTM A-120



LEGEND

- ECV-34 — SOLENOID VALVE 1" MAGNETROL # 16L44 NORMALLY CLOSED
- GATE VALVE 4" JENKINS FIG. 326 OS&Y SCREWED
- GATE VALVE 1½" JENKINS FIG. 370 NON-RISING STEM SCREWED
- CHECK VALVE 2" JENKINS FIG. 352 SWING CHECK SCREWED
- FCV-32 — DIGITAL VALVE 1½" DIGITAL DYNAMICS INC. # DDI 5-60TD-14 1½" FPT
- FI/FT-31 — FLOWMETER 1½" BARTON SERIES 500-DH # 308 PULSE ACTION FM SERIES 7000
- TE 6-55 — THERMAL ELEMENT ½" RDF CORP. TYPE 21A10A4A4B MOUNTED IN T OR CROSS
- PUMP F/M WESTCO BR 610 REGENERATIVE TURBINE 3HP 1800RPM 230-460VAC 3Φ MOTOR
- BALL VALVE 1½" WORCESTER # 1½ 5911 T SE FULL PORT MAXI-MISER
- CHECK VALVE 1½" JENKINS FIG. 352 SWING CHECK SCREWED
- GATE VALVE 1½" JENKINS FIG 368 OS&Y RISING STEM SCREWED
- HEAT EXCHANGER SEE DWG # 7234028
- STRAINER 1½" CRANE NO. 880½ 250 lb SCREWED
- GLOBE VALVE 1½" JENKINS FIG. 106A WITH 119A DISC SCREWED
- TEMPERATURE CONTROL VALVE LESLIE EVENTEMP GTCK 1" TWO STD BULB 120°-220°F RANGE
- ECV 48 — SOLENOID VALVE 1½" JOHNSON # 1550 D-4 W/DISC # 120
- LOCAL PRESSURE INDICATOR (CRANE) MARSHALLTOWN PRESSURE GUAGE P-500 0-100 RANGE
- GATE VALVE 1" JENKINS FIG 370 NON RISING STEM W/ 1120 DISC. SCREWED
- STEAM TRAP ¾" SARCO FT 30 FLOAT THERMOSTATIC
- CHECK VALVE 1" JENKINS FIG 92A 125 lb SCREWED
- ECV-51A/B — SOLENOID VALVE ¾" JOHNSON # 250 C-3 NORMALLY CLOSED SCREWED (2 EACH)
- GATE VALVE ¾" JENKINS FIG 368 OS&Y RISING STEM SCREWED (2 EACH)
- STRAINER 1" CRANE # 880½ 250 lb SCREWED
- ECV-81 — SOLENOID VALVE 1" MAGNETROL # 36L47 NORMALLY CLOSED
- ECV-82 — SOLENOID VALVE ¾" MAGNETROL # 16 LR45 NORMALLY OPEN
- FS 38 — FLOWSWITCH ¾" W.E. ANDERSON FLOTEC V6-EPB-B-S-2-D INSTALLED IN T
- FE 50/FE 51 — FLOW METER 1" FPT BARTON MODEL # 306 (1" SIZE ONLY)
- BALL VALVE ¾" WORCESTER # ¾ 5894 T SE FULL PORT MAXI-MISER
- FS 38 — FLOW SWITCH 1½" W.E. ANDERSON FLOTEC V4-1½ INSTALLED IN T
- FS 41 — FLOWSWITCH 1½" W.E. ANDERSON FLOTEC V4-1½ INSTALLED IN T
- ACCUMULATOR TANK SEE DWG 7234029
- LSL 51A/B LSH 5 — TANK LEVEL GUAGE "GEMS" FIBRALEVEL 34850 SWITCH KIT
- ADJUSTING VALVE ¾" BELL & GOSSET ¾ S CIRCUIT SETTER (BY ACUREX)
- SOLAR CONCENTRATOR
- FLAT PLATE COLLECTOR 8'-0" x 10'-6"
- FLAT PLATE COLLECTOR 8'-0" x 16'-6"
- SWING CHECK VALVE ¾" JENKINS FIG. 352 SCREWED SWING CHECK
- PRESSURE RELIEF VALVE ¾" CONSOLIDATED TYPE 1485 SCREWED. BRONZE

-02	-01	ITEM NO.	CODE IDENT	PART NO.	DESCRIPTION
QTY. REQD.					

LIST OF MATERIALS

NEXT ASSY	QTY	USED ON	QTY

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE DRAWING

MATERIAL

FINISH

DRAWN — DATE 8-19-76

CHECKED

ENGINEER — 10-11-76

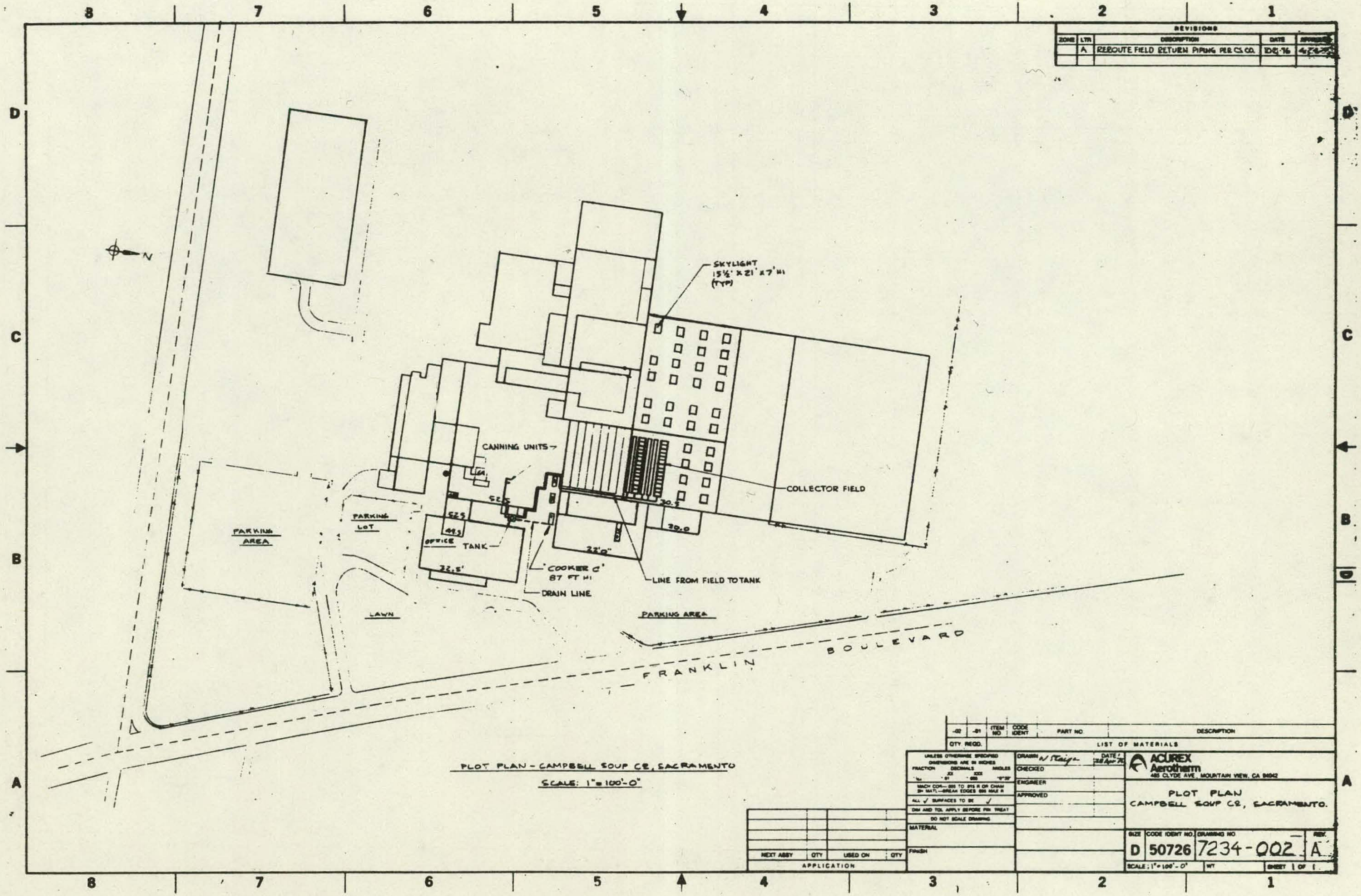
APPROVED — 10-11-76

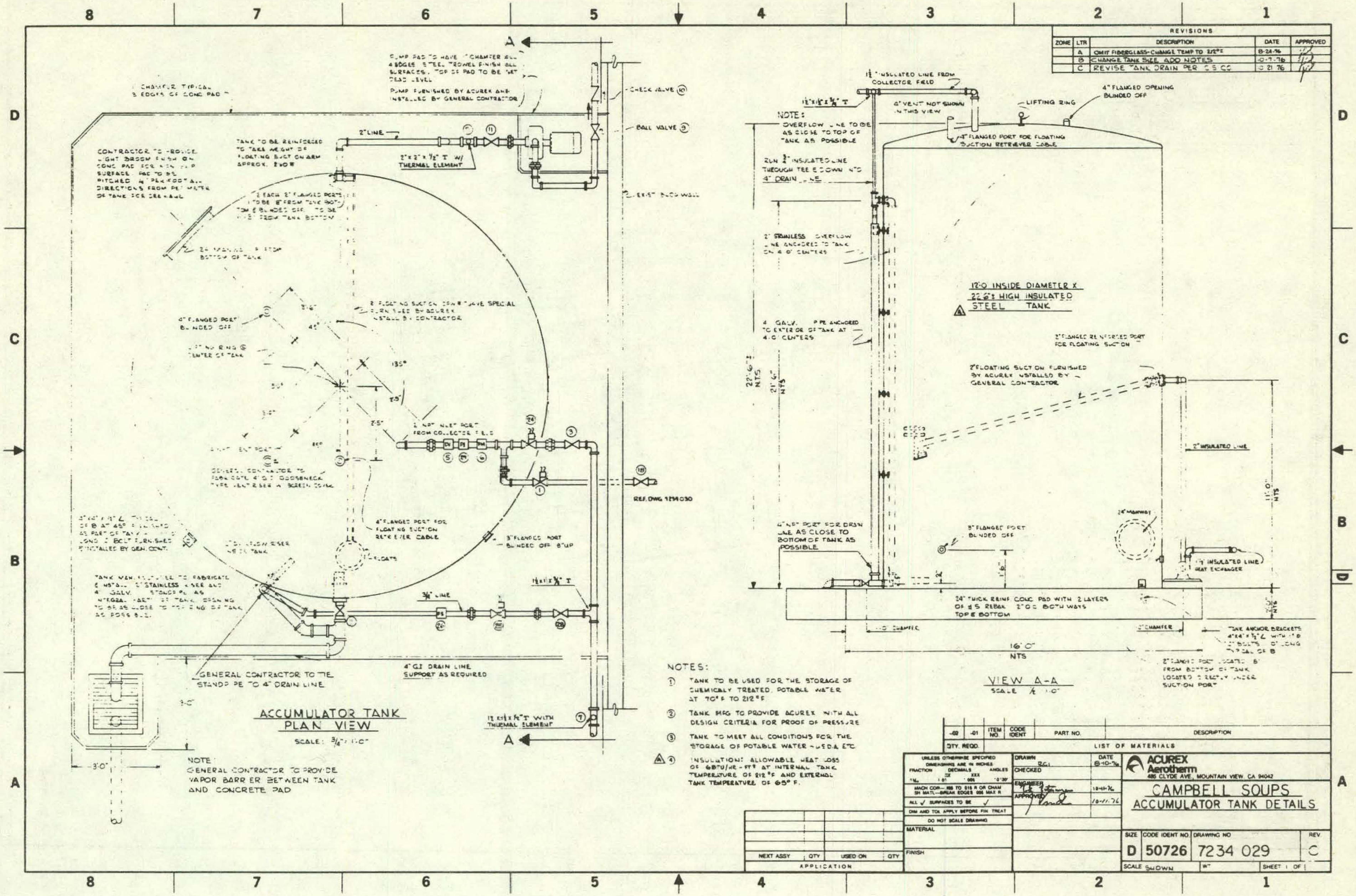
ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042

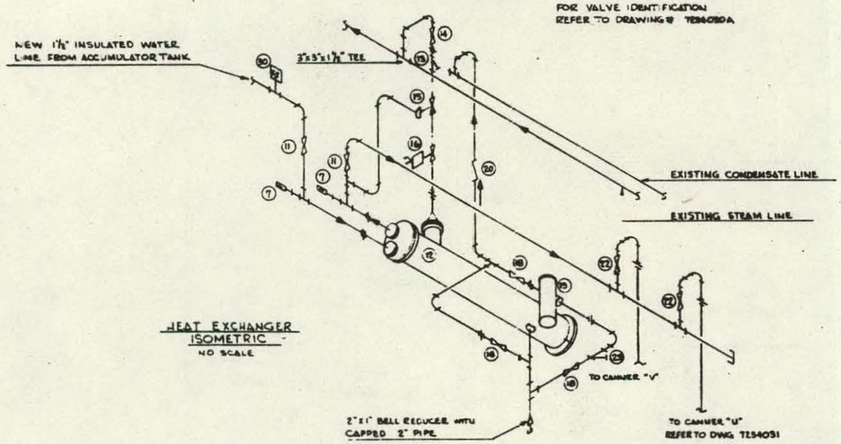
CAMPBELL SOUPS
CAN WASHER
INTERFACE SCHEMATIC

SIZE	CODE IDENT NO	DRAWING NO	REV
D	50726	7234 030	C

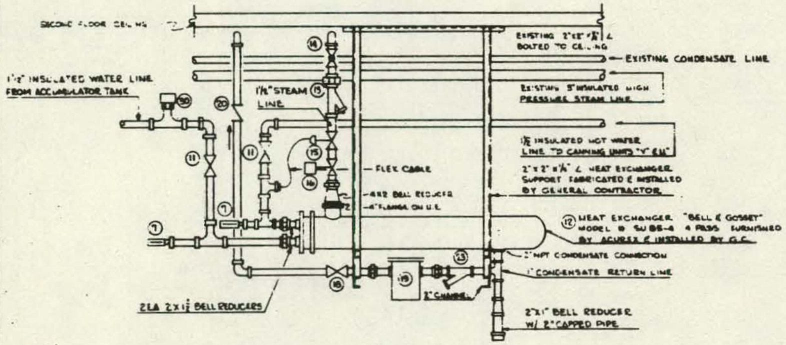
SCALE | WT | SHEET 1 OF 6


REVISIONS
ZONE LTR DESCRIPTION DATE
A REROUTE FIELD RETURN PIPING PER CS CO.
N
SKYLIGHT
15½' x 21' x 7' HI
(TYP)
CANNING UNITS
COLLECTOR FIELD
PARKING AREA
PARKING LOT
OFFICE
TANK
52.5
49.5
30.5
30.0
22'0"
22.5'
'COOKER C'
87 FT HI
DRAIN LINE
LINE FROM FIELD TO TANK
LAWN
PARKING AREA
FRANKLIN BOULEVARD
PLOT PLAN - CAMPBELL SOUP CO, SACRAMENTO
SCALE: 1" = 100'-0"
QTY REQD.
ITEM NO
CODE IDENT
PART NO
DESCRIPTION
LIST OF MATERIALS
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DRAWN
CHECKED
ENGINEER
APPROVED
ACUREX
Aerotherm
PLOT PLAN
CAMPBELL SOUP CO, SACRAMENTO.
SIZE D
CODE IDENT NO. 50726
DRAWING NO 7234-002
REV. A
SCALE: 1" = 100'-0"
SHEET 1 OF 1

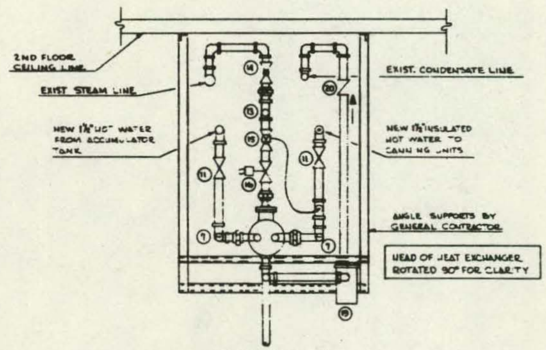

REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
A | OMIT FIBERGLASS-CHANGE TEMP TO 212°F | 8-24-76
B | CHANGE TANK SIZE ADD NOTES | 10-7-76
C | REVISE TANK DRAIN PER C.S.CO. | 10-21-76
CHECK VALVE
BALL VALVE
2" LINE
LIFTING RING
4" FLANGED OPENING BLINDED OFF
NOTE: OVERFLOW LINE TO BE AS CLOSE TO TOP OF TANK AS POSSIBLE
12'-0 INSIDE DIAMETER X 22'-6" HIGH INSULATED STEEL TANK
2" FLOATING SUCTION FURNISHED BY ACUREX INSTALLED BY GENERAL CONTRACTOR
2" INSULATED LINE
3" FLANGED PORT BLINDED OFF
24" MANWAY
16'-0"
NTS
VIEW A-A
REF. DWG 7234030
3/4" LINE
4" GI DRAIN LINE SUPPORT AS REQUIRED
GENERAL CONTRACTOR TO TIE STANDPIPE TO 4" DRAIN LINE
ACCUMULATOR TANK
PLAN VIEW
NOTE: GENERAL CONTRACTOR TO PROVIDE VAPOR BARRIER BETWEEN TANK AND CONCRETE PAD
NOTES:
1 TANK TO BE USED FOR THE STORAGE OF CHEMICALY TREATED, POTABLE WATER AT 70°F TO 212°F
2 TANK MFG TO PROVIDE ACUREX WITH ALL DESIGN CRITERIA FOR PROOF OF PRESSURE
3 TANK TO MEET ALL CONDITIONS FOR THE STORAGE OF POTABLE WATER - USDA ETC
A 4 INSULATION: ALLOWABLE HEAT LOSS OF 6BTU/HR-FT² AT INTERNAL TANK TEMPERATURE OF 212°F AND EXTERNAL TANK TEMPERATURE OF 65° F.
-02 | -01 | ITEM NO. | CODE IDENT | PART NO. | DESCRIPTION
QTY. REQD. | LIST OF MATERIALS
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
MATERIAL
FINISH
NEXT ASSY | QTY | USED ON | QTY
APPLICATION
DRAWN RCL DATE 8-10-76
CHECKED
ENGINEER 10-11-76
APPROVED 10-11-76
ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042
CAMPBELL SOUPS
ACCUMULATOR TANK DETAILS
SIZE D | CODE IDENT NO. 50726 | DRAWING NO 7234 029 | REV C
SCALE SHOWN | WT | SHEET 1 OF 1



HEAT EXCHANGER ISOMETRIC
NO SCALE



HEAT EXCHANGER ELEVATION
NO SCALE



HEAT EXCHANGER ELEVATION
NO SCALE

GENERAL NOTES:

1. ALL PERMANENT HOT WATER PIPING SHALL BE INSULATED TO PREVENT LOSS OF HEAT BY RADIATION. INSULATION ON HOT WATER PIPING BENEATH PLATFORMS THAT ARE WASHED DOWN FREQUENTLY MUST ALSO BE WATERPROOFED. ALL INSULATED PIPE SHALL BE RUN WITH SUFFICIENT CLEARANCE BETWEEN ADJACENT PIPELINES TO PERMIT APPLICATION OF INSULATION.
2. HOT WATER PIPING SHALL BE INSULATED WITH ARMSTRONG "ARMAFLEX 22" PIPE INSULATION TO A THICKNESS OF 1½" AROUND THE PIPE. VALVES & FITTINGS SHALL BE INSULATED WITH ARMSTRONG "ARMAFLEX" 22 SHEET TO A WALL THICKNESS OF 1½". ALL INSULATION WORK TO BE DONE IN ACCORDANCE WITH MANUFACTURER'S SPECIFICATIONS.
3. COMPOUND FOR BOTH STEAM & WATER PIPING SHALL BE EITHER "PIPETITE STIK COMPOUND" OR "KEY GRAPHITE PASTE".
4. PIPE HANGERS SHALL BE "CRANE" # 230F GALVANIZED WROUGHT STEEL, IN PRODUCTION AREAS & # 230 F OUTSIDE OF PRODUCTION AREAS. HOT WATER LINES ARE TO BE GRADED UPSTREAM SO THAT AIR IN RISERS, MAINS & BRANCHES WILL BE CARRIED TO A POINT OF DISCHARGE.
5. THE INSIDE OF ALL PIPES, VALVES & FITTINGS SHALL BE LEFT SMOOTH, CLEAN & FREE FROM BLISTERS, MILL SCALE, SAND & DIRT. NO PIPES TO BE STORED ON THE GROUND AND PRIOR TO ERECTION SHALL BE HELD IN AN INCLINED POSITION & HAMMERED TO LOOSEN SCALE & FOREIGN MATTER. PIPE LINES SHALL NOT BE LEFT OPEN AT ANY PLACE WHERE FOREIGN MATTER MIGHT ACCIDENTLY ENTER PIPE.
6. ALL PIPE LINES SHALL BE BLOWN OR FLUSHED OUT PRIOR TO PLACEMENT IN SERVICE, AND ALL VALVES CHECKED TO BE FREE OF FOREIGN MATERIAL PRIOR TO CLOSING OF VALVE.

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

LIST OF MATERIALS

-02	-01	ITEM NO.	CODE IDENT	PART NO.	DESCRIPTION
QTY. REQD					

NEXT ASSY	QTY	USED ON	QTY
APPLICATION			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
ALL ✓ SURFACES TO BE ✓
DIM AND TOL APPLY BEFORE FIN TREAT
DO NOT SCALE DRAWING
MATERIAL
FINISH

		DATE
DRAWN	RC1	8-4-76
CHECKED		
ENGINEER	[signature]	10-11-76
APPROVED	[signature]	10-11-76

ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042

CAMPBELL SOUPS
HEAT EXCHANGER DETAIL

SIZE	CODE IDENT NO.	DRAWING NO	REV
D	50726	7234 028	

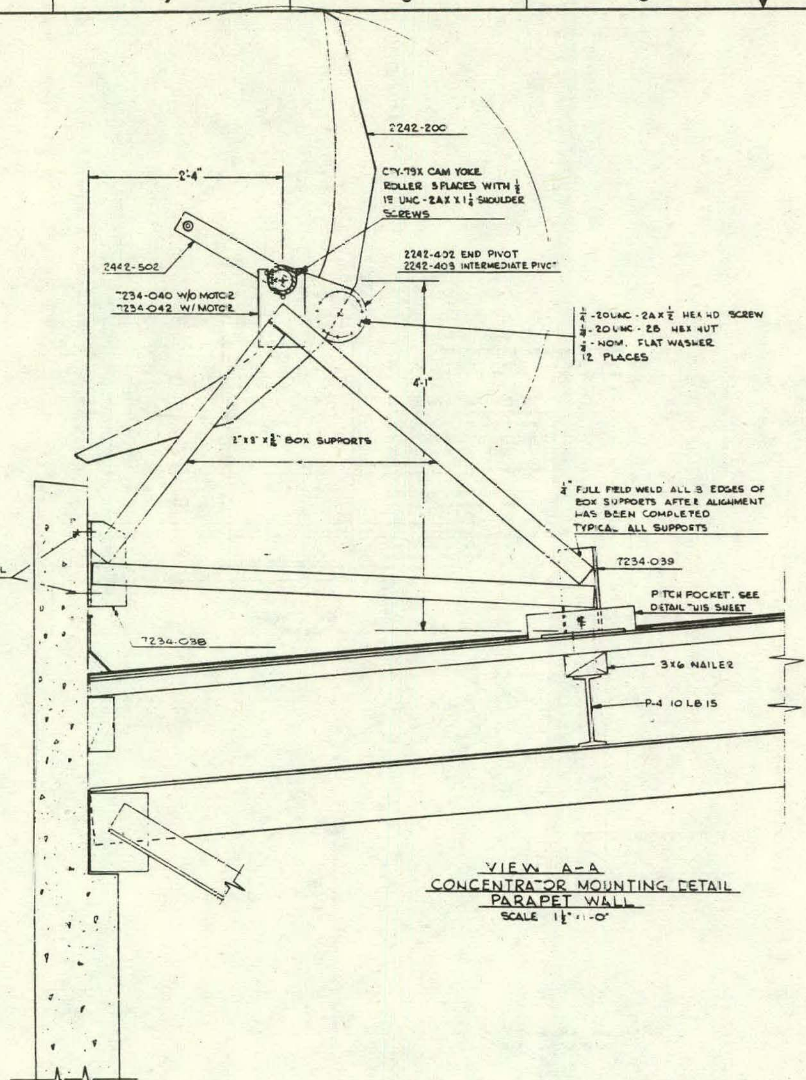
SCALE SHOWN | WT | SHEET 1 OF 1

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	CHANGE BOX BEAMS TO 3X3X $\frac{3}{16}$	9-21-76	
	B	CHANGE T IN PITCH POCKET TO I SECT	9-21-76	
	C	ADD NOTES	10-7-76	

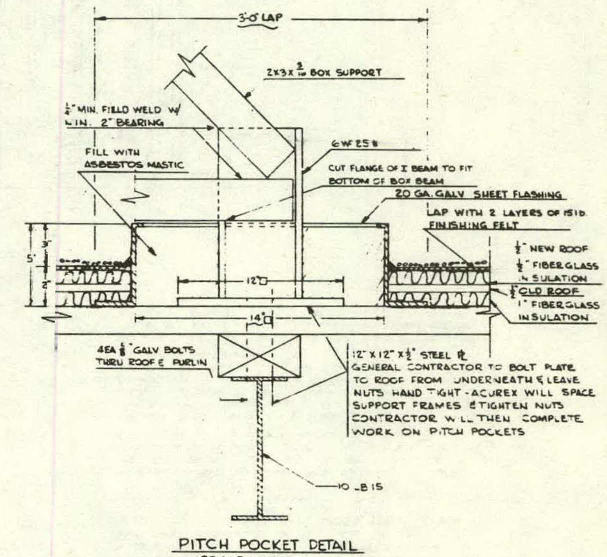
REVISIONS

NOTES:

1. GENERAL CONTRACTOR WILL FURNISH & INSTALL THE FOLLOWING:
   - A. CONCENTRATOR YOKE
   - B. 2"x3"x $\frac{3}{16}$" BOX SUPPORTS
   - C. PARAPET WALL MOUNTS
   - D. ROOF MOUNT
   - E. PITCH POCKET COMPLETE
   - F. FIELD WELDING
   - G. MISC HARDWARE FOR COMPLETE SUPPORT INSTALLATION
2. ACUREX WILL FURNISH & INSTALL THE FOLLOWING:
   - A. COMPLETE CONCENTRATOR
   - B. MOTOR & DRIVE TRAIN
   - C. FLEXIBLE PIPING END CONNECTIONS ON CONCENTRATORS



VIEW A-A
CONCENTRATOR MOUNTING DETAIL
PARAPET WALL
SCALE 1½"=1'-0"



PITCH POCKET DETAIL
SCALE: NONE

QTY. REQD. -02	-01	ITEM NO.	CODE IDENT	PART NO.	DESCRIPTION

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING

DRAWN		DATE 9-13-76	
CHECKED	S.H. [illegible]	10-11-76	
ENGINEER	[illegible]	10-11-76	
APPROVED	[illegible]	10-11-76	

NEXT ASSY	QTY	USED ON	QTY

APPLICATION

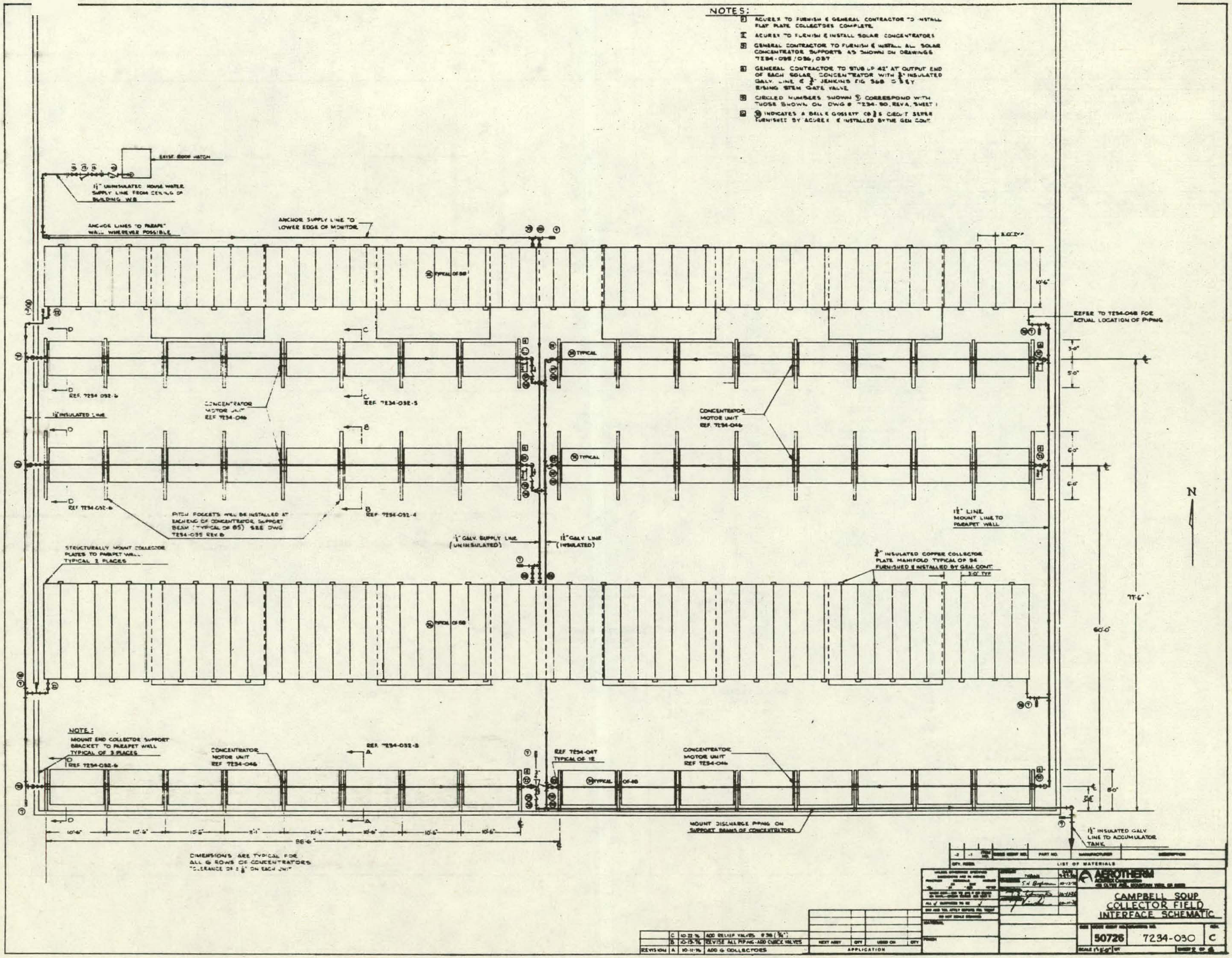
MATERIAL
FINISH

ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042

CAMPBELL SOUP
CONCENTRATOR MOUNTING
PARAPET WALL

SIZE	CODE IDENT NO.	DRAWING NO.	REV
D	50726	7234 030	C

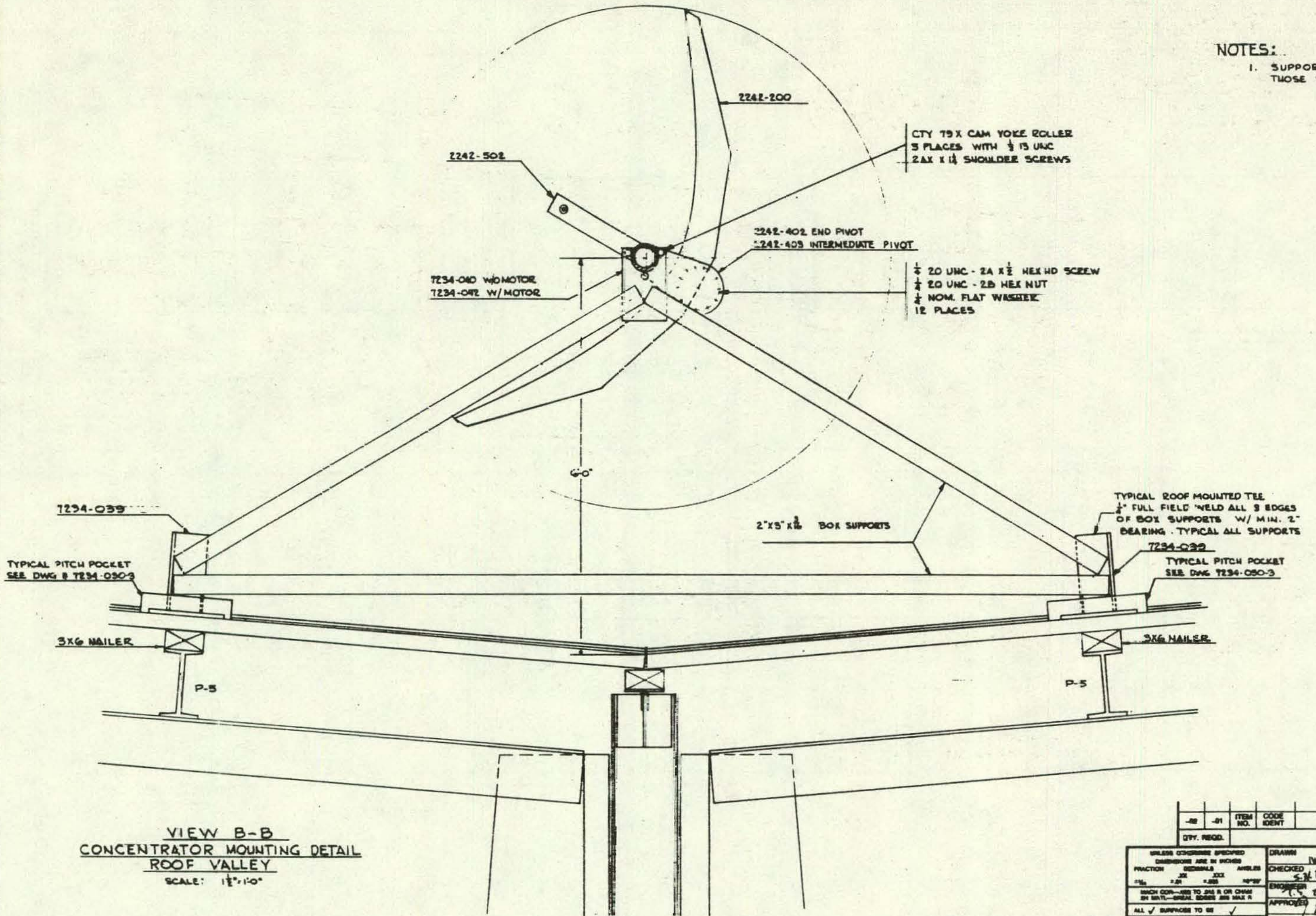
SCALE SHOWN | WT | SHEET 3 OF 6


NOTES:
ACUREX TO FURNISH & GENERAL CONTRACTOR TO INSTALL FLAT PLATE COLLECTORS COMPLETE
ACUREX TO FURNISH & INSTALL SOLAR CONCENTRATORS
GENERAL CONTRACTOR TO FURNISH & INSTALL ALL SOLAR CONCENTRATOR SUPPORTS AS SHOWN ON DRAWINGS 7234-035/036, 037
GENERAL CONTRACTOR TO STUB UP 42" AT OUTPUT END OF EACH SOLAR CONCENTRATOR WITH 3/4" INSULATED GALV. LINE & 3/4" JENKINS FIG 368 RISING STEM GATE VALVE
CIRCLED NUMBERS SHOWN CORRESPOND WITH THOSE SHOWN ON DWG # 7234-90, REV A, SHEET 1
INDICATES A BELL & GOSSETT CB 3/4 S CIRCUIT SETTER FURNISHED BY ACUREX & INSTALLED BY THE GEN CONT.
ANCHOR LINES TO PARAPET WALL WHEREVER POSSIBLE
ANCHOR SUPPLY LINE TO LOWER EDGE OF MONITOR
REFER TO 7234-048 FOR ACTUAL LOCATION OF PIPING
CONCENTRATOR MOTOR UNIT REF 7234-046
1½" INSULATED LINE
1½" GALV. SUPPLY LINE (UNINSULATED)
1½" GALV LINE (INSULATED)
1½" LINE MOUNT LINE TO PARAPET WALL
STRUCTURALLY MOUNT COLLECTOR PLATES TO PARAPET WALL TYPICAL 2 PLACES
NOTE: MOUNT END COLLECTOR SUPPORT BRACKET TO PARAPET WALL TYPICAL OF 3 PLACES
MOUNT DISCHARGE PIPING ON SUPPORT BEAMS OF CONCENTRATORS
1½" INSULATED GALV LINE TO ACCUMULATOR TANK
DIMENSIONS ARE TYPICAL FOR ALL 6 ROWS OF CONCENTRATORS
N
77'-6"
60'-0"
10'-6"
86'-6"
LIST OF MATERIALS
AEROTHERM
CAMPBELL SOUP COLLECTOR FIELD INTERFACE SCHEMATIC
50726 7234-030 C
C 10-22-76 ADD RELIEF VALVES
B 10-15-76 REVISE ALL PIPING - ADD CHECK VALVES
REVISION A 10-11-76 ADD 6 COLLECTORS
APPLICATION

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
	A	CHANGE BOX BEAMS TO 3x2x$\frac{3}{16}$	9-21-76	
	B	ADD NOTES	10-7-76	

NOTES:

1. SUPPORT MOUNTINGS ARE TYPICAL OF THOSE SHOWN ON DRAWING # 7234-030-8



VIEW B-B
CONCENTRATOR MOUNTING DETAIL
ROOF VALLEY
SCALE: 1$\frac{1}{2}$"=1'-0"

-02	-01	ITEM NO.	CODE IDENT	PART NO.	DESCRIPTION
QTY. REQD.		LIST OF MATERIALS			

NEXT ASSY	QTY	USED ON	QTY
APPLICATION			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
FRACTION ±1/64 · DECIMALS .XX ±.01 .XXX ±.005 · ANGLES ±0°30'
MACH COR—.030 TO .015 R OR CHAM; IN MATL—BREAK EDGES .005 MAX R
ALL ✓ SURFACES TO BE ✓
DIM AND TOL APPLY BEFORE FIN. TREAT.
DO NOT SCALE DRAWING
MATERIAL
FINISH

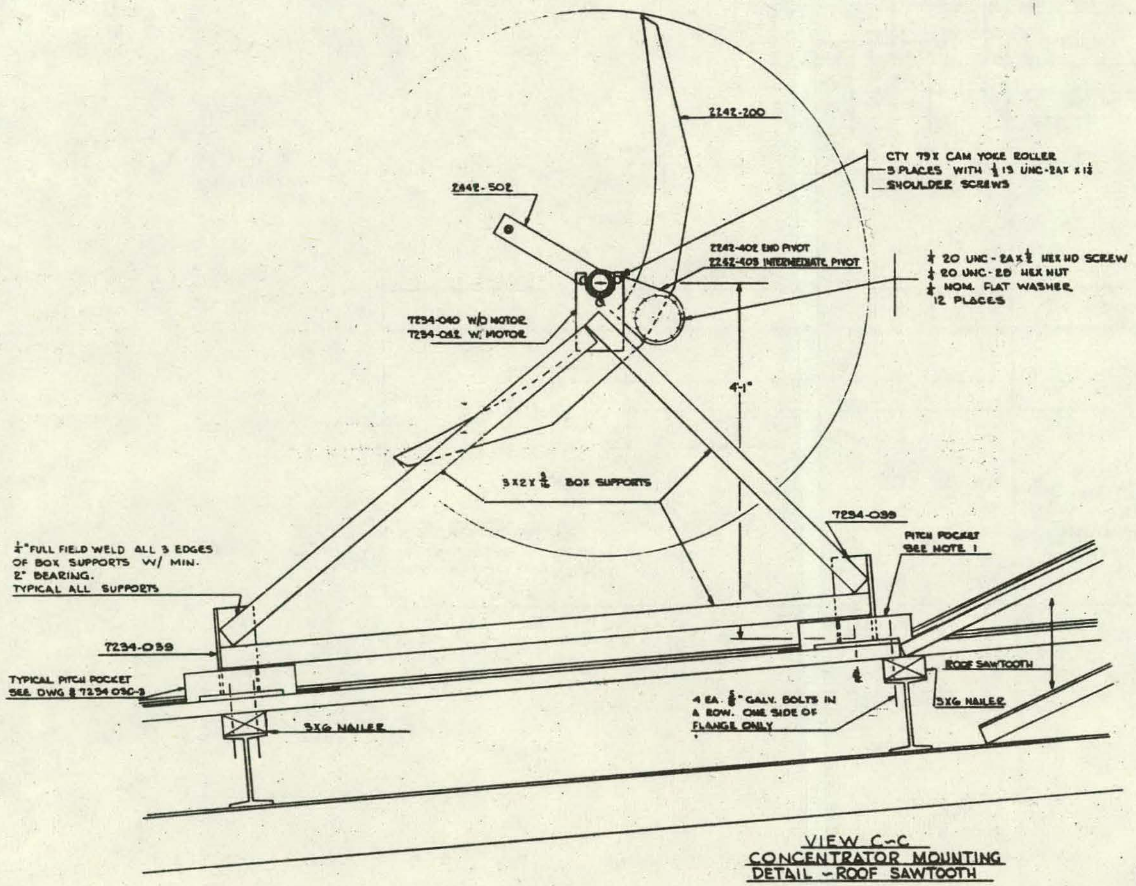
		DATE
DRAWN	[VAN]	9-16-76
CHECKED	S. H. B[illegible]	10-11-76
ENGINEER	T. S. [illegible]	10-11-76
APPROVED	J. [illegible]	10-11-76

ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042

CAMPBELL SOUP
CONCENTRATOR MOUNTING
ROOF VALLEY

SIZE	CODE IDENT NO.	DRAWING NO.	REV.
D	50726	7234-030	B
SCALE		WT	SHEET 4 OF 6

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	CHANGE BOX BEAMS TO 3X2X¼	9-21-76	
	B	ADD NOTES	10-7-76	



VIEW C-C
CONCENTRATOR MOUNTING
DETAIL - ROOF SAWTOOTH

NOTES:

1. INSTALLATION OF PITCH POCKET IS TYPICAL EXCEPT THAT ONE EDGE IS TURNED UP TO FOLLOW CONTOUR OF SAWTOOTH. 12 IN. SQUARE MOUNTING PLATE BUTTS STRUCTURAL MEMBER OF SAWTOOTH.
2. SUPPORT MOUNTINGS ARE TYPICAL OF THOSE SHOWN ON DRAWING # 7234-030-3 WITH THE EXCEPTION OF #1 ABOVE

LIST OF MATERIALS

-02	-01	ITEM NO.	CODE IDENT	PART NO.	DESCRIPTION
QTY. REQD.					

APPLICATION: NEXT ASSY | QTY | USED ON | QTY

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. DO NOT SCALE DRAWING.

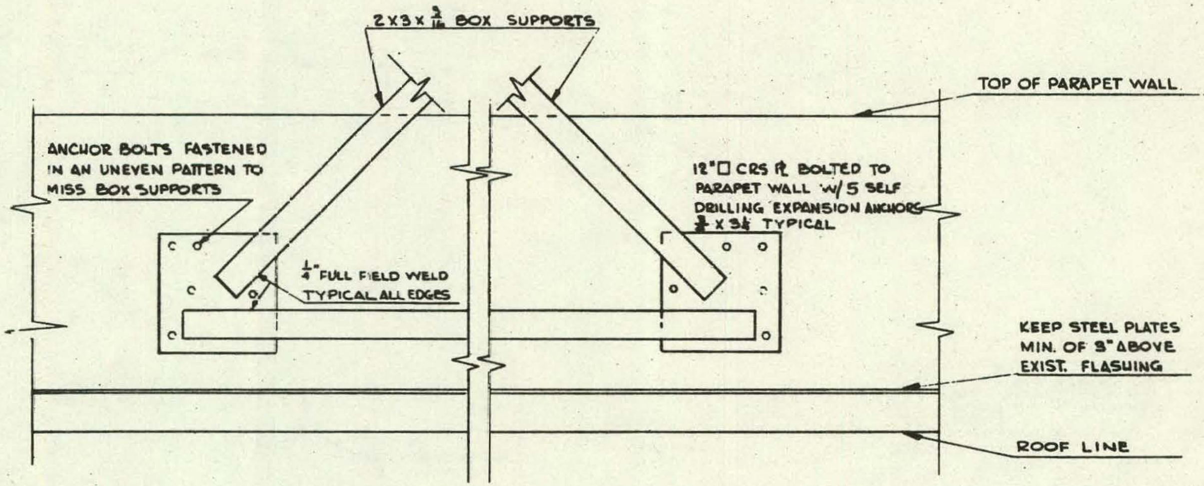
	DATE
DRAWN	9-16-76
CHECKED S.H.	10-11-76
	10-11-76
APPROVED	10-11-76

ACUREX Aerotherm, 485 CLYDE AVE., MOUNTAIN VIEW, CA 94042

CAMPBELL SOUP
CONCENTRATOR MOUNTING
ROOF SAWTOOTH

SIZE D | CODE IDENT NO. 50726 | DRAWING NO. 7234-030 | REV B

SCALE 1½" = 1'-0" | SHEET 5 OF 6



VIEW D-D

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

-02	-01	ITEM NO.	CODE IDENT	PART NO.	DESCRIPTION
QTY. REQD.				LIST OF MATERIALS	

NEXT ASSY	QTY	USED ON	QTY
APPLICATION			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
FRACTION ±1/64 DECIMALS .XX ±.01 .XXX ±.005 ANGLES ±0°30'
MACH COR—.005 TO .015 R OR CHAM
SH MATL—BREAK EDGES .005 MAX R
ALL ✓ SURFACES TO BE ✓
DIM AND TOL APPLY BEFORE FIN. TREAT.
DO NOT SCALE DRAWING
MATERIAL
FINISH

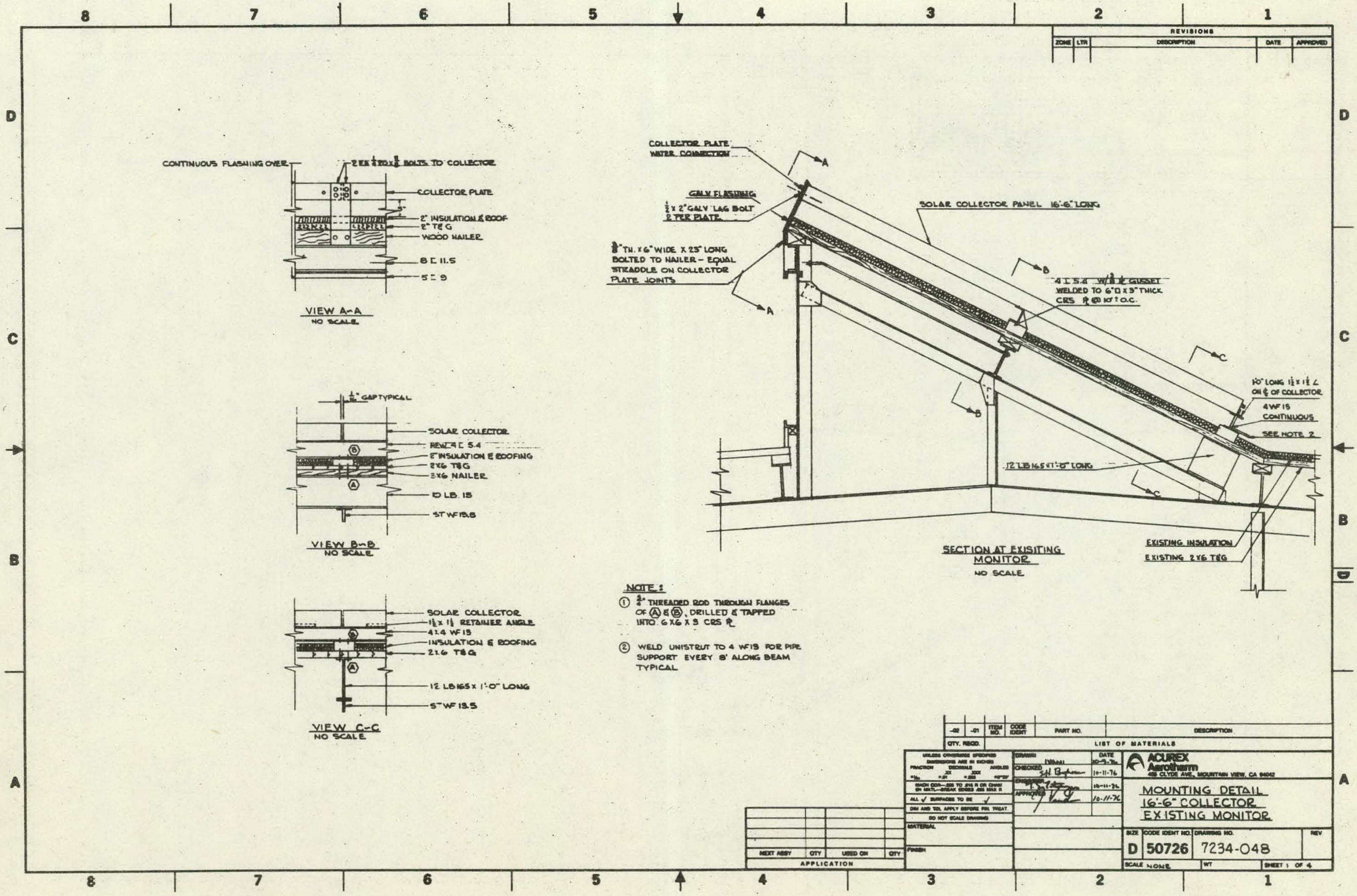
		DATE
DRAWN	IVANI	10-7-76
CHECKED		
ENGINEER	[signature]	10-11-76
APPROVED	[signature]	10-11-76

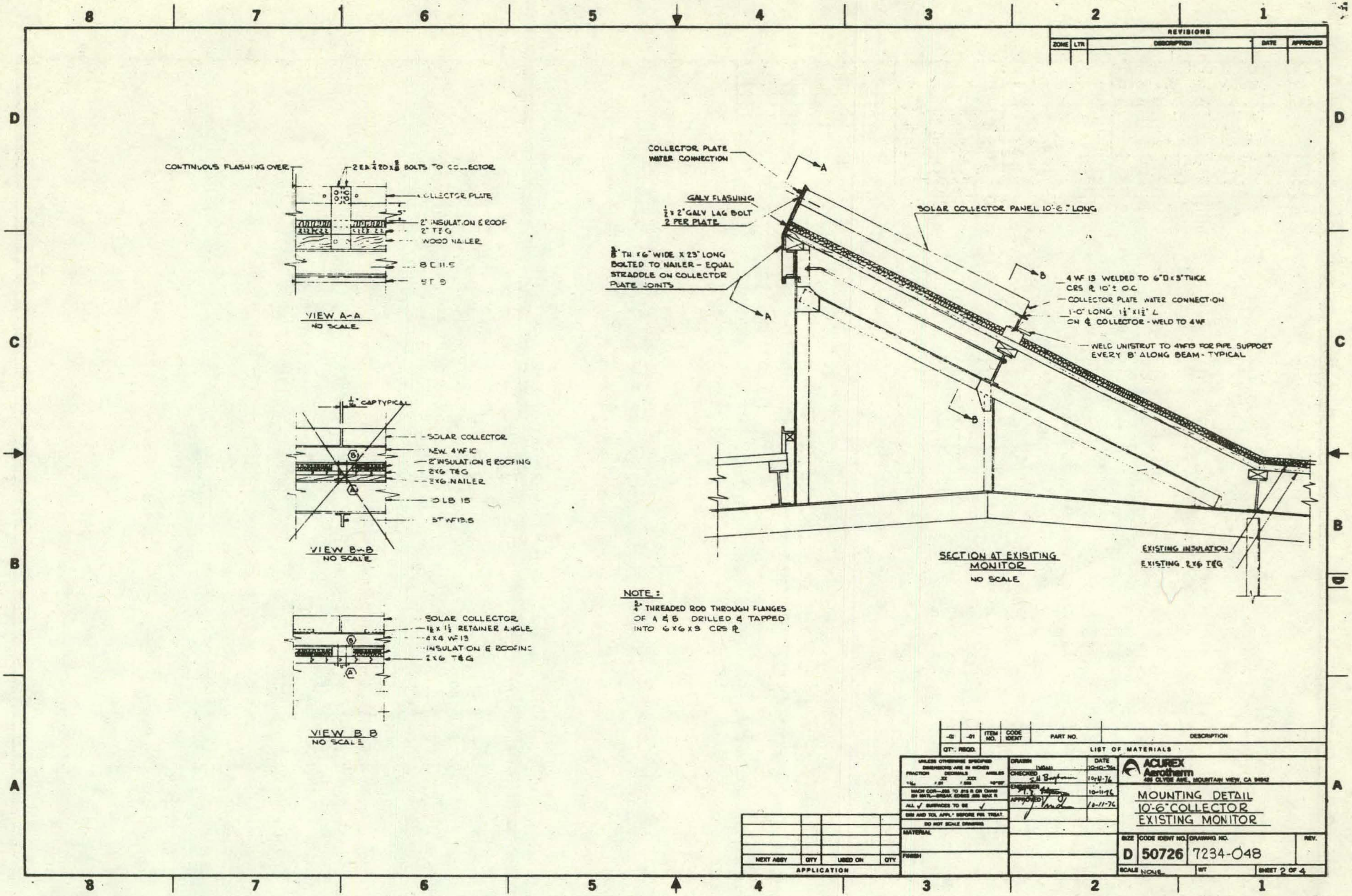
ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042

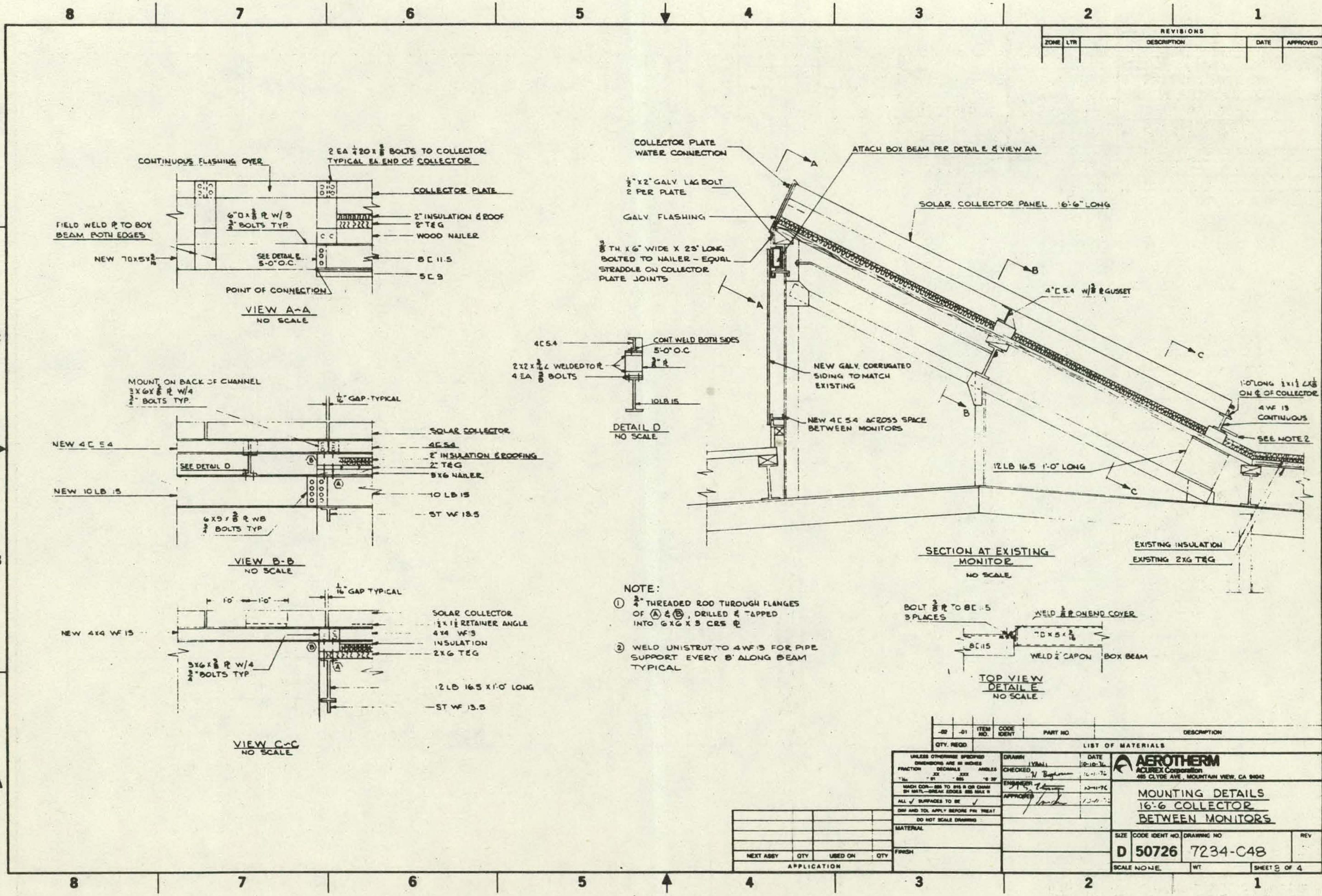
CAMPBELL SOUP
CONCENTRATOR MOUNTING
WEST PARAPET WALL

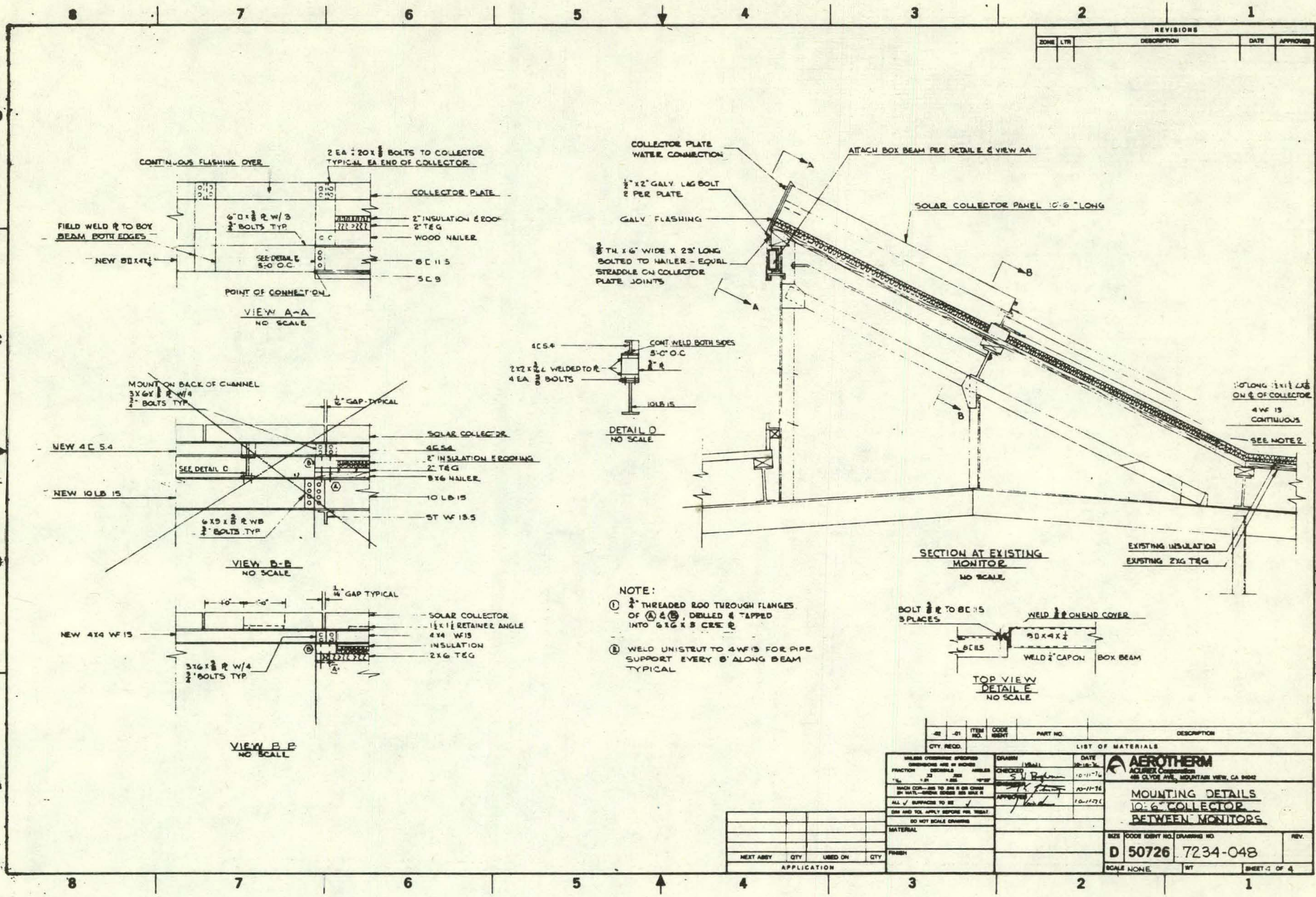
SIZE	CODE IDENT NO.	DRAWING NO.	REV.
C	50726	7234-030	

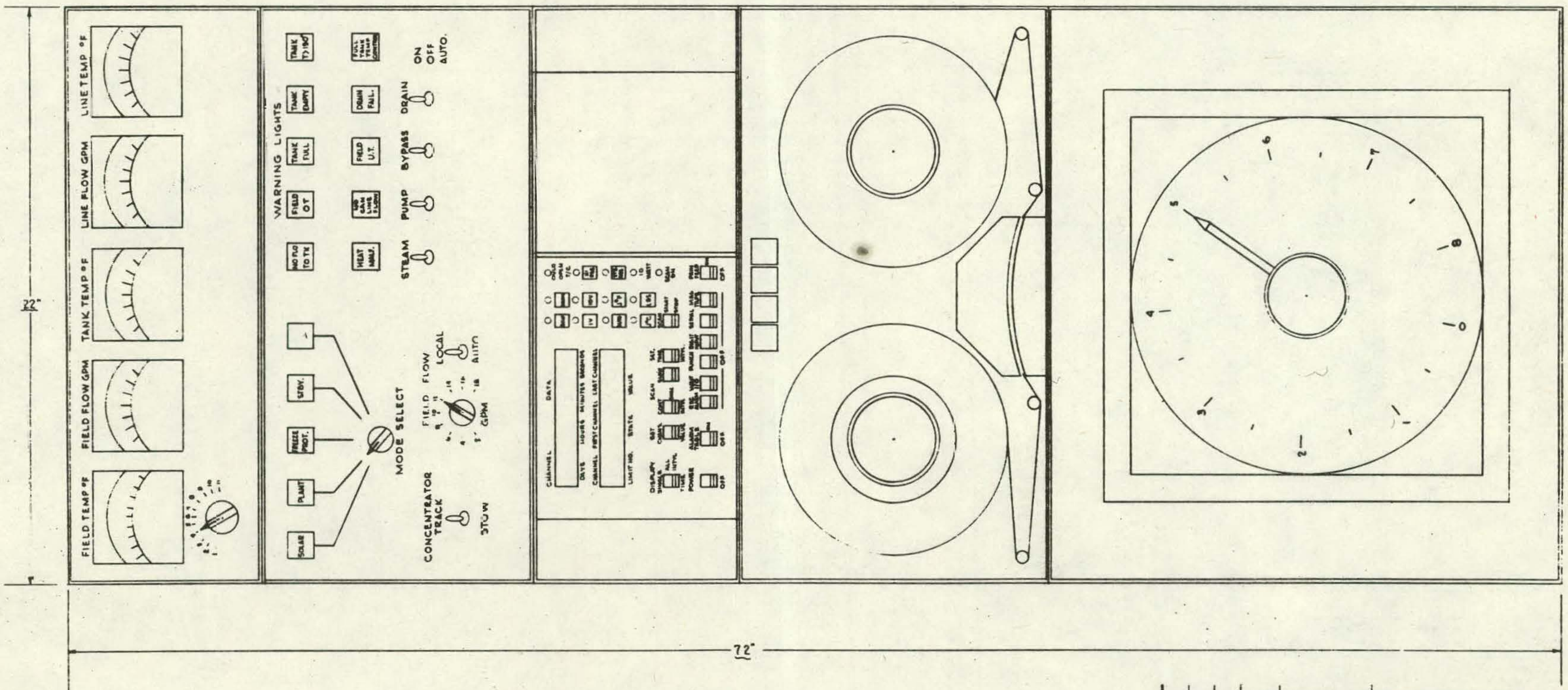
SCALE NONE | WT | SHEET 6 OF 6


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
CONTINUOUS FLASHING OVER
COLLECTOR PLATE
2" INSULATION & ROOF
2" T&G
WOOD NAILER
8 [11.5
5 [9
VIEW A-A
NO SCALE
COLLECTOR PLATE WATER CONNECTION
GALV FLASHING
½ x 2" GALV LAG BOLT 2 PER PLATE
SOLAR COLLECTOR PANEL 16'-6" LONG
TH. x 6" WIDE x 23" LONG BOLTED TO NAILER - EQUAL STRADDLE ON COLLECTOR PLATE JOINTS
WELDED TO 6"□ x 3" THICK
SOLAR COLLECTOR
2" INSULATION & ROOFING
2X6 T&G
3X6 NAILER
10 LB. 15
5" WF 18.5
VIEW B-B
NO SCALE
4WF 13
CONTINUOUS
SEE NOTE 2
SECTION AT EXISITING MONITOR
NO SCALE
EXISTING INSULATION
EXISTING 2X6 T&G
SOLAR COLLECTOR
1½ x 1½ RETAINER ANGLE
4 x 4 WF 13
INSULATION & ROOFING
2 x 6 T&G
12 LB 165 x 1'-0" LONG
5" WF 18.5
VIEW C-C
NO SCALE
NOTE:
① ¾" THREADED ROD THROUGH FLANGES OF Ⓐ & Ⓑ, DRILLED & TAPPED INTO 6 X 6 X 3 CRS
② WELD UNISTRUT TO 4 WF13 FOR PIPE SUPPORT EVERY 8' ALONG BEAM TYPICAL
ITEM NO.
CODE IDENT
PART NO.
DESCRIPTION
QTY. REQD.
LIST OF MATERIALS
DO NOT SCALE DRAWING
MATERIAL
FINISH
NEXT ASSY
QTY
USED ON
QTY
APPLICATION
DRAWN
CHECKED
ENGINEER
APPROVED
DATE
10-11-76
10-11-76
10-11-76
ACUREX Aerotherm
MOUNTING DETAIL
16'-6" COLLECTOR
EXISTING MONITOR
SIZE
CODE IDENT NO.
DRAWING NO.
REV
D
50726
7234-048
SCALE NONE
WT
SHEET 1 OF 4


CONTINUOUS FLASHING OVER
2 EA. 1/4-20 x 5/8 BOLTS TO COLLECTOR
COLLECTOR PLATE
2" INSULATION & ROOF
2" T&G
WOOD NAILER
8 C 11.5
ST 9
VIEW A-A
NO SCALE
1/16" GAP TYPICAL
SOLAR COLLECTOR
NEW 4 WF 10
2" INSULATION & ROOFING
2x6 T&G
2x6 NAILER
10 LB 15
ST WF 13.5
VIEW B-B
NO SCALE
SOLAR COLLECTOR
1 1/2 x 1 1/2 RETAINER ANGLE
4x4 WF 13
INSULATION & ROOFING
2x6 T&G
VIEW B-B
NO SCALE
COLLECTOR PLATE
WATER CONNECTION
GALV FLASHING
1/2 x 2" GALV LAG BOLT
2 PER PLATE
3/8" TH x 6" WIDE x 23" LONG
BOLTED TO NAILER - EQUAL
STRADDLE ON COLLECTOR
PLATE JOINTS
SOLAR COLLECTOR PANEL 10'-6" LONG
4 WF 13 WELDED TO 6"D x 3" THICK
CRS PL 10'± O.C.
COLLECTOR PLATE WATER CONNECTION
1'-0" LONG 1 1/2" x 1 1/2" L
ON CL COLLECTOR - WELD TO 4 WF
WELD UNISTRUT TO 4WF13 FOR PIPE SUPPORT
EVERY 8' ALONG BEAM - TYPICAL
SECTION AT EXISITING
MONITOR
NO SCALE
EXISTING INSULATION
EXISTING 2x6 T&G
NOTE:
3/4" THREADED ROD THROUGH FLANGES
OF A & B DRILLED & TAPPED
INTO 6x6x3 CRS PL
REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
QTY. REQD. | ITEM NO. | CODE IDENT | PART NO. | DESCRIPTION
LIST OF MATERIALS
NEXT ASSY | QTY | USED ON | QTY
APPLICATION
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
MATERIAL
FINISH
DRAWN 10-10-76
CHECKED S.H. Burgham 10-11-76
ENGINEER 10-11-76
APPROVED 10-11-76
ACUREX
Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042
MOUNTING DETAIL
10'-6" COLLECTOR
EXISTING MONITOR
SIZE D
CODE IDENT NO. 50726
DRAWING NO. 7234-048
REV.
SCALE NONE
WT
SHEET 2 OF 4


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
CONTINUOUS FLASHING OVER
2 EA 1/4 20 X 5/8 BOLTS TO COLLECTOR TYPICAL EA END OF COLLECTOR
COLLECTOR PLATE
2" INSULATION & ROOF
2" T&G
WOOD NAILER
FIELD WELD PL TO BOX BEAM BOTH EDGES
6"0 X 3/8 PL W/ 3 3/4" BOLTS TYP
SEE DETAIL E 5-0" O.C.
NEW 7" 0X5X3/16
8 C 11.5
5 C 9
POINT OF CONNECTION
VIEW A-A
NO SCALE
COLLECTOR PLATE WATER CONNECTION
ATTACH BOX BEAM PER DETAIL E & VIEW AA
1/2" X 2" GALV. LAG BOLT 2 PER PLATE
GALV. FLASHING
SOLAR COLLECTOR PANEL 16'-6" LONG
3/8 TH. X 6" WIDE X 23" LONG BOLTED TO NAILER - EQUAL STRADDLE ON COLLECTOR PLATE JOINTS
4" C 5.4 W/ 3/8 PL GUSSET
4 C 5.4
CONT WELD BOTH SIDES 5'-0" O.C.
2 X 2 X 1/4 L WELDED TO PL
4 EA 3/8 BOLTS
10 LB 15
DETAIL D
NO SCALE
NEW GALV. CORRUGATED SIDING TO MATCH EXISTING
NEW 4 C 5.4 ACROSS SPACE BETWEEN MONITORS
1'-0" LONG 1 X 1 1/2 L's ON CL OF COLLECTOR
4 WF 13 CONTINUOUS
SEE NOTE 2
12 LB 16.5 1'-0" LONG
SECTION AT EXISTING MONITOR
NO SCALE
EXISTING INSULATION
EXISTING 2X6 T&G
MOUNT ON BACK OF CHANNEL 3 X 6 X 3/8 PL W/4 3/4" BOLTS TYP.
1/16" GAP-TYPICAL
NEW 4 C 5.4
SOLAR COLLECTOR
4 C 5.4
2" INSULATION & ROOFING
2" T&G
3 X 6 NAILER
SEE DETAIL D
NEW 10 LB 15
10 LB 15
ST WF 13.5
6 X 5 X 3/8 PL WB 3/4 BOLTS TYP
VIEW B-B
NO SCALE
NOTE:
1. 3/4" THREADED ROD THROUGH FLANGES OF (A) & (B), DRILLED & TAPPED INTO 6 X 6 X 3 CRS PL
2. WELD UNISTRUT TO 4 WF 13 FOR PIPE SUPPORT EVERY 8' ALONG BEAM TYPICAL
BOLT 3/8 PL TO 8 C 11.5 3 PLACES
WELD 3/8 PL ON END COVER
8 C 11.5
7" 0 X 5 X 3/16
WELD 1/4" CAP ON
BOX BEAM
TOP VIEW DETAIL E
NO SCALE
1/16" GAP TYPICAL
1'-0"
SOLAR COLLECTOR
1 1/2 X 1 1/2 RETAINER ANGLE
NEW 4X4 WF 13
4X4 WF 13
INSULATION
2 X 6 T&G
3 X 6 X 3/8 PL W/4 3/4" BOLTS TYP.
12 LB 16.5 X 1'-0" LONG
ST WF 13.5
VIEW C-C
NO SCALE
LIST OF MATERIALS
QTY. REQD ITEM NO. CODE IDENT PART NO DESCRIPTION
NEXT ASSY USED ON QTY
APPLICATION
MATERIAL
FINISH
DO NOT SCALE DRAWING
AEROTHERM
ACUREX Corporation
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042
MOUNTING DETAILS
16'-6 COLLECTOR
BETWEEN MONITORS
SIZE D
CODE IDENT NO. 50726
DRAWING NO 7234-C48
SCALE NONE
SHEET 3 OF 4


REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
CONTINUOUS FLASHING OVER
2 EA 1/2-20 x 3/4 BOLTS TO COLLECTOR TYPICAL EA END OF COLLECTOR
COLLECTOR PLATE
6" □ x 3/8 ℞ w/3 3/4" BOLTS TYP
2" INSULATION & ROOF
2" T&G
WOOD NAILER
FIELD WELD ℞ TO BOX BEAM BOTH EDGES
NEW 8□x4x1/4
SEE DETAIL E 5-0 O.C.
8 C 11.5
5 C 9
POINT OF CONNECTION
VIEW A-A
NO SCALE
COLLECTOR PLATE WATER CONNECTION
ATTACH BOX BEAM PER DETAIL E & VIEW AA
1/2" x 2" GALV. LAG BOLT 8 PER PLATE
SOLAR COLLECTOR PANEL 10'-6" LONG
GALV. FLASHING
3/8 TH. x 6" WIDE x 23" LONG BOLTED TO NAILER - EQUAL STRADDLE ON COLLECTOR PLATE JOINTS
4 C 5.4
CONT. WELD BOTH SIDES 5'-0" O.C.
2x2x1/4 ∠ WELDED TO ℞
4 EA 3/8 BOLTS
10 LB 15
DETAIL D
NO SCALE
MOUNT ON BACK OF CHANNEL 3x6x3/8 ℞ w/4 3/4" BOLTS TYP
1/4" GAP-TYPICAL
SOLAR COLLECTOR
4 C 5.4
2" INSULATION & ROOFING
2" T&G
8x6 NAILER
10 LB 15
ST WF 13.5
NEW 4 C 5.4
SEE DETAIL C
NEW 10 LB 15
6x9x3/8 ℞ WB 3/4" BOLTS TYP
VIEW B-B
NO SCALE
SECTION AT EXISTING MONITOR
NO SCALE
10' LONG 1 1/2 x 1 1/2 ∠x1/8 ON ℄ OF COLLECTOR
4 WF 13 CONTINUOUS
SEE NOTE 2
EXISTING INSULATION
EXISTING 2x6 T&G
1/4" GAP TYPICAL
SOLAR COLLECTOR
1 1/2 x 1 1/2 RETAINER ANGLE
4x4 WF13
INSULATION
2x6 T&G
NEW 4x4 WF 15
3x6x3/8 ℞ w/4 3/4" BOLTS TYP
VIEW B-B
NO SCALE
NOTE:
① 3/4" THREADED ROD THROUGH FLANGES OF Ⓐ & Ⓑ, DRILLED & TAPPED INTO 6x6x3 CEE ℞
② WELD UNISTRUT TO 4 WF 13 FOR PIPE SUPPORT EVERY 8' ALONG BEAM TYPICAL
BOLT 3/8 ℞ TO 8C 11.5 3 PLACES
WELD 3/8 ℞ ON END COVER
8□x4x1/4
8C 11.5
WELD 1/4" CAP ON
BOX BEAM
TOP VIEW DETAIL E
NO SCALE
ITEM NO. CODE IDENT PART NO. DESCRIPTION
QTY. REQD.
LIST OF MATERIALS
NEXT ASSY QTY USED ON QTY
APPLICATION
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN DATE 10-18-76
CHECKED 10-11-76
APPROVED 10-11-76
AEROTHERM
ACUREX Corporation
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042
MOUNTING DETAILS 10'-6" COLLECTOR BETWEEN MONITORS
SIZE D CODE IDENT NO. 50726 DRAWING NO. 7234-048 REV.
SCALE NONE
SHEET 4 OF 4



-02	-01	ITEM NO.	CODE IDENT	PART NO	DESCRIPTION
QTY. REQD.		LIST OF MATERIALS			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING

DRAWN: 9-30-76
ENGINEER
APPROVED

ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042

CAMPBELL SCUP
CONTROL PANEL FACE

SIZE	CODE IDENT NO.	DRAWING NO	REV.
D	50726	7234-045	

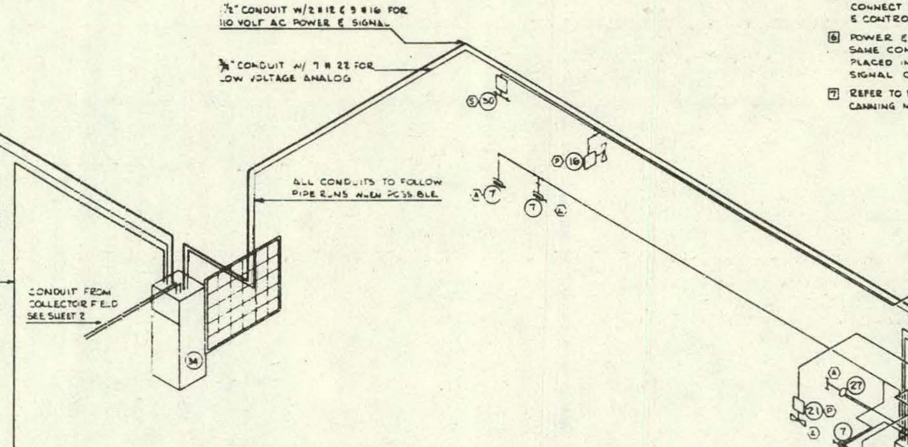
SCALE NONE | WT | SHEET | OF

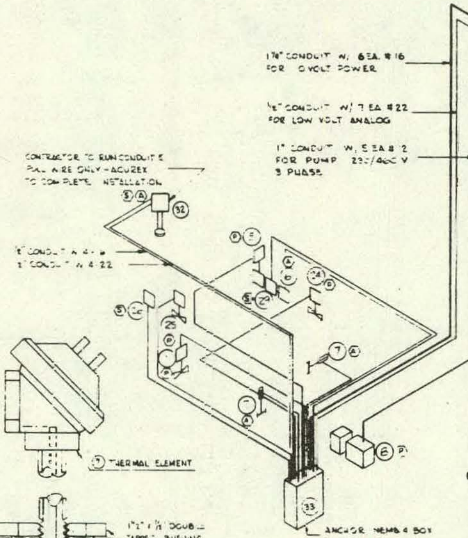
NEXT ASSY | QTY | USED ON | QTY
APPLICATION

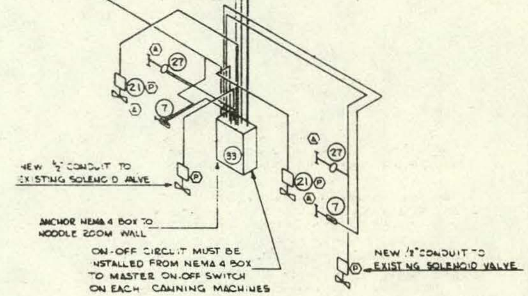
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	ADD'L ELECT SYMBOLS	2-30-76	

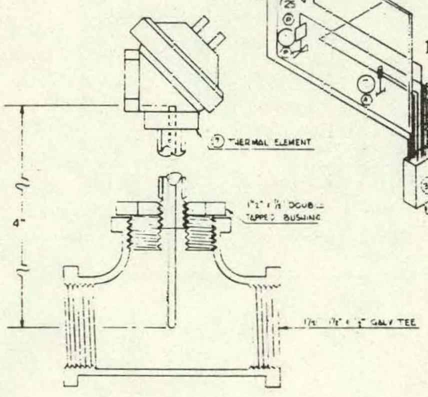
NOTES:

1. ALL WORK TO BE DONE IN ACCORDANCE WITH LOCAL CODES AND ATTACHED SPECIFICATIONS
2. "A" INDICATES ANALOG INSTRUMENTATION CIRCUIT USING # 22 WIRE SIZE - 1 VOLT TO 5 VOLT RANGE
3. "P" INDICATES POWER CIRCUIT 110 V.A.C. & 230-460 V.A.C.
4. "S" INDICATES SIGNAL CIRCUIT 110 VOLTS A.C.
5. ELECTRICAL CONTRACTOR TO PULL WIRES AND CONNECT TO TERMINAL STRIPS ON JUNCTION BOXES & CONTROL PANEL. ACUREX TO MAKE FINAL HOOKUP
6. POWER & SIGNAL CIRCUITS MAY BE PLACED IN THE SAME CONDUITS. ANALOG CIRCUITS MUST BE PLACED IN SEPARATE CONDUITS FROM POWER & SIGNAL CIRCUITS
7. REFER TO DRAWING 7234030 FOR PIPING, TANK & CANNING MACHINE LAYOUTS.









TYPICAL DETAIL
THERMAL ELEMENT
NO SCALE

ECV-34	( )	SOLENOID VALVE ½" MAGNETROL # 16-44 NORMALLY CLOSED 2 # 16
FCV-32	(5)	DIGITAL VALVE 1½" DIGITAL DYNAMICS INC. # DDI 5-607 D-14 1½ FPT 8 # 16
FE/FY-31	(6)	FLOWMETER 1½" BARTON SERIES 500 W # 308 PULSE ACTION PAK SERIES 7000 2 # 22
TE10-37	(7)	THERMAL ELEMENT ½" RDF CORP. TYPE 21010A4A48 MOUNTED IN "T" OR CROSS 3 # 22 (6 PLACES)
ECV-43	(16)	SOLENOID VALVE 1½ JOHNSON # 1550 D4 W/DISC # 120 2 # 16
ECV-51A/B	(21)	SOLENOID VALVE ¾ JOHNSON # 250 D-3 NORMALLY CLOSED SCREENED (2 EACH) 3 # 16
ECV-31	(24)	SOLENOID VALVE 1" MAGNETROL # 36-47 NORMALLY CLOSED 2 # 16
ECV-32	(25)	SOLENOID VALVE ¾" MAGNETROL # 14-243 NORMALLY OPEN 2 # 16
FS-33	(26)	FLOWSWITCH ¾" W.E. ANDERSON FLOTEC V6-EPB-B-S-2-D INSTALLED IN "T" 2 # 16
FE-51	(27)	FLOWMETER 1" FPT BARTON MODEL # 306 (1" SIZE ONLY) 2 # 22 (2 REQD)
FS-35	(29)	FLOW SWITCH 1½" W.E. ANDERSON FLOTEC V4-1½ INSTALLED IN "T" 2 # 16
FS-41	(30)	FLOW SWITCH 1½" W.E. ANDERSON FLOTEC V4-1½ INSTALLED IN "T" 2 # 16
	(33)	NEMA 4 WATERTIGHT ENCLOSURE 24" X 30" X 12" DEEP HOFFMAN # A-30P24 (BY ACUREX)
	(34)	CONTROL PANEL 22" WIDE × 72" HIGH × 24" DEEP (BY ACUREX) SEE DWG
	(32)	TANK LEVEL GUAGE "GEMS" FIBRA LEVEL # 24550 (BY ACUREX - SEE NOTE)
	(8)	PUMP MOTOR F/M WESTCO BR610 3HP 1800 RPM 230-460 VAC 3Ø DP MOTOR

-02	-01	ITEM NO.	CODE IDENT	PART NO	DESCRIPTION
QTY. REQD.					LIST OF MATERIALS

NEXT ASSY	QTY	USED ON	QTY
APPLICATION			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
MACH COR—.005 TO .015 R OR CHAM SH MATL—BREAK EDGES .005 MAX R
ALL ✓ SURFACES TO BE ✓
DIM AND TOL APPLY BEFORE FIN TREAT
DO NOT SCALE DRAWING
MATERIAL
FINISH

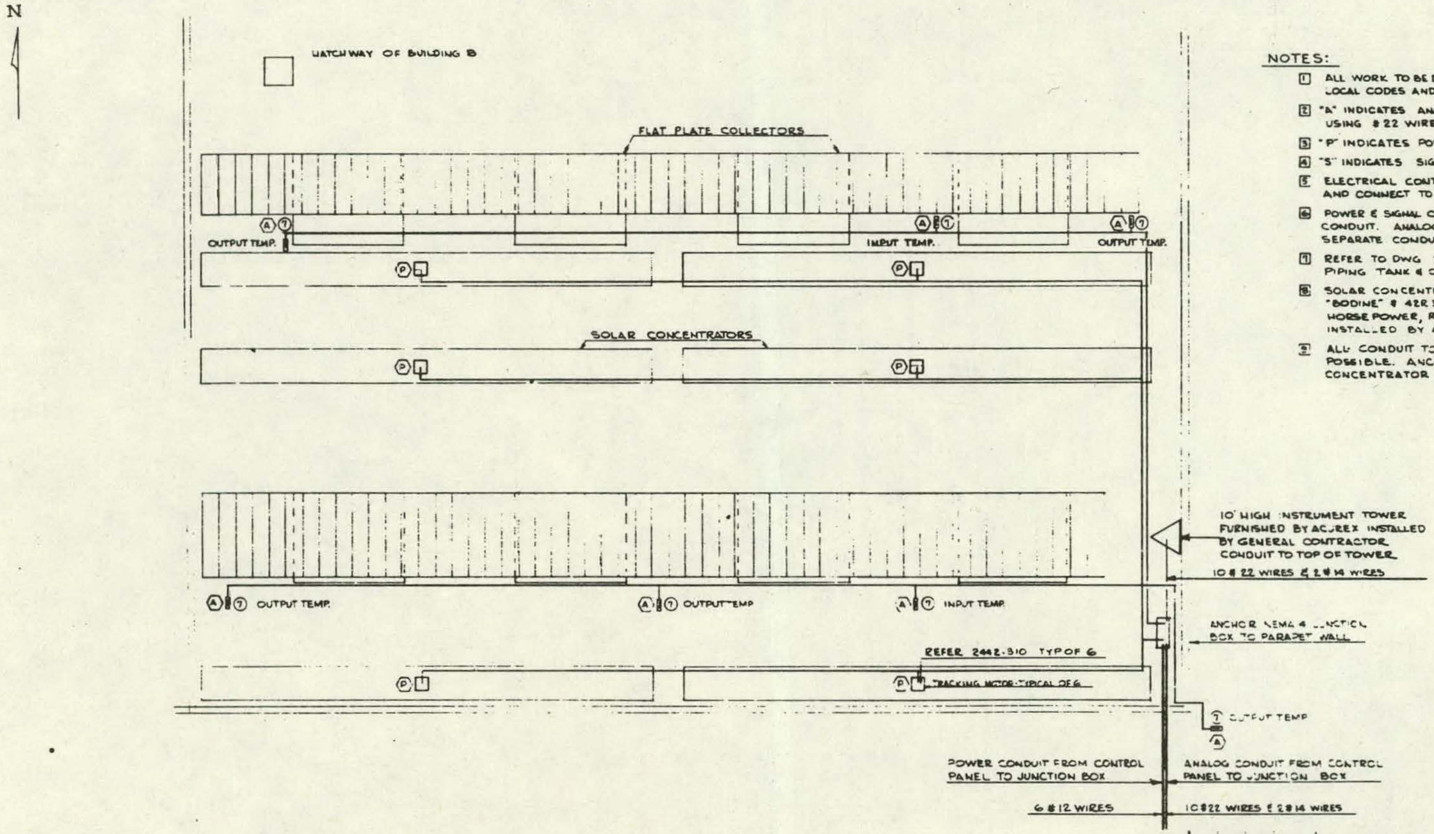
		DATE
DRAWN	IVAN	9-1-76
CHECKED		
ENGINEER		10/11/76
APPROVED		10-17-76

ACUREX Aerotherm
485 CLYDE AVE. MOUNTAIN VIEW, CA 94042

CAMPBELL SOUP
ELECTRICAL SCHEMATIC

SIZE	CODE IDENT NO.	DRAWING NO	REV
D	50726	7234-C31	A

SCALE NONE | WT | SHEET 1 OF 2



NOTES:

1. ALL WORK TO BE DONE IN ACCORDANCE WITH LOCAL CODES AND ATTACHED SPECIFICATIONS
2. "A" INDICATES ANALOG INSTRUMENTATION CIRCUIT USING # 22 WIRE SIZE - 1 VOLT TO 5 VOLT RANGE
3. "P" INDICATES POWER CIRCUIT 110 VAC & 220~440 VAC
4. "S" INDICATES SIGNAL CIRCUIT 110 VOLTS AC
5. ELECTRICAL CONTRACTOR TO INSTALL CONDUIT, PULL WIRES AND CONNECT TO TERMINAL STRIPS ON JUNCTION BOXES
6. POWER & SIGNAL CIRCUITS MAY BE PLACED IN THE SAME CONDUIT. ANALOG CIRCUITS MUST BE PLACED IN SEPARATE CONDUITS FROM POWER & SIGNAL CIRCUITS
7. REFER TO DWG 7234-030-1-2 FOR PIPING OF FIELD PIPING TANK & CANNING MACHINE LAYOUTS.
8. SOLAR CONCENTRATOR TRACKING MOTOR IS A "BODINE" # 42R 3B FCI-E4, 110V, SPLIT PHASE, FRACTIONAL HORSE POWER, REVERSIBLE MOTOR. FURNISHED & INSTALLED BY ACUREX.
9. ALL CONDUIT TO FOLLOW WATER PIPING WHERE POSSIBLE. ANCHOR TO PARAPET WALL & OR CONCENTRATOR SUPPORTS

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

-02	-01	ITEM NO	CODE IDENT	PART NO	DESCRIPTION
QTY REQD				LIST OF MATERIALS	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING

DRAWN	IVANI 9-28-76
CHECKED	
ENGINEER	[signature]
APPROVED	[signature] 10-11-76

ACUREX Aerotherm, 485 CLYDE AVE MOUNTAIN VIEW, CA 94042

CAMPBELL SOUP
FIELD ELECTRICAL
SCHEMATIC

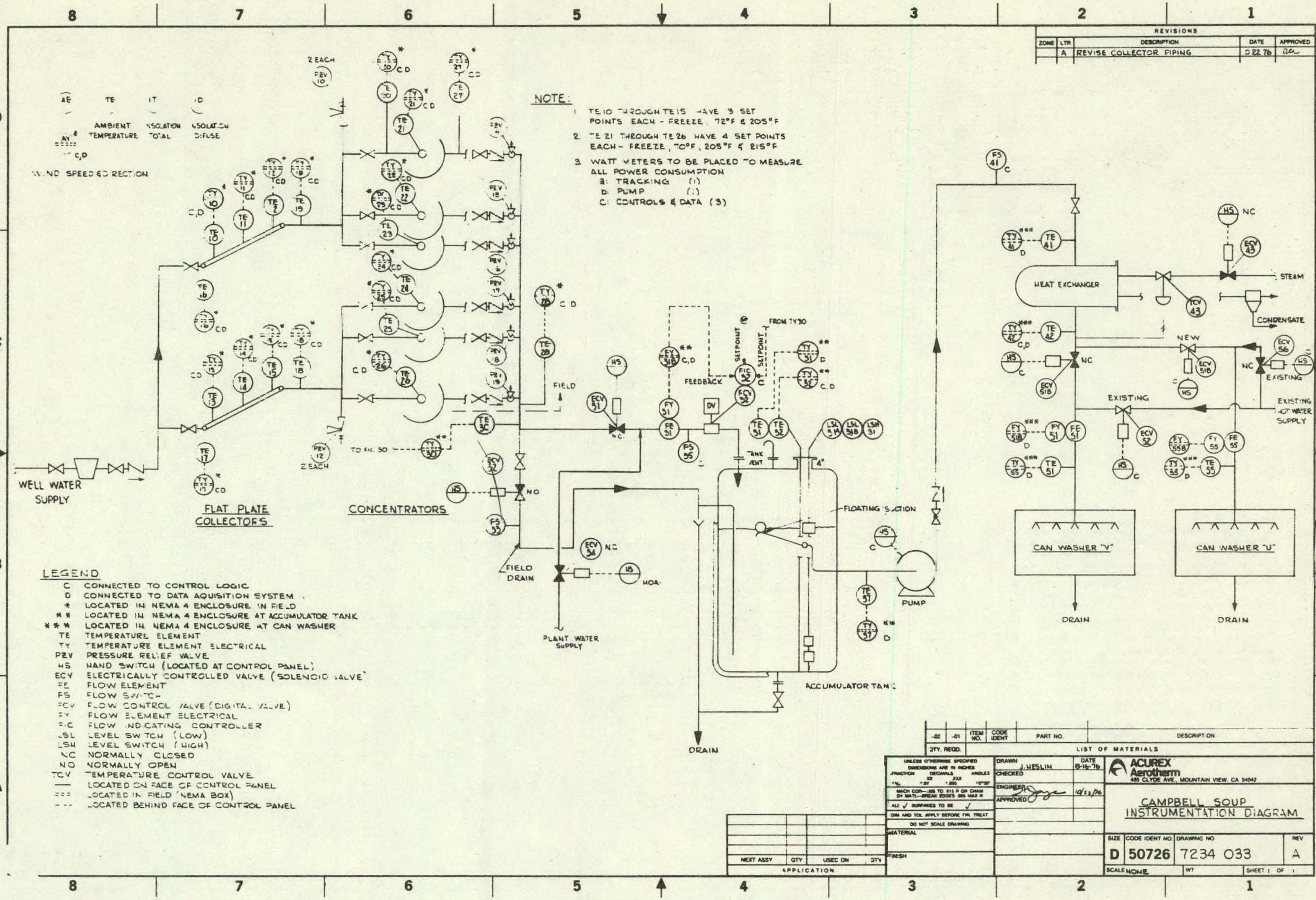
SIZE	CODE IDENT NO	DRAWING NO	REV
D	50726	7234 031	

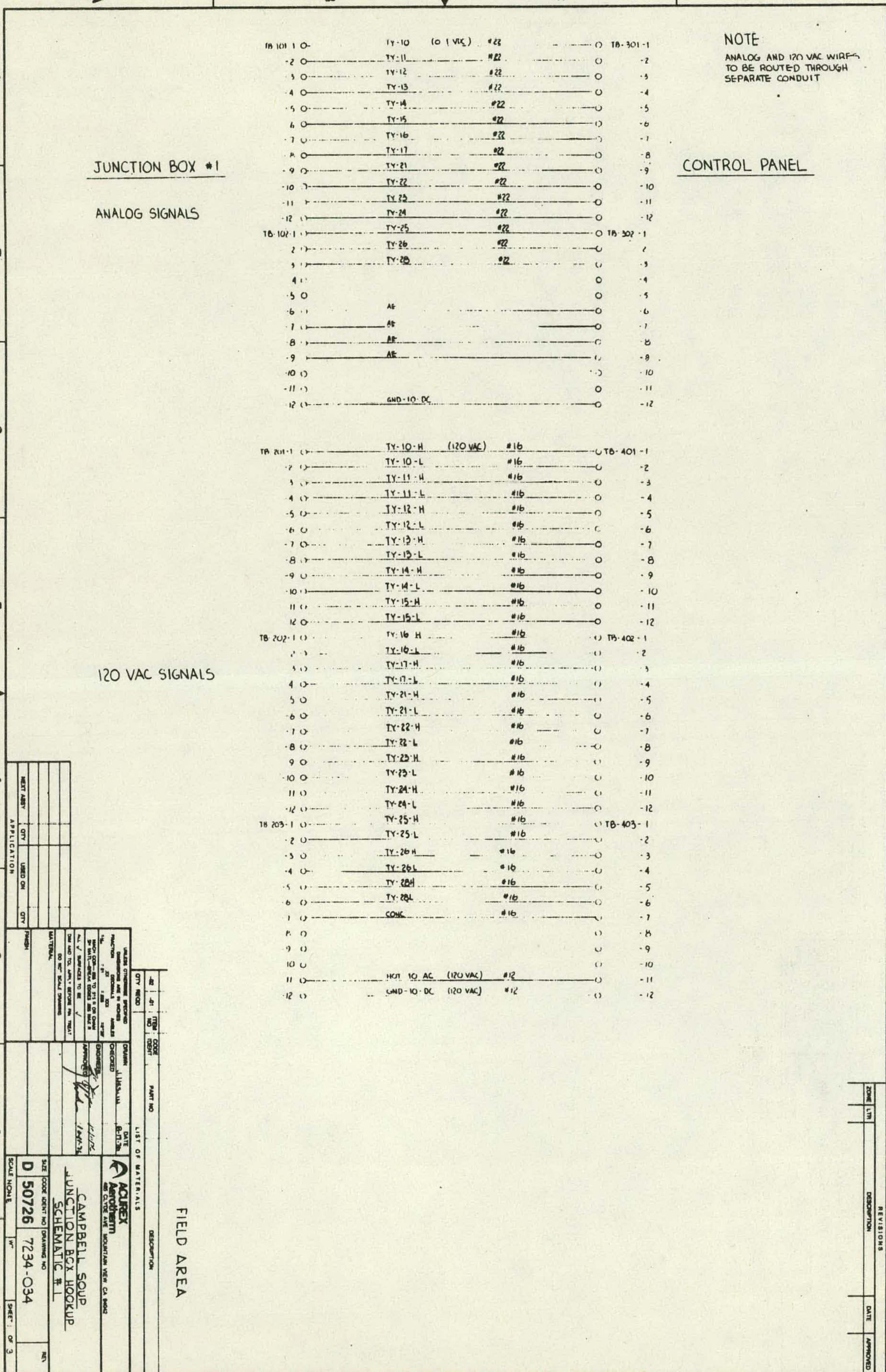
SCALE 1" : 10 | WT | SHEET 2 OF 2

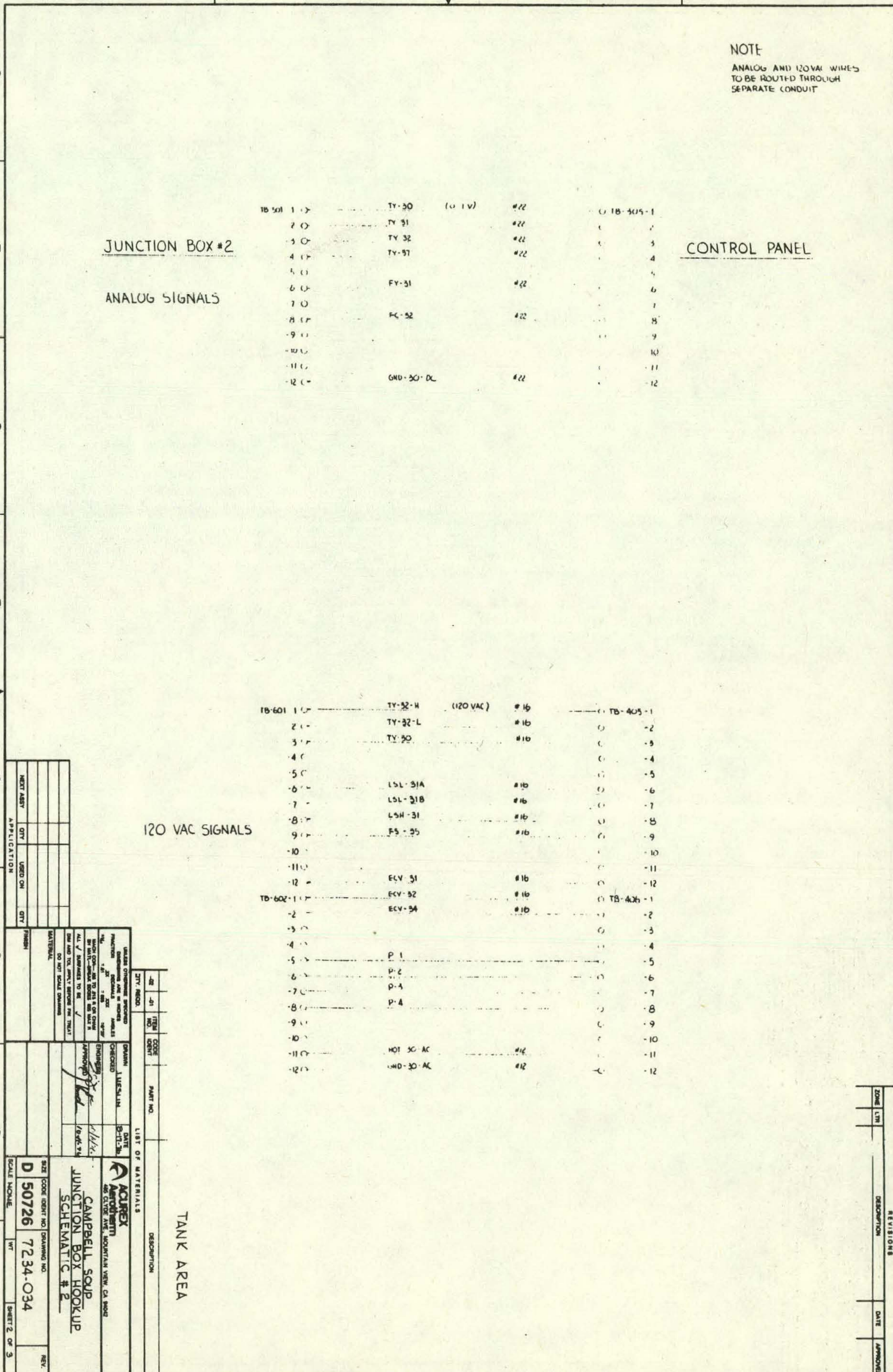
NEXT ASSY	QTY	USED ON	QTY
APPLICATION			

MATERIAL

FINISH


REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
A | REVISE COLLECTOR PIPING | 2 22 76
NOTE:
1. TE 10 THROUGH TE 15 HAVE 3 SET POINTS EACH - FREEZE, 72°F & 205°F
2. TE 21 THROUGH TE 26 HAVE 4 SET POINTS EACH - FREEZE, 70°F, 205°F & 215°F
3. WATT METERS TO BE PLACED TO MEASURE ALL POWER CONSUMPTION
a: TRACKING (1)
b: PUMP (1)
c: CONTROLS & DATA (3)
AMBIENT TEMPERATURE
INSOLATION TOTAL
INSOLATION DIFUSE
WIND SPEED & DIRECTION
WELL WATER SUPPLY
FLAT PLATE COLLECTORS
CONCENTRATORS
FIELD DRAIN
PLANT WATER SUPPLY
HOA
FEEDBACK
SETPOINT
FROM TY30
TO FIC 30
TANK VENT
FLOATING SUCTION
ACCUMULATOR TANK
PUMP
DRAIN
HEAT EXCHANGER
STEAM
CONDENSATE
NEW
EXISTING
EXISTING HOT WATER SUPPLY
CAN WASHER "V"
CAN WASHER "U"
LEGEND
C CONNECTED TO CONTROL LOGIC
D CONNECTED TO DATA AQUISITION SYSTEM
* LOCATED IN NEMA 4 ENCLOSURE IN FIELD
** LOCATED IN NEMA 4 ENCLOSURE AT ACCUMULATOR TANK
*** LOCATED IN NEMA 4 ENCLOSURE AT CAN WASHER
TE TEMPERATURE ELEMENT
TY TEMPERATURE ELEMENT ELECTRICAL
PRV PRESSURE RELIEF VALVE
HS HAND SWITCH (LOCATED AT CONTROL PANEL)
ECV ELECTRICALLY CONTROLLED VALVE (SOLENOID VALVE)
FE FLOW ELEMENT
FS FLOW SWITCH
FCV FLOW CONTROL VALVE (DIGITAL VALVE)
FY FLOW ELEMENT ELECTRICAL
FIC FLOW INDICATING CONTROLLER
LSL LEVEL SWITCH (LOW)
LSH LEVEL SWITCH (HIGH)
NC NORMALLY CLOSED
NO NORMALLY OPEN
TCV TEMPERATURE CONTROL VALVE
— LOCATED ON FACE OF CONTROL PANEL
=== LOCATED IN FIELD (NEMA BOX)
- - - LOCATED BEHIND FACE OF CONTROL PANEL
LIST OF MATERIALS
DRAWN J. WESLIN 8-16-76
ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042
CAMPBELL SOUP
INSTRUMENTATION DIAGRAM
SIZE D CODE IDENT NO. 50726 DRAWING NO. 7234 033 REV A
SCALE NONE SHEET 1 OF 1


NOTE
ANALOG AND 120 VAC WIRES TO BE ROUTED THROUGH SEPARATE CONDUIT
JUNCTION BOX #1
ANALOG SIGNALS
CONTROL PANEL
TB 101-1 TY-10 (0-1 VDC) #22 TB-301-1
-2 TY-11 #22 -2
-3 TY-12 #22 -3
-4 TY-13 #22 -4
-5 TY-14 #22 -5
-6 TY-15 #22 -6
-7 TY-16 #22 -7
-8 TY-17 #22 -8
-9 TY-21 #22 -9
-10 TY-22 #22 -10
-11 TY-23 #22 -11
-12 TY-24 #22 -12
TB-102-1 TY-25 #22 TB-302-1
2 TY-26 #22 2
3 TY-28 #22 -3
AF
GND-10-DC
120 VAC SIGNALS
TB 201-1 TY-10-H (120 VAC) #16 TB-401-1
TY-10-L
TY-11-H
TY-11-L
TY-12-H
TY-12-L
TY-13-H
TY-13-L
TY-14-H
TY-14-L
TY-15-H
TY-15-L
TB 202-1 TY-16-H #16 TB-402-1
TY-16-L
TY-17-H
TY-17-L
TY-21-H
TY-21-L
TY-22-H
TY-22-L
TY-23-H
TY-23-L
TY-24-H
TY-24-L
TB 203-1 TY-25-H #16 TB-403-1
TY-25-L
TY-26H
TY-26L
TY-28H
TY-28L
COMC
HOT 10 AC (120 VAC) #12
GND-10-DC (120 VAC) #12
FIELD AREA
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
APPLICATION
NEXT ASSY USED ON QTY
LIST OF MATERIALS
QTY REQD CODE IDENT PART NO DESCRIPTION
DRAWN CHECKED ENGINEER APPROVED DATE
ACUREX Aerotherm
485 CLYDE AVE MOUNTAIN VIEW CA 94042
CAMPBELL SOUP
JUNCTION BOX HOOKUP
SCHEMATIC #1
SIZE D CODE IDENT NO 50726 DRAWING NO 7234-034
SCALE NONE SHEET 1 OF 3


NOTE
ANALOG AND 120VAC WIRES TO BE ROUTED THROUGH SEPARATE CONDUIT
JUNCTION BOX #2
ANALOG SIGNALS
CONTROL PANEL
TB 501 1 TY-30 (0 1 V) #22 TB-305-1
2 TY 31 #22
3 TY 32 #22
4 TY-37 #22
6 FY-31 #22
8 FC-52 #22
12 GND-30-DC #22
120 VAC SIGNALS
TB-601 1 TY-32-H (120 VAC) #16 TB-405-1
2 TY-32-L #16
3 TY-30 #16
6 LSL-31A #16
7 LSL-31B #16
8 LSH-31 #16
9 FS-35 #16
12 ECV 31 #16
TB-602-1 ECV-32 #16 TB-406-1
2 ECV-34 #16
5 P 1
6 P-2
7 P-3
8 P-4
11 HOT 30 AC #12
12 GND-30-AC #12
TANK AREA
REVISIONS
ZONE LTR DESCRIPTION DATE APPROVED
LIST OF MATERIALS
QTY. REQD. ITEM NO. CODE IDENT PART NO. DESCRIPTION
APPLICATION
NEXT ASSY QTY USED ON QTY
MATERIAL
FINISH
DO NOT SCALE DRAWING
ACUREX Aerotherm
485 CLYDE AVE., MOUNTAIN VIEW, CA 94042
CAMPBELL SOUP
JUNCTION BOX HOOKUP
SCHEMATIC # 2
SIZE D CODE IDENT NO. 50726 DRAWING NO. 7234-034
SCALE NONE
SHEET 2 OF 3

NOTE:
ANALOG AND 120 VAC WIRES TO BE ROUTED THROUGH SEPARATE CONDUIT

JUNCTION BOX #3 — ANALOG SIGNALS → CONTROL PANEL

Junction Box #3				Control Panel
TB-701-1	TY-41	(0-1 VDC)	#22	TB-310-1
-2	TY-42		#22	-2
-3	TY-51		#22	-3
-4	TY-55		#22	-4
-5				-5
-6				-6
-7	FY-51		#22	-7
-8				-8
-9	FY-55		#22	-9
-10				-10
-11				-11
-12	GND-50-DC		#22	-12

120 VAC SIGNALS

Junction Box #3				Control Panel
TB-801-1	TY-42-C	(120 VAC)	#16	TB-410-1
-2	FS-41		#16	-2
-3	XS-51		#16	-3
-4	XS-55		#16	-4
-5	ECV-45		#16	-5
-6	ECV-51		#16	-6
-7	ECV-52		#16	-7
-8	ECV-55		#16	-8
-9	ECV-56		#16	-9
-10				-10
-11	HOT-50-AC		#12	-11
-12	GND-50-AC		#12	-12

CAN WASHER AREA

ACUREX Aerotherm

CAMPBELL SOUP
JUNCTION BOX HOOKUP
SCHEMATIC #3

D 50726 7234-034

SCALE NONE — SHEET 3 OF 3

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APPENDIX A

DESIGN AND PERFORMANCE REPORT

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Aerotherm Report TR-76-219 Rev A

14 October 1976

Contract E043-1218

CDRL/PA 7

APPLICATION OF SOLAR ENERGY TO THE SUPPLY OF INDUSTRIAL PROCESS HOT WATER

PRELIMINARY DESIGN AND PERFORMANCE REPORT

Volume I

Technical Report

Prepared for

Energy Research and Development Administration
1333 Broadway
Oakland, California 94612

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SECTION 1

SUMMARY

This design and performance report describes a solar hot water system which has specifically been designed for installation at the Campbell Soup Plant in Sacramento, California.

This report includes detail drawings and descriptions of the collector field, installation, piping, controls, data acquisition equipment, and roof structure. Furthermore, a program schedule with equipment and manpower costs for successfully completing Phase II of this contract has been included. Also included is an organization chart of the Phase II program personnel. The personnel involved during Phase II will be same as those supporting Phase I.

The economic analysis and energy reduction analysis is included in the Energy Reduction Analysis report CDRL/PA 5 published under separate cover.

The Campbell Soup Company's Sacramento plant was selected for the installation because it has many advantages over other plants for the experimental installation of a solar heated hot water system. In this respect, the Sacramento plant is quite unique and assures a high degree of success for the program. For example, the energy demand for the selected can washing line is uniform year around a steady 2 shifts 5 days a week. An identical can washing line exists directly adjacent to the selected line which can be used for comparison with the solar converted line. The can washing process selected is also ideal for the solar experiment in that it can easily be converted to solar without changes having to be made to the process equipment. The only physical interface between the existing equipment and the solar hardware is a simple "T" connection in the hydraulic supply line and control wires to a flow control valve. After the installation, either the existing system or the solar system can supply the hot water to the can washer.

The size of the Sacramento facility not only allows for the proposed installation, but could accommodate future expansions of the solar equipment so that all 20 can washing lines could be solar heated. The roof selected for the field is well suited for solar collectors, for it contains a series of saw-tooth shaped sky lights which make good supports for the flat plate collectors and it has flat areas between the sky lights which are well suited for the concentrators. The layout of the plant further allows for the placement of the storage tank directly outside the can washing building and for the location of the control and data acquisition equipment on a stairway landing directly adjacent to the can washing line. This area is separated by a closed door from the high noise and humidity environment which exists in the can washing area.

The biggest advantage with the selected location has been the dedicated support Acurex has enjoyed during the design phase from both the Sacramento Plant engineering staff and the Campbell Soup Corporate Headquarters Engineering Staff at Camden, New Jersey. Drawings, designs, installation procedures, and the installation procurement specification were all reviewed by both staffs. Comments and suggestions made throughout the design phase have been most helpful as has the large amount of information relative to the plant's energy requirements and uses. Furthermore, it has become apparent that a successful installation of experimental equipment cannot be made without a plant's full cooperation. Nor can a successful installation be made without using subcontractors who are familiar with the plant. For this reason the major subcontractor who will be doing the installation work has been picked from one of three which were recommended by the Sacramento engineering staff.

The Acurex designed system is quite simple compared to solar systems used for space heating or cooling. For example, there is no recirculation through the system, but only a single pass with the water used for the can washing. Storage is done with a simple accumulator tank so that energy collected during the weekend can be used during the week. With this type of system one always uses all the collected energy. The energy is collected at the highest collection efficiency since the incoming water is always well temperature, and the Btu's collected per dollar of equipment is therefore maximized.

To further maximize the collection efficiency a dual collector type field is used for the design. Initial heating of the water takes place in the flat plates and the final heating to occur in the concentrators. The percentage mix of each type was determined by optimizing the average yearly collected energy by using the flat plates in the temperature region where they are most effective and using the concentrators in the region where their efficiency exceeds the flat plates.

For the purpose of defining the system details in the report, the system has been divided into:

- The collector field
- The storage system

- The can washer interface

- The control system

- The data acquisition system

- The installation

Each of these components is then further divided and described in detail in Section 3. Section 2 describes the design requirements and approach.

The following briefly describes the system. The collector field is located on the roof of the finished products warehouse of the Campbell Soup Sacramento plant (see Figure 1 and 1a). Water is supplied from a 3.8 cm (1-1/2-inch) supply line which is located directly below an existing roof access hatch. A supply pipe will be brought up through that hatch and connected to the input of each flat plate collector array.

The preheated water from the flat plates is then passed into six sets of parallel connected concentrators. Each set consists of eight 1.83 x 3.05 m (6 x 10 foot) modules connected in series. The water from these units is gathered in a 3.8 cm (1-1/2-inch) insulated pipe which transports it to the storage tank. This pipe will be attached to an existing pipe run until it reaches the can washing building. From there the pipe will follow the can washing building around to the storage tank.

The storage tank is 75,200 l (20,000-gal) steel tank which is coated internally with a USDA approved phenolic liner. The outside of the tank is insulated. A 2.2-kw (3-hp) motor is used to pump the stored water for the tank into the can washing line.

The pipe entry into the can washing building will be through a plastic windowpane. The water will be passed through a steam heated heat exchanger so it can be brought up to its required use temperatures. In order not to waste energy from the solar collector system, the collector field was sized to supply exactly the required amount on a peak June day. The heat exchanger will therefore be used most of the year to augment the solar system. The hot water pipe will be routed to both lines U and V. Electrically operated solenoid valves will control which line is used as well as whether the solar or existing hot water system is utilized.

The control system has been kept as simple as possible, while still allowing for contingencies such as can filler downtime, temperature overheat, frost, power failure, and tank overflow. The control components will be standard commercially available parts assembled to perform the required control functions. The special control functions will be based on temperature inputs from

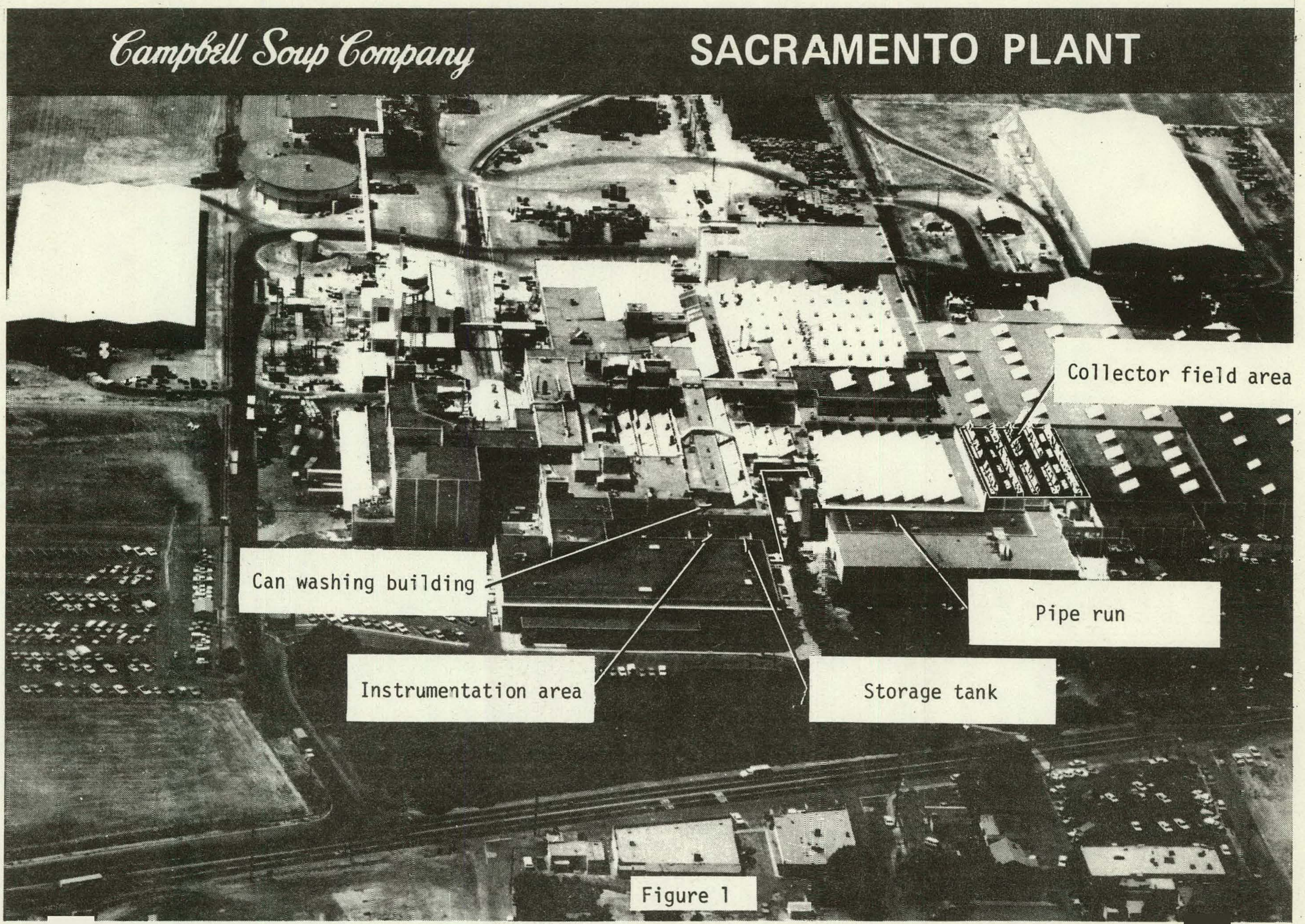
Campbell Soup Company
SACRAMENTO PLANT
Collector field area
Can washing building
Pipe run
Instrumentation area
Storage tank

Figure 1

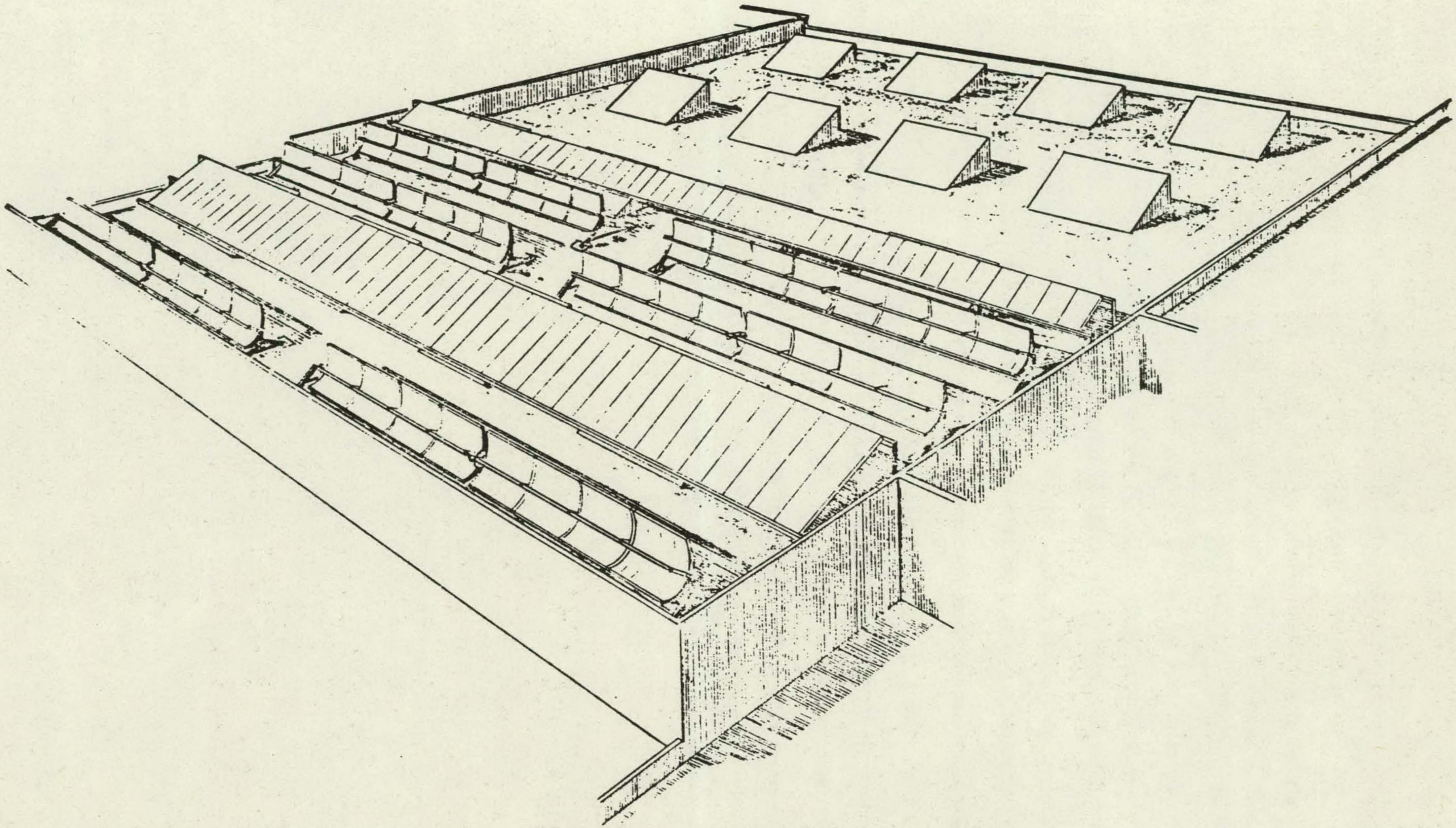

Figure 1a. Collector field.

measuring points in the system. Normal flowrate control is based on a variable flow value which will follow a cam operated program. This program will be varied each month.

Data will be collected and handled in several modes. First, data will be collected at the site and stored on magnetic tape for computer data reduction, plotting and analysis at Acurex. Secondly, selected data will be available for the IBM data storage unit and transmitted by phone to the central data facility at Huntsville. Thirdly, data can be printed out in realtime at the site for use in making field adjustments. Also all abnormalities in the system will be recorded on the written record since this may require immediate attention.

Installation of a system of the magnitude presented in this report must be carefully considered. Major considerations related to the selection of the construction contractor are:

- Use subcontractors which are familiar with the plant
- Use union labor which is consistent with plant policy
- Make a single contractor responsible for the installations so that no gaps of responsibility occur which delay the completion of the system approval by the plant management

Acurex has submitted request for proposals to three contractors who are familiar with the Sacramento plant. The selected contractor will be used for the complete installation of all hardware and structural supports.

SECTION 2

PRELIMINARY DESIGN ANALYSIS

2.1 SYSTEM REQUIREMENTS

Campbell Soup Plant interfaces, regulatory agency constraints, economics, and can washing system requirements all influence the solar process hot water system design. This section presents a detailed description of the can washing process, the performance requirements for the solar system, the regulatory constraints incorporated into the design, and the Campbell plant interfaces.

2.1.1 Process Description

The process selected for this demonstration program is the can washing process which is a part of a soup manufacturing production line. Can washing occurs at two points along the line. First, the empty cans are thoroughly washed with hot water and sterilized. Then the cans, after being filled and sealed, are washed to remove any spilled food residue from the exterior. All of the production lines at the Campbell Sacramento plant start out with fresh hot water from the mains for empty can washing. The converted lines then reuse this water to accomplish filled can washing. The unconverted lines use separate supplies for both empty-can and filled-can washing.

Line U, which will be supplied by the solar collector system, is used for manufacture of chicken noodle soup during the regular season. Line V, which will be monitored for comparison purposes, is used for beef noodle soup. The processing rates and the can sizes for both lines are similar. The cans are 6.8 cm (2-11/16 inches) in diameter and 10.2 cm (4 inches) in height. In August and September, during the tomato harvesting season, both lines U and V change over to processing tomato soup. The two lines are then identical both in product and process during that time period.

The can washing devices are quite simple in operation. A schematic diagram of the process is shown in Figure 2. The empty cans are conveyed through the washers on six metal rails which form a cage. The empty washer itself is a sheet metal enclosure approximately 2.4 m (8 feet) long

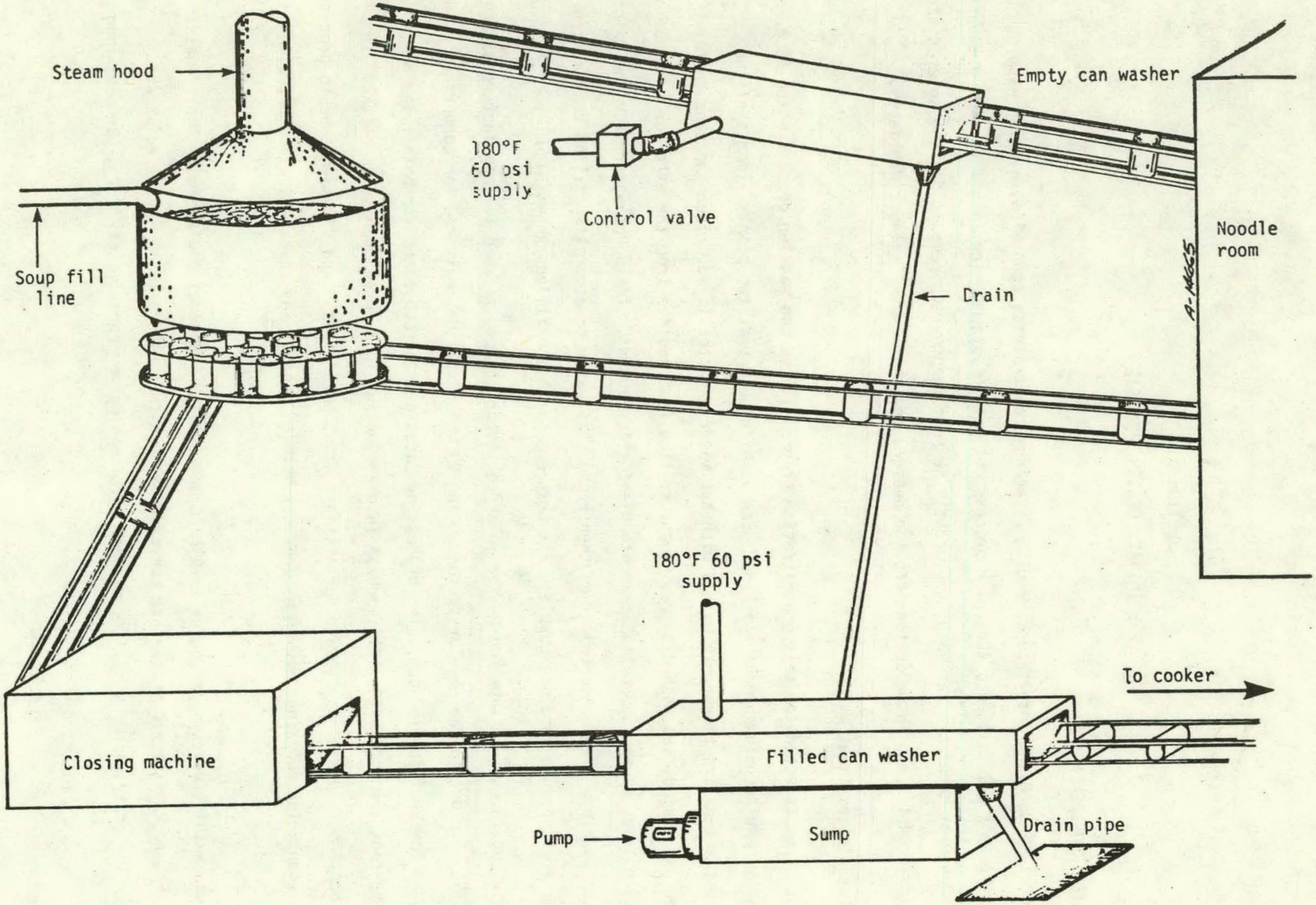

Figure 2. Can washer configuration.

and has a water supply tube with a series of eight nozzles located along one lower corner. During the transit through the washer the rail cage is twisted through an angle so that all surfaces of the can are exposed to the fixed streams of hot water. For the converted lines, the hot water draining off from the empty can washer flows into a sump below the filled can washer. Part of this water is fed with detergent and sprayed into the first section of the washer through a bank of 18 nozzles. The remaining hot water from the sump is then used to rinse off the filled cans in the second section of the washer which is equipped with 19 nozzles.

2.1.2 Performance Requirements

In order to support the can washing operation, the hot water supply for each process line must meet the following requirements:

- Flowrate. A continuous supply of hot water is required at the rate of 47.3 l/min ± 20 percent (12.5 gpm)
- Pressure. The supply pressure must be $\geq$42.5 kg/cm^2 (60 psi)
- Temperature. The temperature of the hot water must be within the range of 82°C and 90.5°C (180°F and 195°F).
- Duty Cycle. The can washer must be supplied with hot water during the two shifts. There is a 4 to 5 minute cleanup period every hour. When the soup production is interrupted, the can washing operation is shut down. The plant normally operates 5 days a week. For 4 to 6 weeks during the tomato harvest season, the plant operates 6 days a week. The plant is shut down for 2 weeks in June and 1 week at Christmas.

2.1.3 Regulatory Agency Restrictions

The design, construction, and installation of machinery and equipment for the food industry is regulated by a number of agencies. The major regulatory agencies and standards which affect the design of a solar collector for hot water in the canning industry are listed below:

- Food and Drug Administration (FDA), Good Manufacturing Practice Regulation, Part 128 — Sanitation, April 21, 1969
- United States Department of Agriculture (USDA), Accepted Meat and Poultry Equipment, June 30, 1974
- American National Standards Institute (ANSI), Food, Drug, and Beverage Equipment, ANSI-ASME, F 2.1, 1975

- Environmental Protection Agency (EPA), National Interim Primary Drinking Water Regulations, December 24, 1975
- Codified Federal Regulation (CFR), Title 9, Chapter III — Animal, Plant Health Inspection Service, October 3, 1970
- OSHA

The regulations covering food processing equipment are quite detailed and complex. For the purposes of supplying hot water for the can washing operation, the salient constraints can be summarized as follows:

a. Materials. Equipment in the food area must be constructed of materials capable of preventing deterioration from normal use and from chemicals, cleaning agents, and atmospheric exposure in the normal production environment. They must be smooth surfaced, corrosion and abrasion resistant, shatterproof, nontoxic, nonabsorbent, and must not stain or migrate to the product.

b. Design and Construction. All equipment in the food area must be of such workmanship as to be readily cleanable. The design and construction of such equipment must preclude the contamination of food with lubricants, fuel, metal fragments, glass, contaminated water, or any other contaminants. Culinary steam, process air and water are not excluded from this consideration.

c. Installation. All parts of stationary or not readily removable equipment must be installed far enough away from floors, walls, and ceilings to provide access for cleaning and inspection. As an alternative, permanently mounted equipment may be sealed with a watertight seal to the adjacent structure. Wall mounted cabinets and electrical connections must be installed at least 1 inch from the wall or sealed watertight to the wall.

d. General Safety Considerations. All machines must be suitably designed and should employ materials of construction and a degree of workmanship which will provide adequate safety and protection for personnel.

USDA approval is required prior to installation of any new equipment in the Campbell Soup Company Plant. Copies of complete drawings and plans, including list of materials have been submitted for preliminary approval.

2.1.4 Campbell Plant Interfaces

The major plant interfaces with the solar process hot water system are external to the production area. The collector field will be mounted on a warehouse roof. All roofing penetrations must be made according to Campbell design specifications.

Piping, valving, and insulation must all meet Campbell specifications. All hot components within human reach (≈2.4 m (8 feet) from floor level) must be insulated.

2.2 DESIGN APPROACH AND PRELIMINARY TRADE-OFFS

The system design approach is reviewed in this section. It was established to satisfy regulatory agencies, interface with the Campbell plant, and meet the can washer demands.

Based upon the system design constraints, the potential system configurations and operating modes (e.g., stratified versus accumulator storage, constant versus variable flowrate, etc.) were summarized for evaluation. A system schematic, presented in Figure 3, was constructed to satisfy both stratified and accumulator control philosophies.

The performance and cost of each system component (collector and mounting structure, piping/pump/insulation combinations, and storage tank) were analyzed to establish the economic optimum. Transient system simulations were used both to verify the system performance and identify the annual average solar contribution to the can washer energy demand.

2.2.1 Design Constraints

At the program outset the solar hot water system performance and installation requirements were summarized. The system was sized to meet the can washer energy demand on a peak June day. On this day, solar energy would supply:

- 47.3 l/min (12.5 gpm)
- Water temperature >82°C (180°F)

This design constraint essentially eliminates the need to dump energy at any time during the year, and consequently, improves the system economics.

Secondly, the system must be the most economical configuration to supply the needed energy (i.e., maximum Btu/$). System interfaces with existing equipment and buildings can significantly affect the system cost. This cost is composed of installation labor, materials, and loss of plant production. All cost components were considered in the selection of the system components.

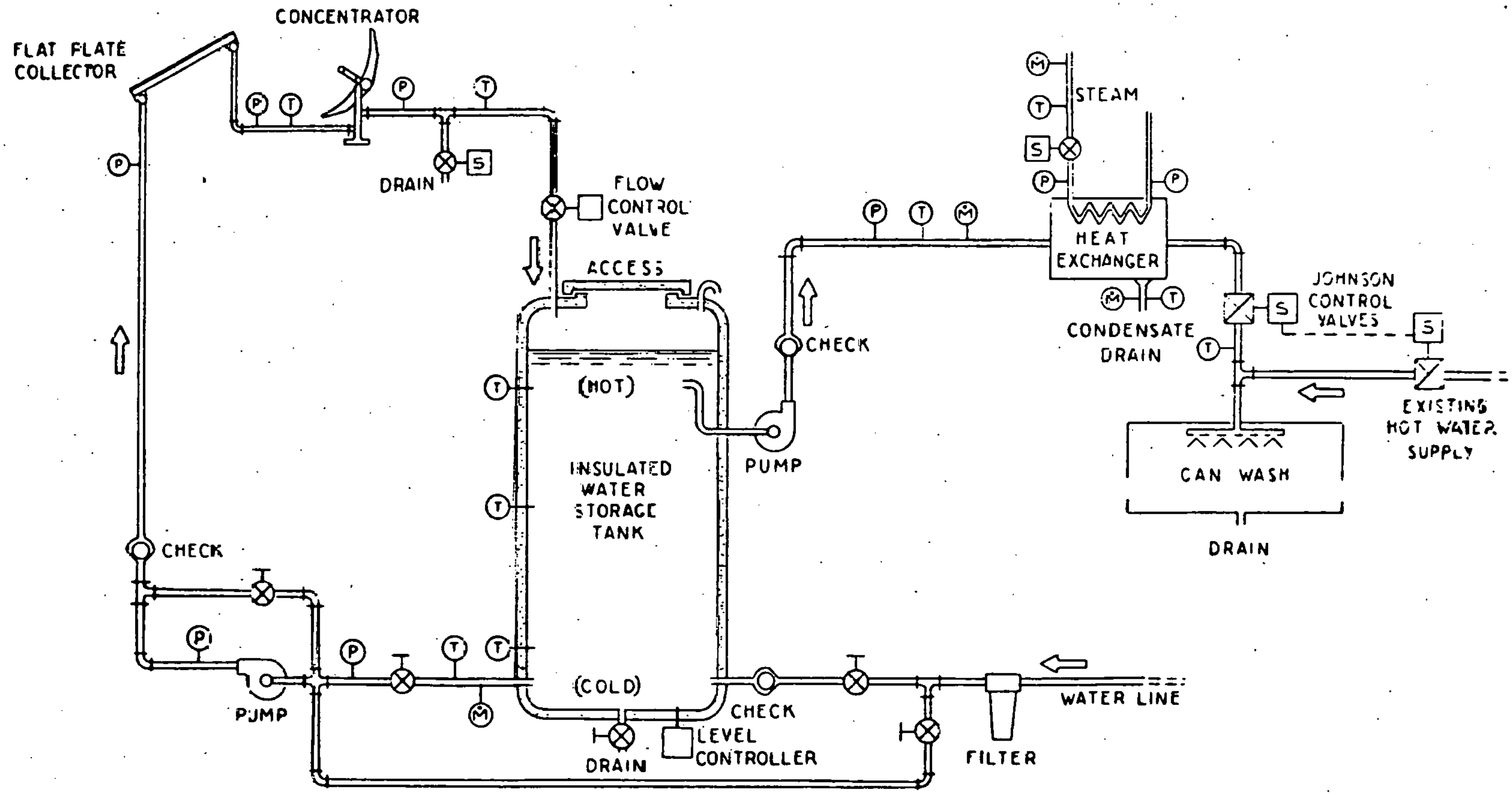

Figure 3. Preliminary solar process hot water system schematic.

2.2.2 Collector Field

This section describes the evaluations performed to establish the collector field location, size, and mix between concentrating and flat plate collectors. Once a matrix of collector field locations was established, both the shading from surrounding buildings and the mutual shading between collectors were evaluated to estimate associated collector field performance reductions. At a selected location, the collector field size and mix were evaluated to provide an economically optimized system.

Upon review of the Campbell Soup Sacramento facility, three potential locations for the collector field were identified (Figure 4). Area 1 is located on the roof of the finished product warehouse. The administration building and a portion of the labeling building compose area 2, and area 3 is a grass field.

The criteria for selecting the field location are:

- Minimal collector field shading by buildings
- Cost of installation
- Accessibility
- Campbell Corporate approval

Table 1 summarizes the advantages and disadvantages associated with each of the potential locations. Both locations 1 and 3 are free of shading problems due to buildings or other existing structures. A typical afternoon shading of area 2, as presented in Figure 5, reveals that collector output would be affected by the surrounding buildings.

The cost was estimated for installation of the collector field in each of the candidate locations. Location 1 resulted in the lowest cost alternative. This, along with the many other advantages, resulted in the selection of location 1. This selection has been approved by Campbell.

With area 1 selected, the various collector field installation possibilities were evaluated for mutual shading effects. A typical sun path diagram for each month of the year is presented in Figure 6. For the selected concentrator mounting configuration, the shaded areas represent times of the day in which mutual shading reduces the incident energy by either 0 to 50 percent or 50 to 100 percent. It is important to recognize that for this baseline orientation, mutual shading only occurs early in the morning or late in the afternoon. At these times, the useful energy loss is negligible. The effect of finite trough length (end loss) upon the incident collectable energy was incorporated into these evaluations.

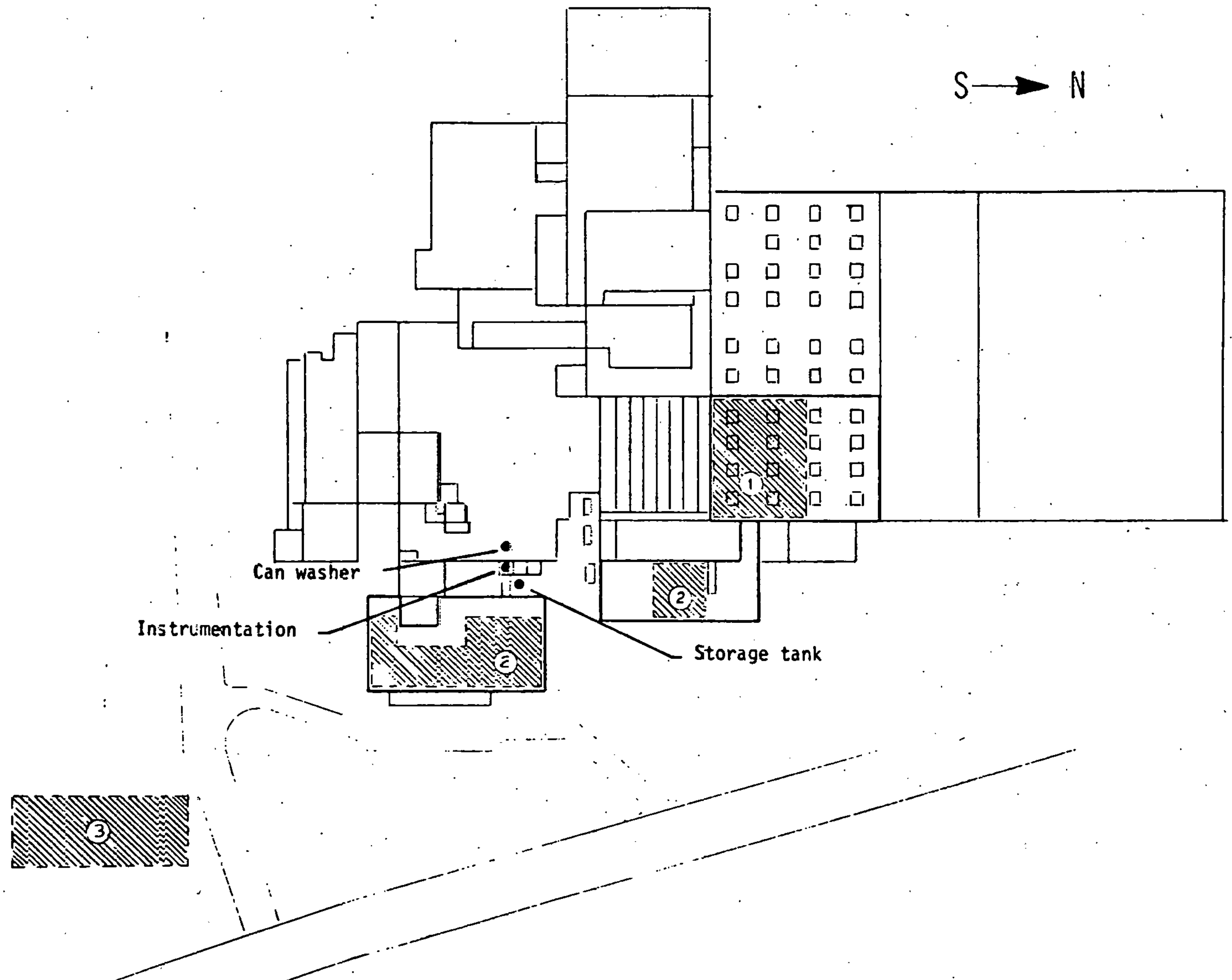

Figure 4. Candidate collector field locations at Campbell.

TABLE 1. COLLECTOR FIELD LOCATION ASSESSMENT

Location	Advantages	Disadvantages
1. Finished Products Warehouse	• Skylights provide some of required support structure • Expansion area available • Minimal building shading • Maintenance • Lowest installation cost	• Slightly longer pipe run than Location 2 • Roof leakage
2. Office and labeling buildings	• Shortest pipe run	• Building shading • Multiple roof locations are required • Roof leakage
3. Corner Lot	• No building shading problems • Ease of maintenance • Roof leakage is not a problem • Readily accessible for visitors	• Expensive & time consuming installation • Requires fence — vandalism • Dust from passing traffic • Future parking lot

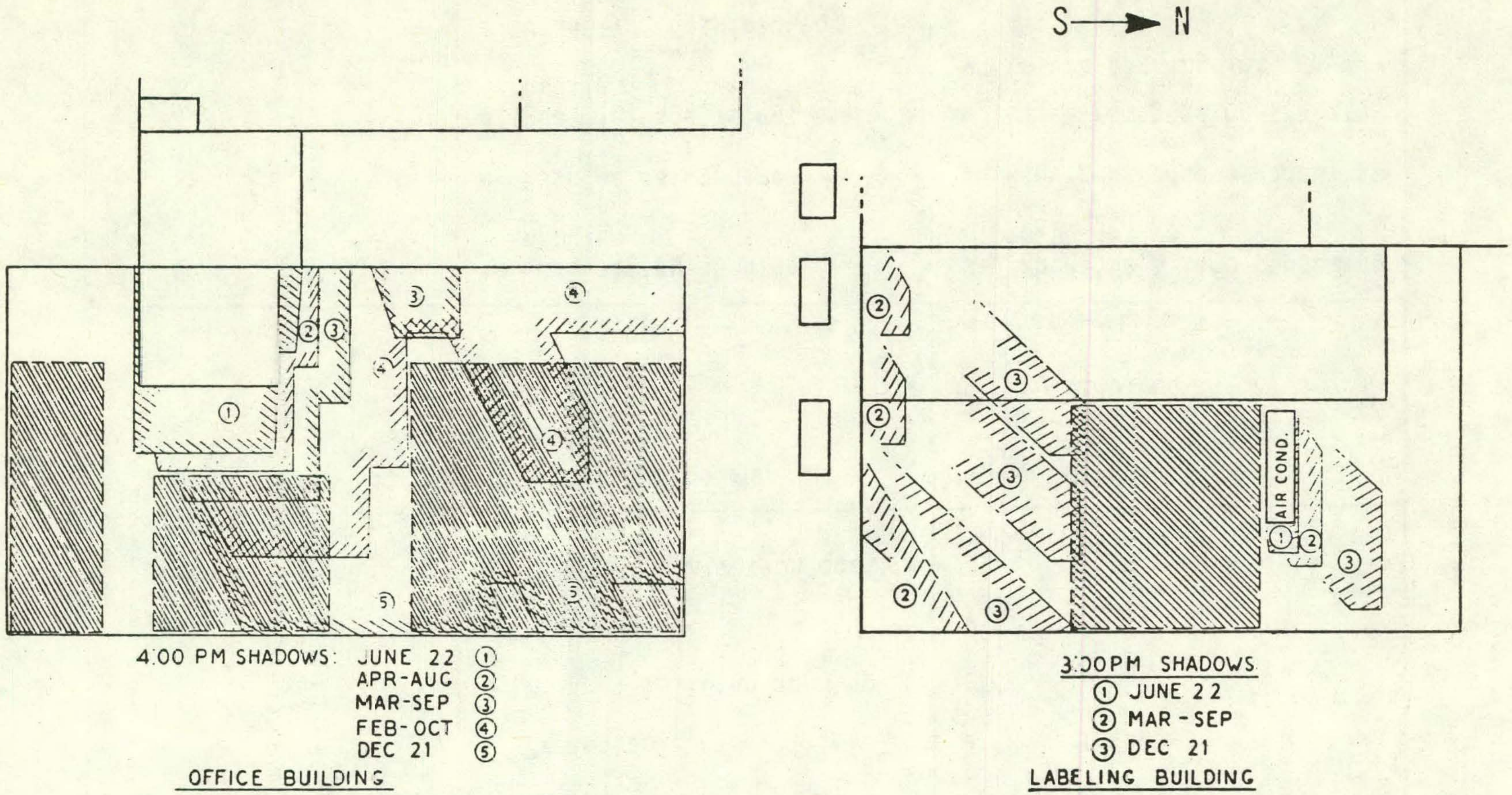

Figure 5. Location 2 afternoon shading.

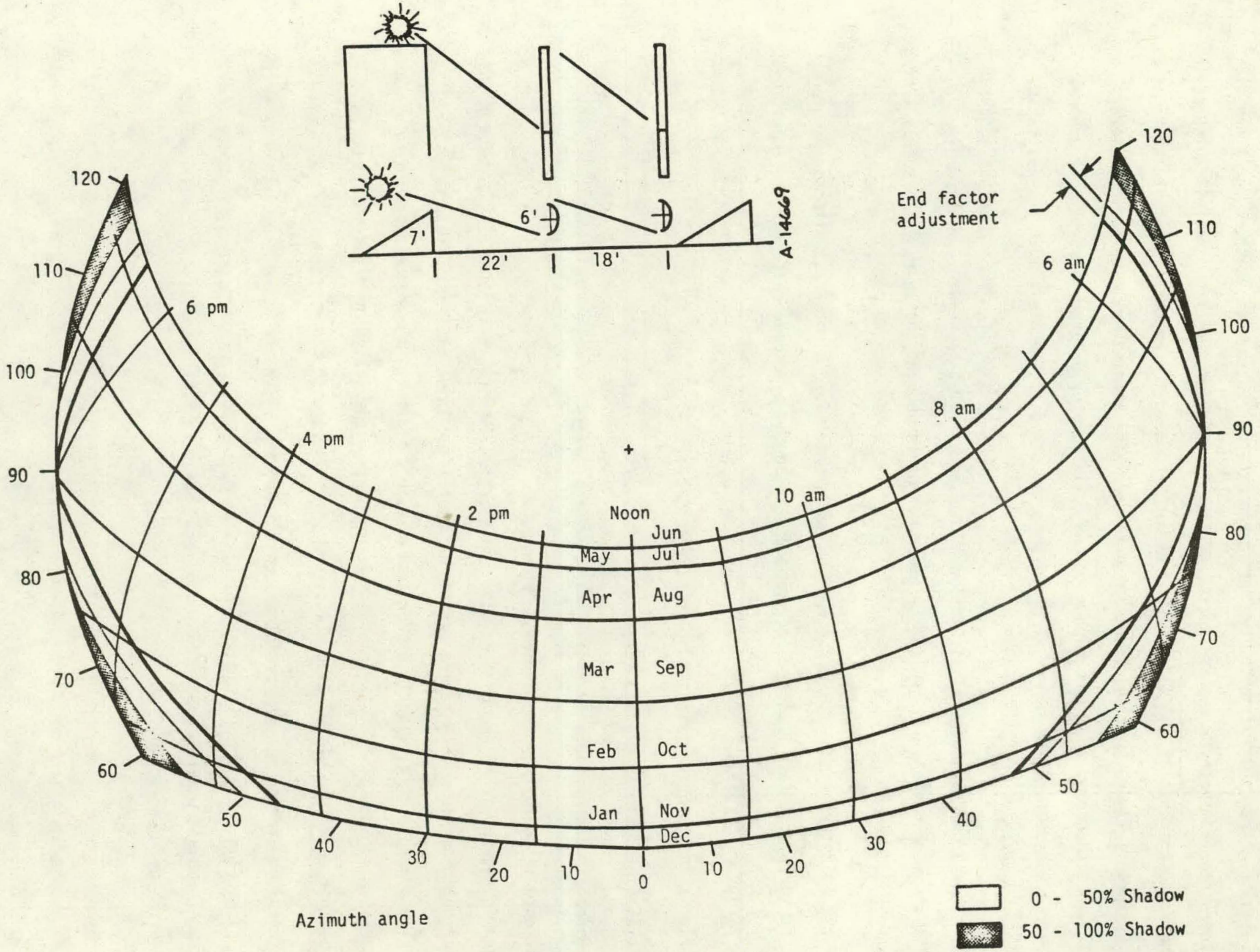

Figure 6. Relative collector shading.

The collector field analysis was performed to identify the field size and mix (concentrators and flat plates) required to provide the design performance for Sacramento weather conditions. Actual weather data from both Fresno and Davis, California were obtained from the National Oceanic and Atmospheric Administration (NOAA). These data were compared to the correlation procedure of Liu and Jordan (Reference 1) and good agreement was obtained. The statistical clearness parameters (Reference 2) were then used in conjunction with the collector performance to identify the hourly useful collected energy for selective flat plates, nonselective flat plates, and east-west axis tracking concentrating collectors.* This combination of statistical days was then averaged to obtain monthly average useful energy as a function of collector inlet temperature minus ambient temperature. This same procedure was applied to other months throughout the year, and a yearly average was obtained.

The cost effectiveness of collector options was evaluated. Seventy-one collector manufacturers were surveyed to obtain cost and performance data on the candidate collector configurations.

The average cost results were:

- Flat plate, single glazed, nonselective = >$10/ft^2
- Flat plate, single glazed, selected = >$12/ft^2
- Parabolic trough concentrating = >$12.50/ft^2

The June collectable energy for these various options was divided by their cost, and these results are presented in Figure 7. As one can see, the nonselective flat plate is more cost effective than the selective option up to a temperature difference (collector inlet-ambient) of approximately 19.5°C (67°F). However, at a slightly higher temperature difference, the concentrator displays an economic benefit over both of the flat plates. Consequently, the collector field should be composed of nonselective single glazed flat plates and parabolic trough concentrators.

From the June average monthly useful energy curves, the field was sized to satisfy the design constraints of Section 2.2.1 with various mixes of flat plates and concentrators. For these field mixes and sizes, ambient weather conditions and system operation characteristics, the annual useful energy collection was determined.

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*By using existing skylights (25° tilt angle, south facing) as a support structure for flat plates, the installation cost for the flat plate collectors could be reduced. Even though this tilt is not optimum, performance degradation is minimal.

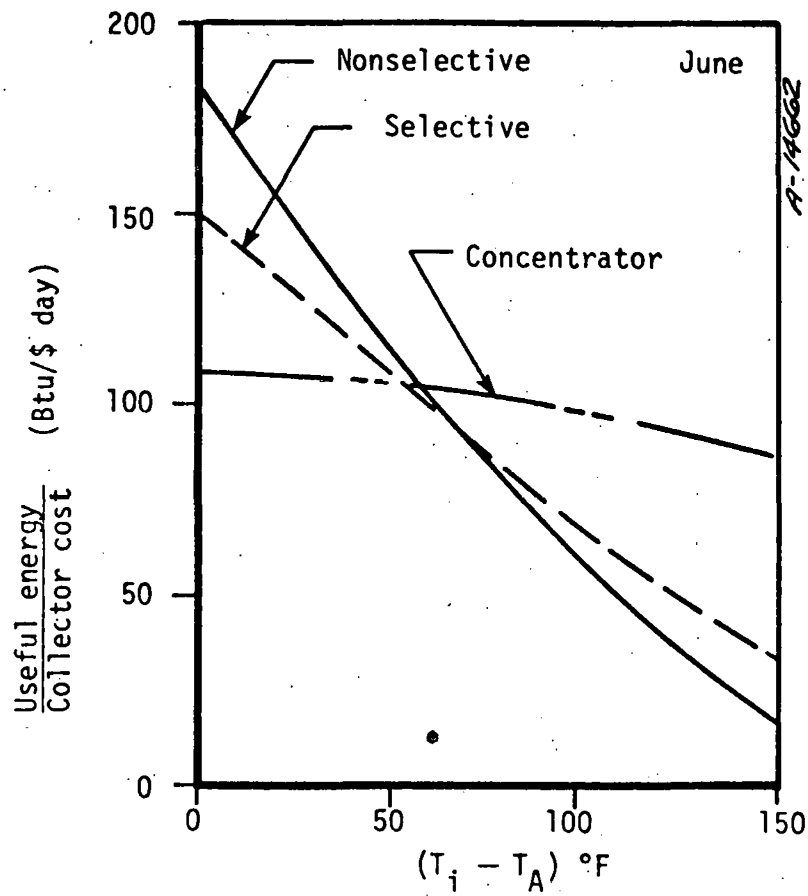

Figure 7. Economic comparison of flat plate and concentrating collectors for June.

Figure 8 displays these results as useful energy per unit cost as a function of collector field mix, A_c/A_T where A_c is the area of concentrators and A_T is the total field area. The optimum field size has been determined to occur at a mix of 40 percent concentrators and 60 percent single glazed nonselective flat plates. The total collector area required to supply the June design day is about 615 m^2 (6620 ft^2) based on the efficiency curves assumed for the study. It should be noted that as the ratio of concentrators to total field area varies, the total collection area required to supply a fixed amount of energy also varies. This is due to the efficiency differences between the flat plate and the concentrating collectors.

The TRNSYS computer code (Reference 3) was substantially modified to more appropriately simulate the process hot water system performance. System simulations were performed using the actual weather data for Fresno adjusted to reflect the Davis daily total radiation levels and ambient temperatures. These results substantiated the collector field size and mix identified in the above described analysis.

2.2.3 Storage

Two basic control modes were evaluated for the storage tank: stratified and accumulator. In the stratified control mode, fluid is removed from the bottom of the storage tank, circulated through the field, and returned to the top of the tank. The can washing hot water demand would be supplied from the top of the tank, and makeup well water would enter the bottom of the tank.

In the accumulator storage option, cold well water would enter the collector field directly, pass through the field once, and enter the top of the tank. A floating suction would remove water for the can washing operation from the top of the fluid. For 7 days a week energy collection, the accumulator volume required is 75,700 l (20,000 gal). Figure 9 presents a summary of the fluid volume in the tank throughout the week. For this control option, the flowrate through the field is a programmed function approximating the daily insolation profile. The integrated mass flux is equal to 5/7ths of the total weekly can washer demand; this allows collection on weekends. The profiled flowrate is selected to maintain the collector field outlet temperature at 195°F on a peak June day throughout the entire daily collection period.

Transient system simulations were performed for three stratified tank sizes and a 75,700 l (20,000 gal) accumulator tank to identify the tank/control mode which provides the most useful energy to the can washer. These results, presented in Figure 10, reveal that for a given field size and mix, the accumulator is optimum. In order to provide the same useful energy, the collector

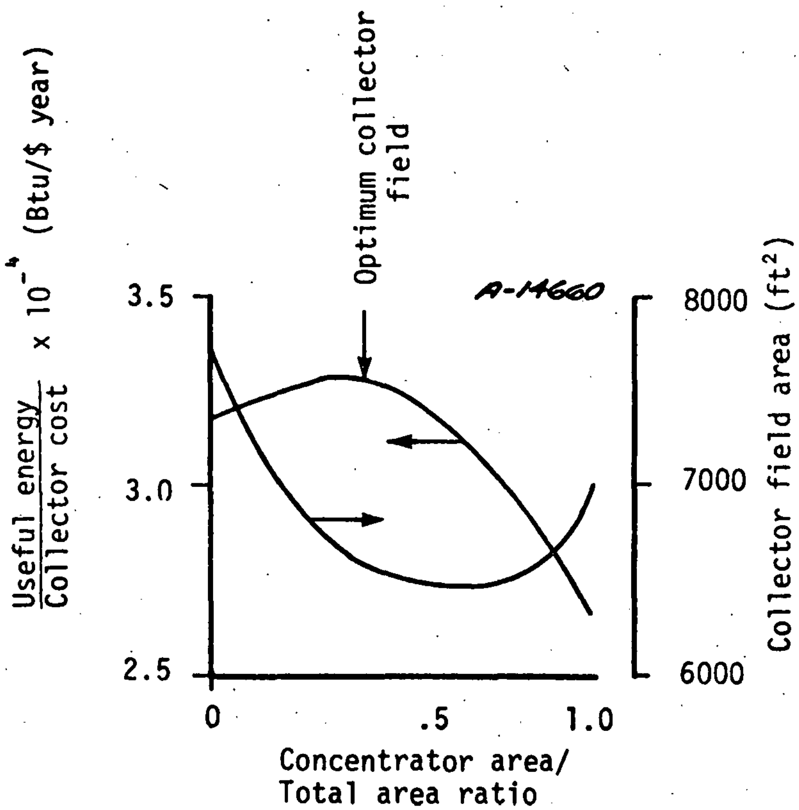

Figure 8. Economic optimization of collector field mix.

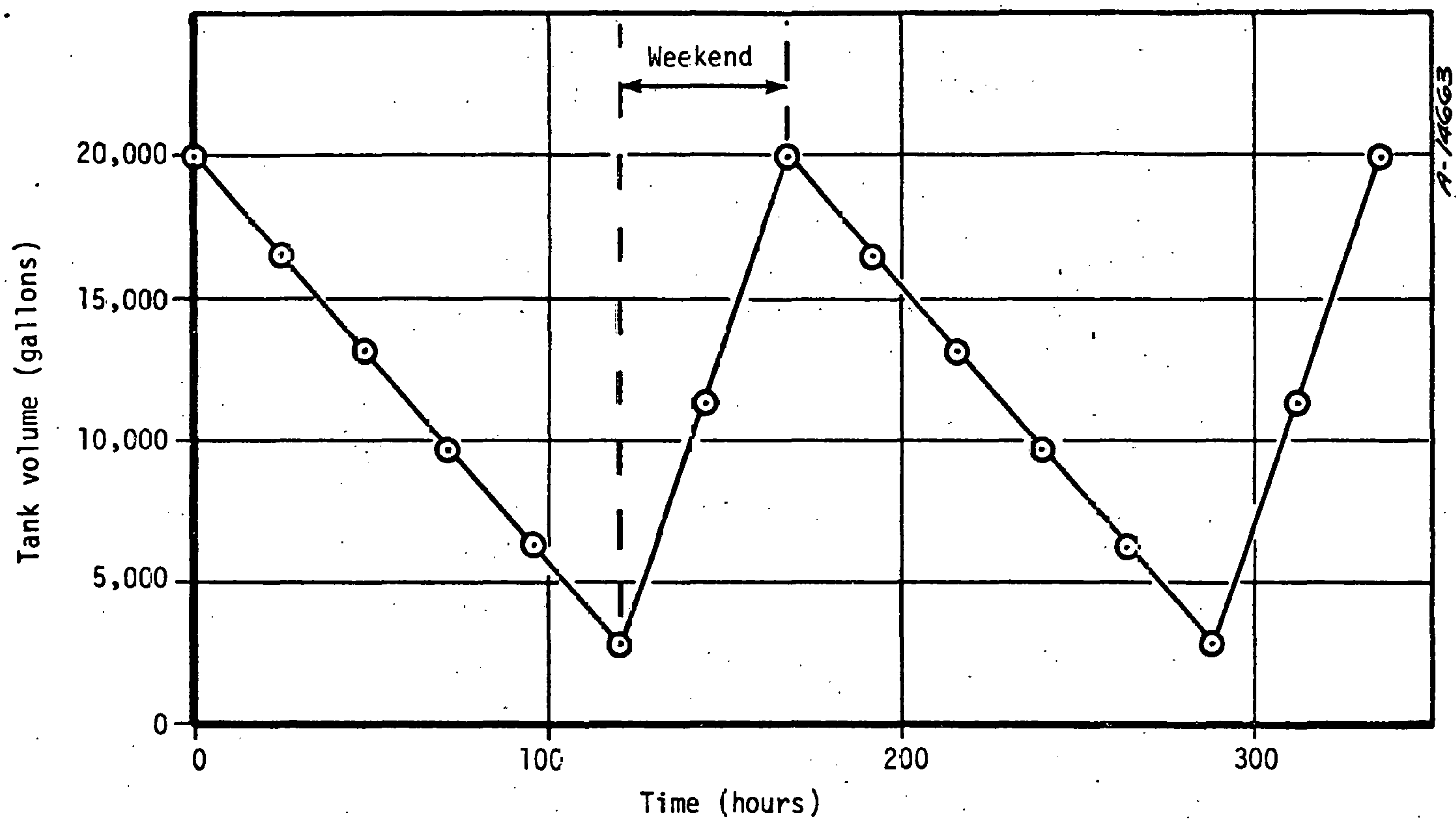

Figure 9. Accumulator tank volume history.

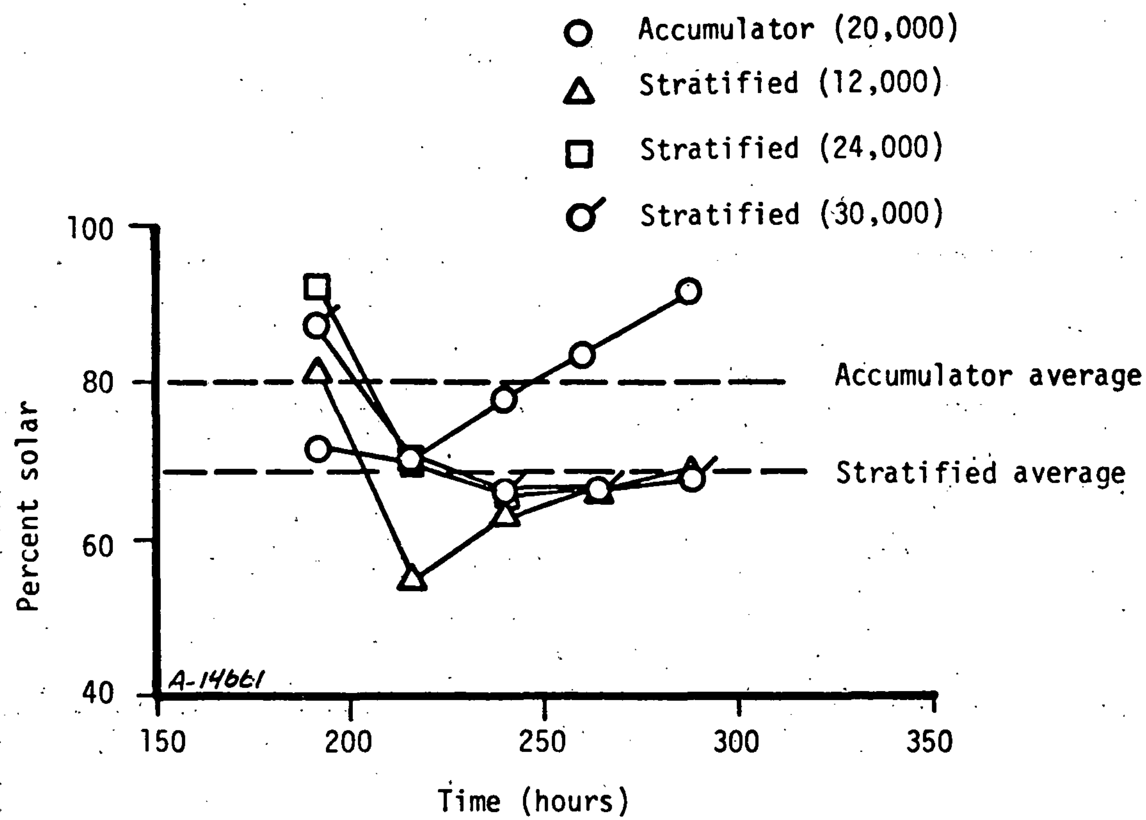

Figure 10. Effect of tank size and control mode on solar contribution.

field and tank costs for the stratified system were determined to exceed the accumulated options costs. Thus, a 75,700 l (20,000 gal) accumulator storage tank was selected.

The location for the storage tank was selected near the can washing line where it will be readily accessible for maintenance and installation. The distance from the tank to the can washer is minimized so that the water temperature and pressure drops are minimal.

2.2.4 Control Philosophy

In this section, a description of the system control philosophy will be presented. The accumulator control option was selected based upon the results of collector field and storage tank optimizations. Since the can washing line only operates 5 days a week and useful energy will usually be collected for all 7 days, a storage tank will be used. The tank will be virtually empty after Friday's second shift and will be filled with hot water by Sunday evening.

The flowrate through the collector field will vary throughout the day. A programmable controller will adjust the flowrate in a predetermined manner to approximate the incident energy. The total integrated daily mass flow will be equal to 5/7ths of the weekly washer demand. This program will be changed monthly to account for changes in the length of the day.

2.2.5 Annual System Performance

A transient computer simulation of the entire solar process hot water system was made. A modified version of TRNSYS (Reference 3) was used in this analysis. This analysis used actual weather data from NOAA for Fresno, California adjusted for differences in daily total radiation between Fresno and Davis, California.* Since neither Fresno nor Davis record the beam radiation, the methods of Liu and Jordan (Reference 2) were used to estimate the beam component from the total radiation data. The month-by-month solar contribution to the can washer is displayed in Figure 11. These results indicate that approximately a 70-percent solar substitution will result from the baseline system design.

*Davis, California is approximately 15 miles from Sacramento, California.

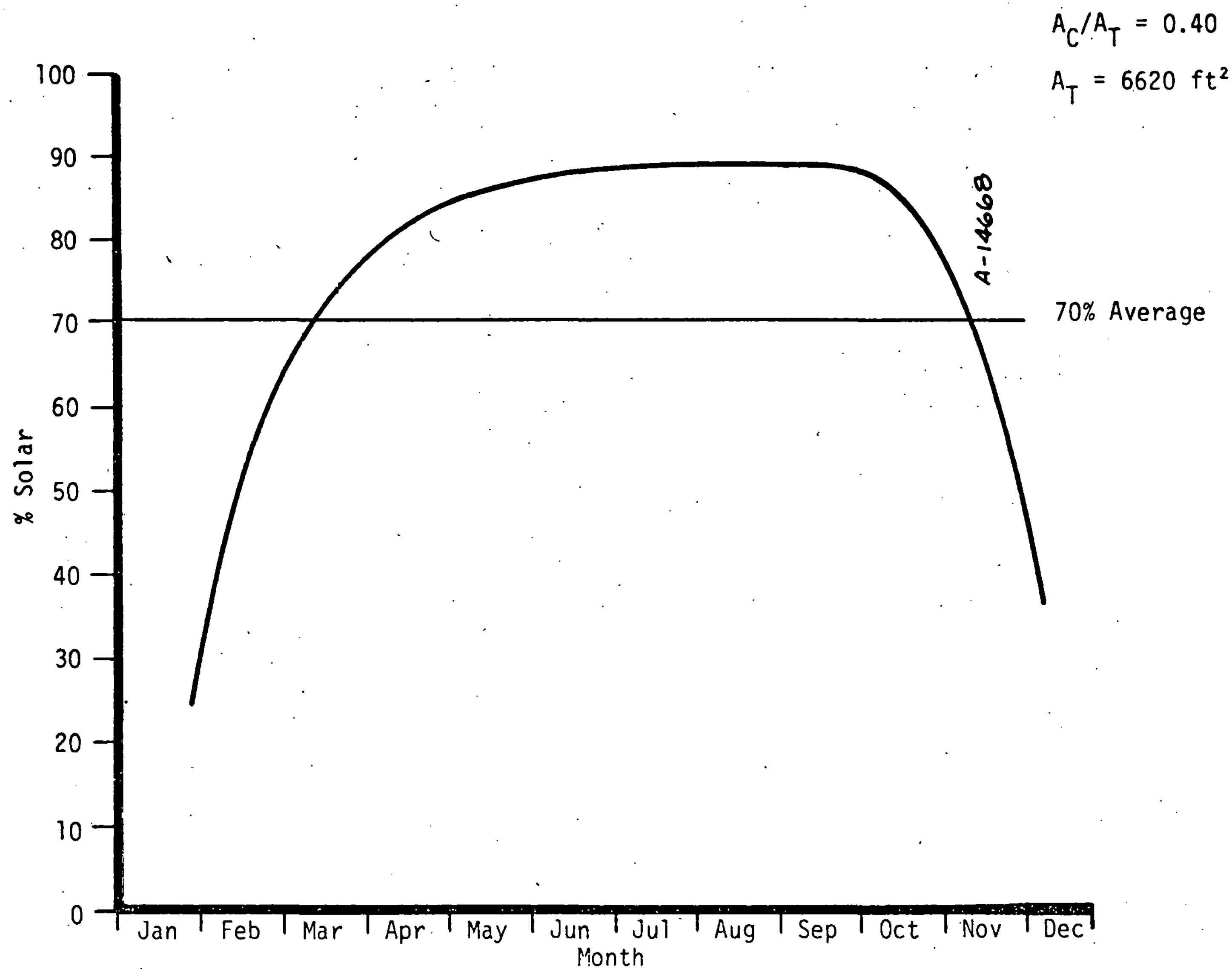

Figure 11. Transient system performance simulation.

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SECTION 3

DETAIL DESIGN

The collector field design relies heavily upon the design values and concepts generated in the conceptual design phase of this project. The design values generated in that study were based on the following heating requirements for a single can washing line:

Heated water flow rate: .79 ℓ/sec (12.5 gpm)

Required water temperature rise: 51.7°C (125°F)

Hours of continuous water supply per day: 16 hours (2 shifts)

The resulting daily requirements derived from these values were:

Total water supplied to canning line per day: 45,420 l (12,000 gal)

Total heat required to raise water from 21.1 to 90.5°C (70°F to 195°F): 1.319×10^{10} J/day (12.5×10^6 Btu/day)

Based on these requirements, a collector field was designed in the conceptual design phase of this project which had the following description:

1. Field placement: On building W-8 roof as pictured in Figure 1 of Appendix A-2
2. Type of collectors utilized:
   a. Flat Plate collectors: Single glazed, nonselective coating
   b. Concentrating collectors: Parabolic trough, east-west axis, tracking
3. Water flow path: From cold water supply through flat plate collectors, into concentrators, and finally to storage tank
4. Total effective area of field: 615 m^2 (6620 ft^2)
5. Field mix: 40 percent concentrators, 60 percent flat plate collectors
6. Collector field flowrate: Preprogrammed to match flowrate to hourly insolation

The field design requirements and basic design decisions have been reviewed during the detailed phase. Of the six conceptual design characteristics listed above, field placement (Item 1) and water flow path (Item 3) were not reconsidered during the present phase. The field placement was previously studied with respect to building shadows at various roof locations, potential for field expansion, and (as in the case of a potential ground location) the appropriate usage of open land. The conclusions of that study (Section 2) have not been altered. Both accumulator storage tank and recirculating storage tank options were evaluated in the conceptual design. This study used the TRNSYS computer simulation program. As a result of that study, the accumulator storage was incorporated into the detail design. Reference is again made to Section 2 for description of the storage tradeoff study.

3.1 COLLECTOR FIELD

The choice of collector types, field size, collector mix ratio, and field layout has been reviewed in light of the bid responses of the various collector manufacturers. The bid responses will be discussed at this point and a discussion of the final design decisions will follow.

Bids for the solar collectors were solicited from 22 manufacturers. The bid list, along with bid responses and initial screening information, are contained in Table 2. Of the 22 quotation requests, 13 flat plate collector manufacturers responded, and only Aerotherm submitted a concentrator bid. Of the respondents, 4 were eliminated immediately for being unable to provide adequate information in response to the RFP or for having an excessive collector cost.

The secondary selection procedure involved a preliminary sizing of the flat plate portion of the field. The sizing groundrule was to provide the same amount of energy as the flat plate field resulting from the conceptual design (for a typical June day). This preliminary sizing method made use of the monthly-averaged daily insolation and monthly-averaged clearness factor (K_T) values to generate hourly insolation values on a flat plate according to the procedure outlined on pages C-2 to C-7 of Reference 4 and demonstrated in Table 3. This is a conservative method, but it yields acceptable values for a relative collector comparison. By this method, 3 more collectors were rejected because the field size required was considerably greater than the available area. The SunSav collector was rejected due to its high field cost. The KTA collector is not a true flat plate collector; it relies on sunlight concentration. Consequently, it does not collect a significant amount of diffuse radiation in winter months. The KTA collector was rejected at this point due to intolerably low winter efficiency.

With the collector field sized as described above, the relative flat plate collector field costs were computed. Table 4 displays these results. Also, the efficiencies of these collectors are plotted in Figure 12. The field cost reflects the relative efficiency differences between

TABLE 2. SUMMARY OF COLLECTOR BIDDERS

Company Receiving Bid Package	Responding Companies	Initial Selection Process: Reason for Rejection	Second Selection Process Reason for Rejection
• Steelcraft Corp., Environmental Designs Division			
• Hexcel Corp. (concentrator)			
• KTA Corp.	X		Does not collect diffuse radiation. Winter efficiency too low.
• Northrup, Inc. (concentrator)			
• Owens-Illinois	X	Too expensive: Cost = $22.60/ft^2$	
• Sheldahl Advanced Products Division (concentrator)			
• Honeywell	X		Collector too small. Inefficient use of area and large installation cost. Size: 3' x 6'
• Alcoa			
• Allied Equipment Co.	X		
• American Heliotherm	X		
• Ametek			
• Sunearth, Inc.			
• Heliotherm, Inc.	X	Non-responsive. Acceptable data not provided.	
• PPG	X	Non-responsive. Acceptable data not provided.	
• Reserve Copper and Brass, Inc.			
• Solar Development, Inc.	X		Extremely poor efficiency: $F_{t_{stagnation}} = .26$
• Solargenics, Inc.	X		
• Solar Corp. of America	X		
• Sunsave, Inc.	X		High field cost due to low effective area: $\frac{\text{net area}}{\text{grass area}} = .77$
• Sunwater Co.			
• Sunworks	X		Collector too small. Inefficient use of area and large installation cost. Size: 3' x 7'
• Raypak, Inc.	X	Non-responsive. Acceptable data not provided.	

TABLE 3. DEMONSTRATION OF COLLECTOR SIZING PROCEDURE UTILIZING MONTHLY-AVERAGED DAILY INSOLATION VALUES[a]

Hours from Solar Noon	Insolation Values for Flat Plate, q_i w/m² (Btu/hr-ft²)	$F_t = (\overline{T}_p - T_a{}^b)/q$, (°F-hr-ft²)/Btu	Collector Efficiency, η^c	Collected Heat
0.5	990 (313)	0.0936	0.671	660 (210.2)
1.5	900 (286)	0.102	0.662	600 (189.4)
2.5	780 (246)	0.119	0.642	495 (158.0)
3.5	595 (189)	0.155	0.60	355 (113.1)
4.5	380 (121)	0.242	0.498	190 (60.4)
5.5	175 (55.6)	0.528	0.162	28 (8.9)
6.5	30 (9.5)	3.08	0	0 (0)
		Daily total = 4650 w/m² day (1480.2 Btu/ft²day)		

[a]For June, collector inclination angle toward south: 28.5°

[b]T_a = 75.7°F, $\overline{T}_p$ = average of projected inlet and outlet temperatures:
T_i = 70°, T_o = 140°, $\overline{T}_p$ = 105°

[c]For Allied Equipment Co. collector

Flat plate heat required per day: $\frac{140° - 70°}{195° - 70°} \times 12.5 \times 10^6$ Btu/day $\times \frac{5}{7}$

$= 5 \times 10^6$ Btu/day

Flat plate net area required: $\frac{5 \times 10^6 \text{ Btu/day}}{1480.2 \text{ Btu/ft}^2\text{day}} = 3377 \text{ ft}^2$

Number of units required: $\frac{3377 \text{ ft}^2}{61.57 \text{ ft}^2\text{/unit}} = 66$ units

Gross area required: 66 units x 60.06 $\frac{\text{ft}^2}{\text{unit}}$ = 3964 ft² gross

Field cost: 3964 ft² x \$10.75/ft² = \$42,613

TABLE 4. FINAL SELECTION COLLECTOR DESCRIPTION

Collector Manufacturer	Collector Dimensions	Effective Area / Gross Area	Collector Weight kg/m² (#/ft²)	Absorber Coating	Collector Cost $/m² effective area ($/ft² effective area)	Total Field Cost For Projection, $
Allied Equipment Co.	0.91m x 5.94m (3' x 19.5')	0.86	49 (10.0)	Nonselective	134.76 (12.52)	42613
American Heliothermal Corp.	1.07m x 2.44m (3.5' x 8.0') 1.07m x 3.05m (3.5' x 10.0')	0.87	41 (8.4)	Selective	136.57 (12.13)	39644
Solar Corp. of America	1.22m x 2.49m (4' x 8')	0.93	36 (7.4)	Nonselective	130.35 (12.13)	42444
				Selective	137.13 (12.74)	39544
Solargenics, Inc.	0.91m x 3.05m (3' x 10') 0.91m x 5.03m (3' x 16.5')	0.88	28 (5.7)	Nonselective	119.64 (11.12)	40366
				Selective	136.59 (12.69)	41000

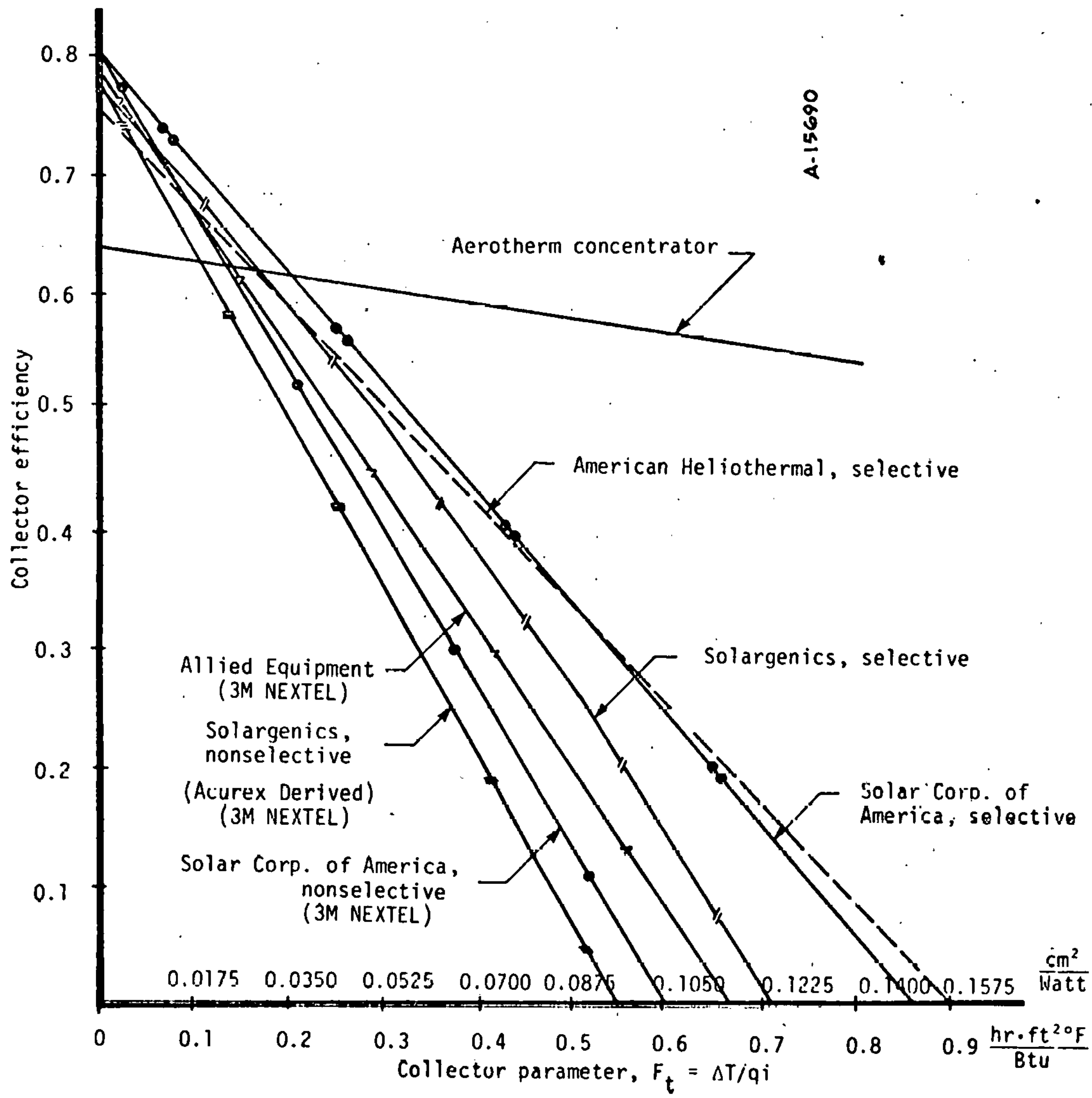

Figure 12. Collector efficiencies.

collectors, installation costs, and the basic collector cost. Based upon these results, the Solargenics nonselective collector results in the lowest field cost.

The Solargenics nonselective collector has been selected as the best collector for the following reasons:

1. Absorber coating: Selective coatings require special treatment in handling, are subject to deterioration in the presence of inevitable moisture, and may not be easily recoated on large surfaces. Given these considerations and the fact that all of the final collector candidates were very close to each other in total field cost, a nonselective collector coating was chosen.

2. Collector size: Solargenics, Inc., is capable of manufacturing collectors to any length required. Because of this, they can provide collectors which span the entire length of the 5.03 m (16.5 foot) skylight faces. This feature will greatly reduce installation time and will permit easy access to both ends of each collector, will reduce piping complexity, and will simplify structural modifications to the roof for collector support purposes.

3. Field cost: Of the three nonselective collectors in the final selection, the Solargenics collector has the lowest field cost.

4. Potential efficiency improvement: Solargenics, Inc., has guaranteed a collector efficiency significantly higher than the curve (shown in Figure 12) from which present field size requirements have been estimated.

The choice of a nonselective flat plate collector is consistent with the original projection* that a nonselective collector whould be optimum for the present application.

Since the Solargencies area requirement was reasonably close to the area used in the conceptual design, the roof areas utilized remain unchanged from the conceptual design (Figure 1 of Appendix A-2).

*This projection was made by comparing the efficiencies and costs of known collectors (not necessarily those collectors for which bids were submitted) and by considering the desirability of avoiding the maintenance and longevity problems associated with selective coatings.

3.1.1 Flat Plate Collectors

The following list describes the design features of the Solargenics collector:

- Absorber plate — Copper tubes sandwiched between two formed aluminum plates. 10 tubes, 1.27 cm (0.5 inch) internal diameter
- Header — 2.54 cm (1.0 inch) ID, copper tube
- Frame and back plate — Aluminum extrusion and plate
- Glazing — Low iron tempered glass 0.3715 cm (0.125 inch) thick. Installed at factory.
- Bottom insulation — 2.54 cm (1.0 inch) fiberglass insulation plus 3.175 cm (1.25 inch) isocyanrate foam
- Absorber coating — 3M brand Nextel black velvet coating
- Fluid entrance/exit — Located at ends and staggered to facilitate short intercollector connections 1.91 cm (3/4 inch) MIP

The flowrate in the collectors will be as high as possible within the limits of pressure drop and cavitation. High flow velocities are important to both reduce scale formation and increase the tube-to-fluid thermal conductance. The latter increases the collector efficiency slightly. Flow distribution and piping will be discussed in Section 3.1.3.

The Solargenics collector, which normally has a selective coating, has not been tested with a flat black coating. The curve drawing in Figure 12 represents the efficiency projected by Aerotherm of its performance with the Nextel coating. The manufacturer, however, guarantees better performance. Before any contract with Solargenics is finalized, efficiency data will be obtained.

3.1.2 Concentrating Collectors

The Aerotherm concentrator is pictured in Figures 13, 14, and 15 and detailed in the technical drawing section of this report. The concentrator utilizes aluminum lighting sheet to concentrate beam radiation on the receiver tube. The efficiencies are much higher than for flat plate collectors in the range of F_t >0.2.

The collector tube assembly consists of a main receiver tube through which water passes. The solar energy is concentrated on this tube wall. The outside wall itself is selectively coated with black chrome over nickel plate. A tubular pyrex glazing is used to reduce convective heat losses. The receiver tube contains an internal plug. The annular flow passage which results raises the fluid velocity, thereby increasing the internal heat transfer coefficient. The receiver tube is made

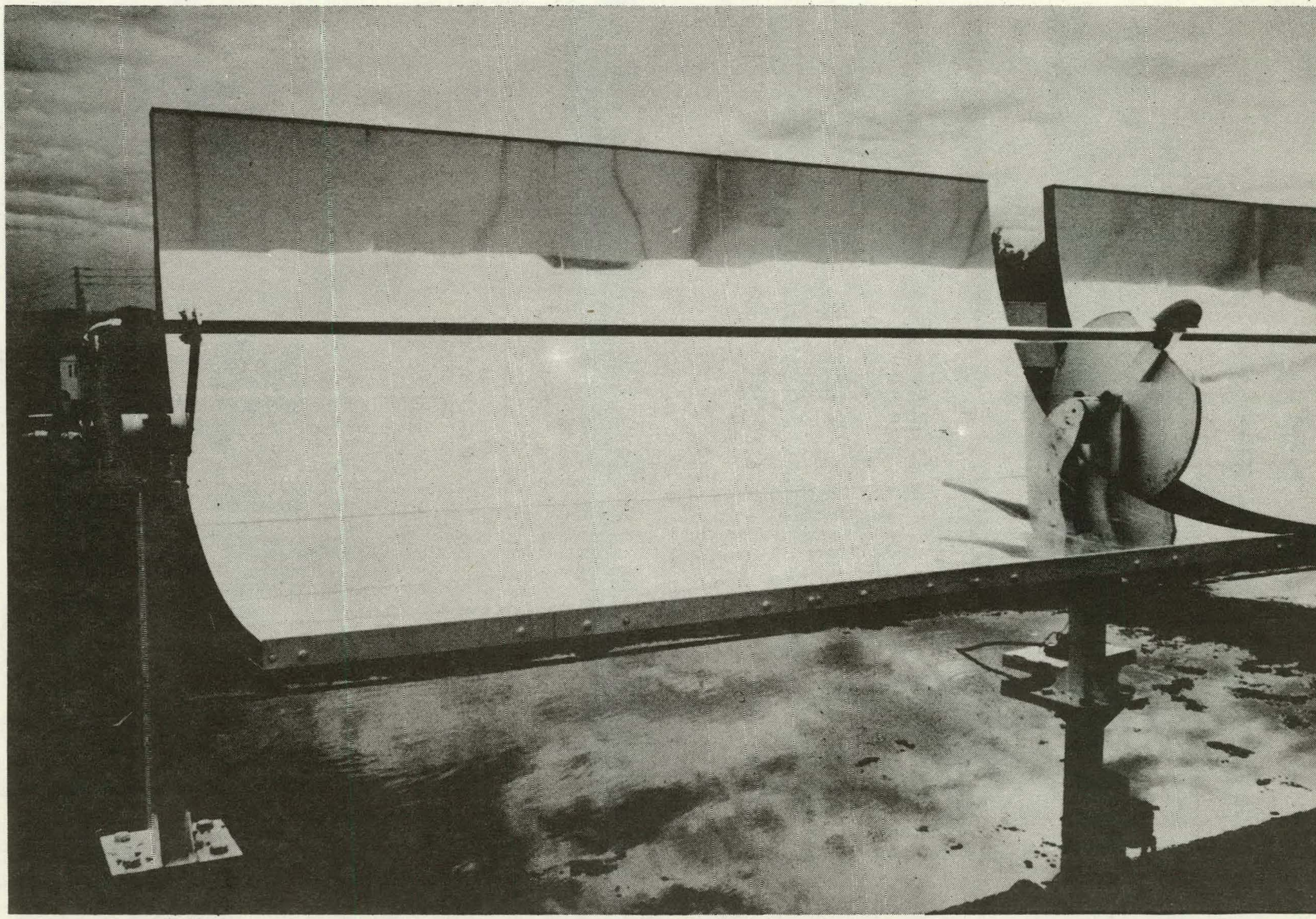

Figure 13.
Solar concentrator, drive gear and sun sensor.

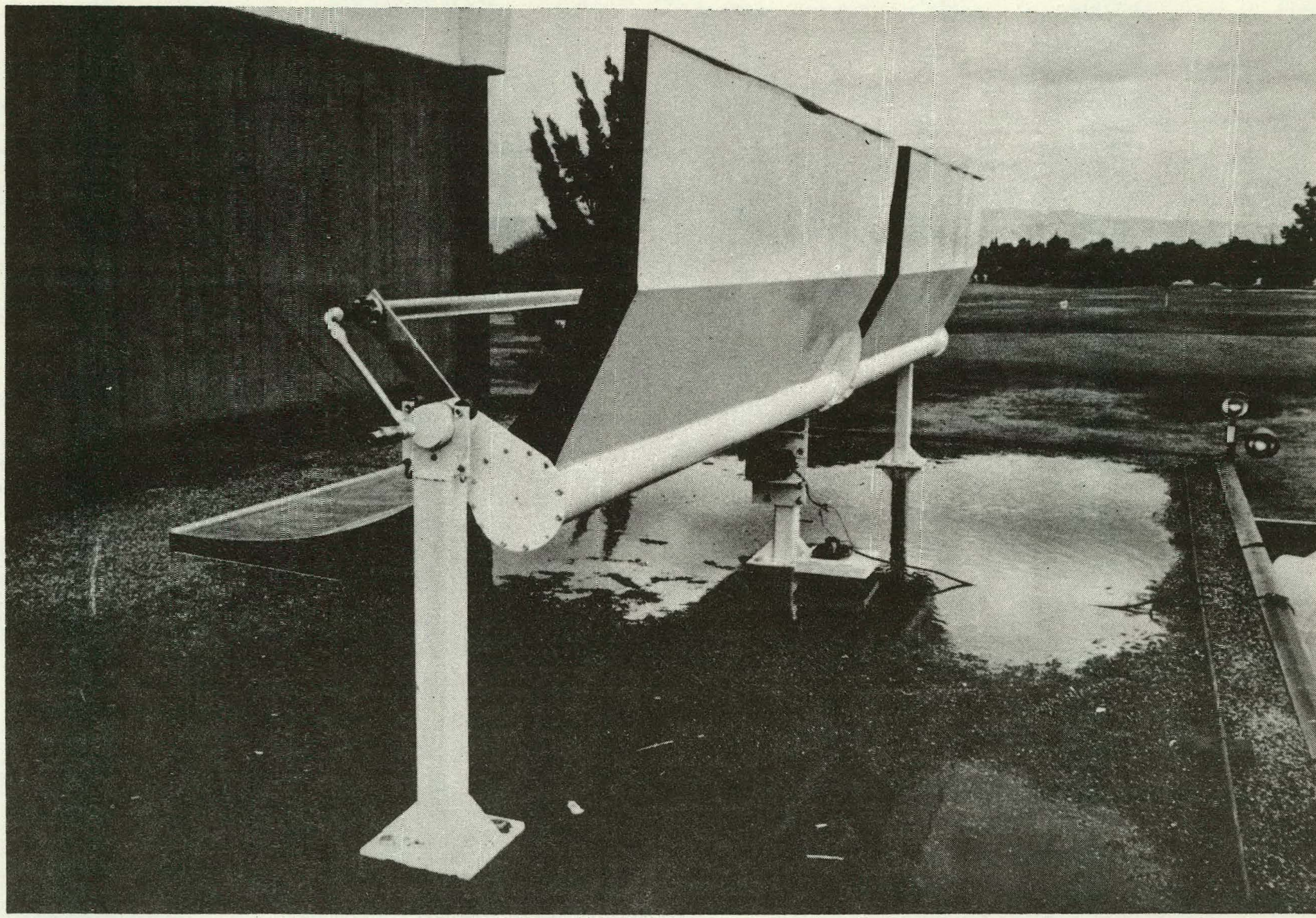

Figure 14.
Solar concentrator, rear view.

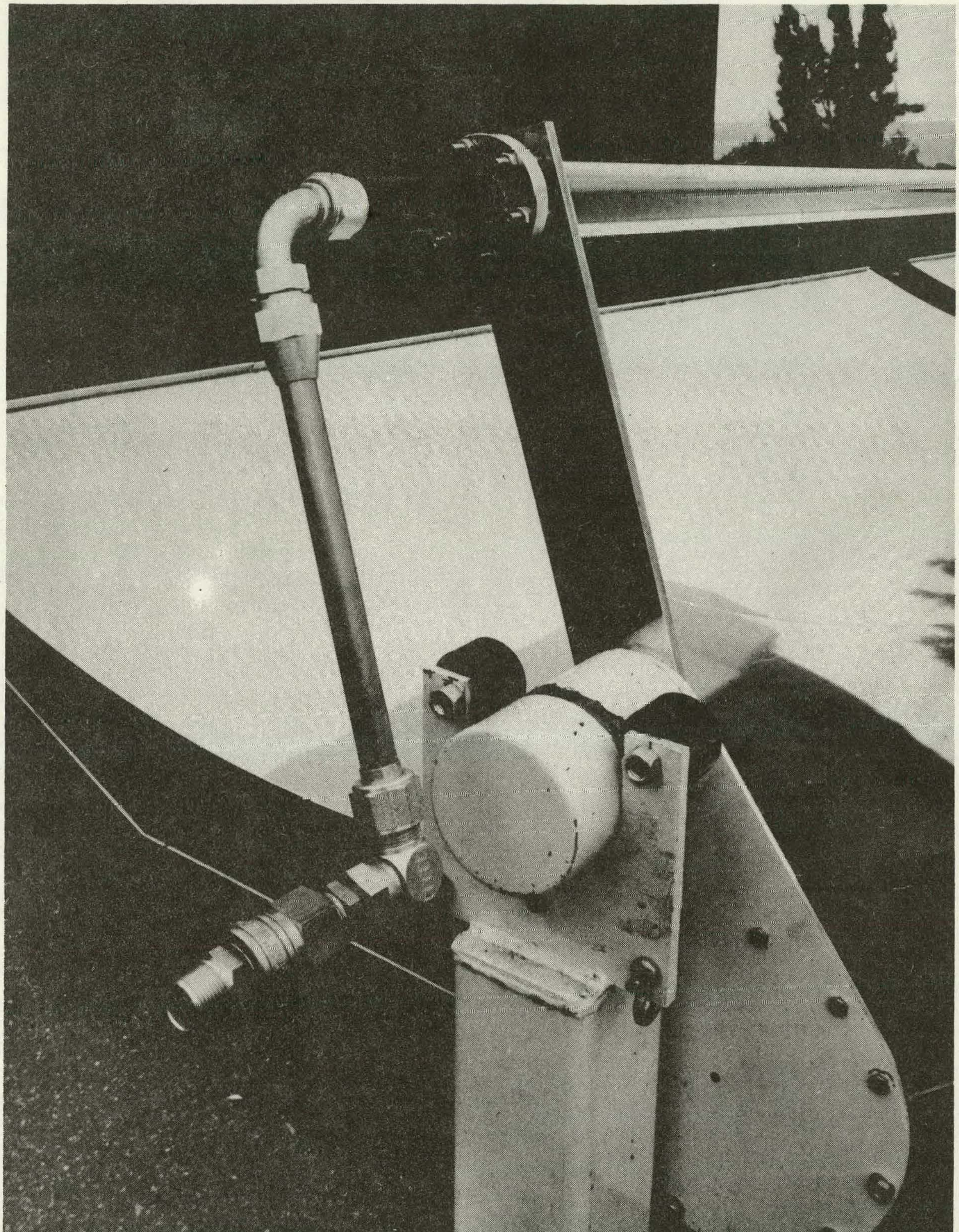

Figure 15.
Solar concentrator, end termination.

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continuous from collector module to collector module by weld connections, while the plug is inserted in sections.

Concentrator steering is accomplished with a worm driven gear pictured in Figure 13. The worm is driven by a permanent-split capacitor motor with a total gear reduction ratio of 1900-to-1. One steering unit is used to steer eight collector modules and is located in the center of a collector row.

The steering signal is obtained by a shadow band sun direction sensor pictured in Figure 13 and diagrammed in Figure 16. The diagrammed sensor shows a shadow over half of the near side photocell. When enough sun illuminates the photocell, a small voltage is generated and amplified to trigger a triac. The triac is an A.C. solid state switch for the worm gear motor. The motor will turn in the appropriate direction until both photocells are again shaded. Tracking error is less than 0.1°.

It is necessary in some control modes to steer the concentrator away from the sun (as in a pump failure). In this case, an alternate pair of photocells is used in addition to the diagrammed pair. This second pair is switched into the positioning circuit to steer the concentrator several degrees away from the sun. The unit can also be stowed by activating a triac directly. When the collection must be stowed, a triac is actuated. The collector is turned in one direction until a limit switch is activated.

The following is a technical description of the concentrator:

Aperture:	1.8 m (6.0 ft)
Length:	3.05 m (10.0 ft)
Length between supports:	3.2 m (10.5 ft)
Concentration ratio:	35
Rim angle:	90°
Efficiency: (plotted in Figure 12)	
Receiver tube diameter:	3.175 cm (1.25 inch)
Receiver tube emittance:	0.12
Receiver tube absorbance:	0.94
Transmittance of pyrex glazing:	0.90
Reflectance of aluminum lighting sheet:	0.75
Slew rate:	180° in 15 minutes
Weight (not including mount supports):	540 kg (244 lbs)

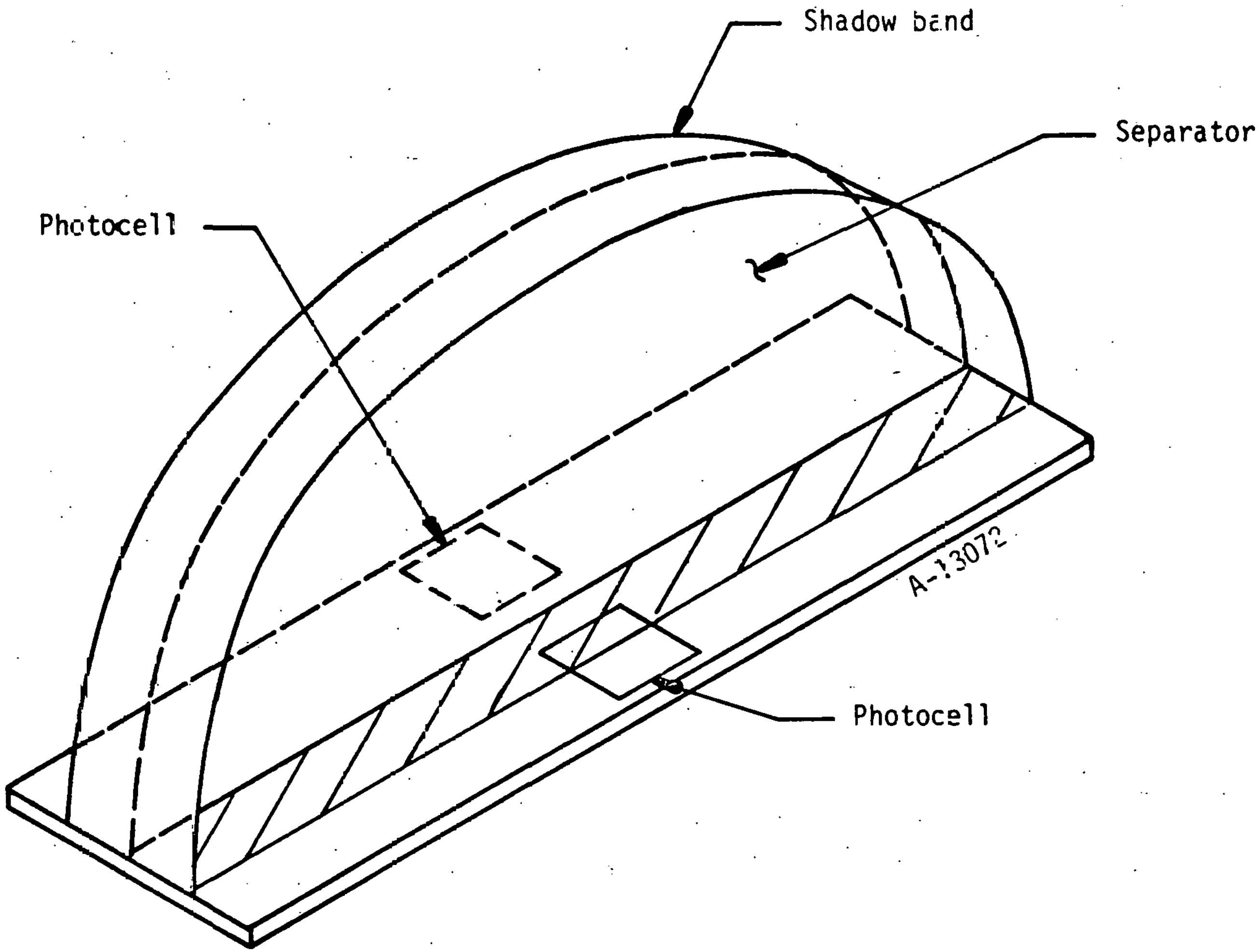


Figure 16. Sun sensor.

3.1.3 Piping Design

The process piping for the collector field connects to the existing water supply in the finished products warehouse, Building W8. From here the pipe is routed through the roof hatch directly above the connection point and into the collector field. The exact routing of the pipe, manifolding, valving, etc., is shown on Drawing 7234-030 Sheet 2 (see Attachment 2).

The material for the pipe and insulation for the hot water lines were specified in Campbell Soup specifications. The pipe sizes were selected after an engineering analysis of the flat plate collectors and concentrating collector flow distribution was completed. Design parameters considered included:

- Total pressure drop across the field
- Flow distribution in both types of collectors
- Minimum line size
- Scaling

The piping was designed for a maximum flow rate of 1.77 l/sec (28 gpm). At the flow rate the pressure drop across the field will be 28.3 kg/cm^2 (40 psi). The flat plate collectors will be divided into four arrays each containing 29 units. As a result, the flow rate, per collector will be 53 l/sec (8.5 gpm) for the long collectors and 359/sec (5.5 gpm) for the short collectors. This array size was selected in order to obtain the proper pressure drop ratio between the collector and the manifolds to ensure natural balanced flow and to keep the water velocity in the risers within acceptable limits for efficient heat transfer. The maximum velocity in the risers will be 0.4 m/sec (1.3 ft/sec) which is well below the recommended maximum flow rate for copper tubing.

The field contains six concentrating collector arrays. The maximum flow rate per array is 0.30 l/sec (4.7 gpm). The input and output line for each concentrating collector array is designed to handle this flow rate.

For the flat plates the collector-to-collector connections will be made with flexible spiral-wound bronze alloy tubes. Typical of domestic hot water heater connectors, these flexible lengths have union type terminations, allowing rapid connections to be made. Flexible connections have been used to eliminate the effect of differential thermal growth that occurs when the collectors are heated. Metal is used here as opposed to rubber due to the short life of rubber hosing (approximately 10 years) under exposure to sun, ozone, and other atmospheric pollutants. The metal hoses will be insulated. Expansion joints will be provided in all the pipe lines by the contractor in accordance with Campbell's specification.

Air vents are normally required in solar collection piping systems. However, because each Solargenics collector contains an automatic air vent valve, separate vents will not be required in the piping system. The Bell and Gossett CB series valves were selected because they have convenient taps for measuring instantaneous flow in addition to the normal valve function. This feature will save a considerable amount of time during field startup flow balancing as well as during field operation.

The potential scaling effects of water at the Campbell plant on the solar water heating system was evaluated using the Langelier Saturation Index. This index is a common tool used by industry to evaluate the tendencies toward scaling or corrosion for water systems. The method compares the concentration of calcium carbonate to the saturation concentration of calcium carbonate for specific water chemistry. The parameters which must be taken into account are listed below along with the water analyses obtained for the Sacramento plant water by the Central Environment Laboratory of the Campbell Soup Company.

Total dissolved solids:	313 ppm
Calcium hardness (as $CaCO_3$):	120 ppm
Total alkalinity (methyl orange):	110 ppm
pH	7.88

The results of the Langelier Index evaluation for the above water conditions are as follows:

Temperature	21.1°C (70°F)	90.6°C (195°F)
Langelier Index	+0.1	+1.25

The generally accepted indications of system tendencies are as follows:

Value of Langelier Index	Tendency Indicated
+ 2.0	Scale forming, noncorrosive for practical purposes
+ 0.5	Slightly corrosive and scale forming
0.0	Nonscaling, pitting corrosion possible
- 0.5	Slighly corrosive, nonscaling
- 2.0	Seriously corrosive

The results of the index computation indicate that scaling could take place at the higher system temperatures. No scaling rates are given by the index. Scaling will not be a problem because any scaling taking place in the system will be removed by the descaling solution which is used once yearly throughout the Sacramento plant water system as a normal maintenance procedure.

3.1.4 Roof Loading

In addition to the dead weight of the collectors, the roof structure must also support the aerodynamics or wind loads imposed on the collectors.

The first step in determining a wind load is to establish the wind velocity to be used for calculating loads. ANSI building code A58.1-1972 was used to determine the appropriate effective velocity. In general, a wind pressure on the surface of a structure is given by

$$p = C_f q$$

where C_f is a nondimensional coefficient determined by analysis or experiment, and q is called the velocity pressure with units of pressure. The effective velocity pressure was established according to paragraph 6.3.4.1* by the following classification:

- Mean recurrence interval — For structures which are highly sensitive to wind forces, a 100-year mean recurrence interval shall be used in determining fastest-mile winds. For Sacramento, the 100-year fastest mile speed is 35.8 m/sec (80 mph)
- Building height — Wind velocity varies with height above the ground. The Campbell's roof is 9.1 m (30 ft).
- Location — Tabular information for velocity pressures is given by the ANSI code according to the type of location in which a structure is found. The Sacramento plant can be classified as a city outskirt or suburban area.
- Type of structure — Tabular velocity pressure information is divided into applications for (1) structures and (2) parts or portions of structures. The analysis here is for the second classification.

The velocity pressure for the above classifications is 73.2 kg/m² (15 psf). For conservatism, a 122 kg/m² (25 psf) velocity pressure was used for load analysis and structural member sizing. This pressure corresponds to the dynamic head ($1/2\ \rho V^2$) of an air velocity of 44.7 m/sec (100 mph).

Pressure coefficients, C_f, were taken from the data for flat plates between walls for Area II (see Figure 1, Appendix A-2) and for wedge shaped obstructions at ground level for Area 1 (see Reference 5). Initial analysis for Area I indicated that upward loads were much too severe when

*Analysis according to paragraphs 6.3.4 and A6.3.4.1 yielded less conservative results.

wind approached from the rear of the monitor. Thus, the space between the monitors has been designed to be closed off with a back wall and sealed. An attempt was made to avoid mounting to the roof for Areas I and II, since each roof mounting point is expensive due to the need to make water tight penetrations. Instead, the sides of the sawtooth monitors will be opened and structural members placed between the monitors by mounting to existing structural members within the sawtooth. Drawings 7234-048, Pages 12 to 15 of Appendix C, contain the structural modification assemblies for these areas. The minimum safety factor for the structure is 1.67, based on the wind pressure analysis.

Pressure coeficients for the concentrator have been taken from wind tunnel test data for concentrators of similar configuration (See Reference 6). The determined peak drag and lift coefficients are both C = 1.75. In addition, a peak moment is applied to the concentrator axis of 207 kg-m (1500 lb-ft). Using the value of C = 1.75 with the 44.7 m/sec (100 mph) velocity yeilds a horizontal or a lift force of 11,700 nt (2630 lb) per collector module. These design values were used to size the triangular frame structures, used every 3.2 meters (10.5 feet), shown on pages 8 through 11 of Appendix C.

In order to minimize building modifications in the form of roof mounting points, the possibility of using collector modules of twice the present length was investigated. The concentrated loads on the roof increased to twice their value for that case and were judged too high to consider the idea further.

After all wind loads and dead weight loads were tabulated, Aerotherm employed the structural consulting firm, of Buehler, Cole, Yee & Schubert as specified by the Campbell Soup Company, to analyze the original roof structure to determine its capability to handle and added loads. The consulting firm has verified the adequancy of the warehouse roof structure.

3.2 STORAGE

The water storage system consists of the accumulator tank, pump, and associated equipment and piping. The system was designed to store the output of the solar collector field and supply the hot water to can line U on demand. The collector field will operate 7 days a week and the can washer line five days. The layout of the system is shown on Drawings 7234-026 and -027. Drawing 7234-029 shows the installation at the Campbell Soup Plant.

3.2.1 Accumulator Tank

The accumulator tank working volume is based on a process demand (output) of 47.3 liters/minute (12.5 gpm) of potable water for two shifts, 5 days a week and an input from the field spread over 7 days a week. Therefore, the total daily input to the tank will be 5/7 of the output resulting in a net decrease in the tank level Monday through Friday and filling of the tank on Saturday and Sunday. The total daily process demand will be 45,420 liters (12,000 gal) and the collector field will supply 5/7 of that, or 32,456 liters (8575 gal) per day. The net outflow from the tank will be 12,982 liters (3430 gal) per day or a total of 64,912 liters (17,150 gal) from Monday through Friday. On Saturday and Sunday the process demand will be zero and the input from the field will be 32,456 liters (8575 gal) each day for a total increase of 64,912 liters (17,150 gal). On Monday morning, the tank will be full and ready for the next working cycle. The cycle is shown in Figure 9.

The diameter of the tank was selected on the basis of the following design and cost factors.

- Area available for the accumulator tank and pump at the Campbell Soup facility in the location specified
- Allowance for clearance for walkways around the equipment, clearance around the doorway, access to the equipment after installation and during operation.
- Transportation of the tank from the tank fabricator to the erection site.
- Maximum allowable height
- Cost of field fabrication versus fabrication at vendor's facility.

An analysis of the above factors showed that a tank with a diameter of 12 feet was the most cost effective.

The total volume of the tank is a nominal 72,672 liters (19,200 gal). This size is based on a working capacity of 64,912 liters (17,150 gal) of water, a nominal water level of 0.229 meters (9 inches) to accomodate the floating suction, and a clearance of 0.38 meters (15 inches) between the water level and the top of the tank when the tank is full. The total height of the tank will be 6.86 meters (22 feet 6 inches), with a straight height of 6.71 meters (22 feet) and a conical cover 0.15 meters (6 inches) high welded to the shell.

The tank will be equipped with a 0.051 meter (2 inch) overflow pipe that will drain the tank from the bottom under certain conditions. This feature is designed to remove colder water from the bottom of the tank, while hotter water is being fed in from the field at times when the tank is full and a net gain in energy can be realized by operating the field. (See Section 3.4.2).

The tank material of construction must be compatible with potable water up to a temperature of 100°C (212°F). Several materials were considered including:

- Fiberglass
- Stainless steel
- Steel with special lining

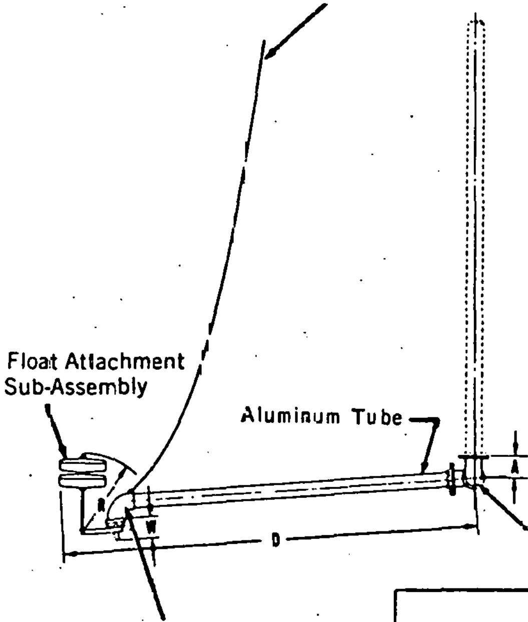
A cost analysis of the various material options showed that the steel tank with a USDA approved PLACITE 3055 baked phenolic lining met all the design requirements and was cost effective. Table 5 shows the properties of the lining. The tank selected will be fabricated in two sections, shipped to the job site, field welded, erected, and then the phenolic lining will be applied.

A floating suction will be used in the tank to insure that the hottest water from the top of the tank is being pumped to the can line at all times. The inlet from the field will be located far enough away from the floating suction to minimize the temperature influence of the water being pumped out. The floating suction consists of a 0.051 meter (2 inch) diameter pipe with a swivel joint on one end and a suction stub and float assembly attached to the other end. The swivel joint will be mounted directly to the tank wall approximately 3.66 meters (12 feet) above the bottom and the suction will have a travel distance of ± 3.11 meters (10.2 feet). The entire assembly will be made of bronze and the swivel joint will be sealed with three o-rings to prevent lube grease from entering the potable water in the tank and to stop water from entering the ball races. Figure 17 shows the floating suction assembly. The nylon coated stainless steel cable is desinged to allow easy inspection of the assembly when necessary.

The accumulator tank will be insulated to minimize heat loss. The insulation was designed for a maximum heat loss of 18.2 watt/m^2 (6 Btu/hr-ft^2) at an ambient temperature of 15.6°C (60°F) and a water temperature of 100°C (212°F). Several insulation/ application systems were analyzed to determine the lowest cost one. The insulation selected will consist of 15.2 cm (6 inches) of fiberglass intermediate service board, manufactured by Owens Corning Fiberglass Corporation, covered with a

TABLE 5. ACCUMULATOR TANK INTERNAL PROTECTIVE COATING

TYPE	A straight phenolic type of the high bake series. The coating has superior resistance to acids and solvents.
INTENDED USE	Tank lining for solvent, acids, food products and as a protective coating for ducts, machinery parts, filter press plates, rayon machine parts, fans, oil well tubular goods, etc. Meets requirements of FDA and M.I.D. of U.S.D.A.
TEMPERATURE RESISTANCE	Dry film basis is 400°F continuous and 500°F for short periods of time
COLOR	Color changes from brown to cherry red after final baking.
PIGMENTS	Iron oxide in pigmented primer coats
SOLIDS	Primer 60% by weight – finish coat 50% by weight
SHELF LIFE	At 70% – 6 months
VISCOSITY	For spray, adjust with No. 30 thinner to 16 seconds Ford Cup No. 4 at 70°F. (Two parts No. 30 Thinner to 3 parts 3055 Primer or finish will approximate this viscosity.) For dipping, start with same viscosity. This may be varied as needed to conform with size and shape of material. Not normally recommended for brush application.
COVERAGE	For 100 square feet of surface use approximately 1 gallon 3055 Primer (pigmented), 1/2 gallon 3055 Finish (clear) and 1 gallon No. 30 Thinner to produce the st. 5 to 7 mil film. Use 4 coats of Primer and 2 coats of Finish at a spreading rate of 400 sq. ft/gal/coat, undiluted basis.
BAKING SCHEDULE	The approximate schedule is based on metal temperatures and coatings on 18 guage steel. The time schedule shall be adjusted to meet conditions and to meet the proper color requirements. • Intermediate Coats – 10 to 20 minutes at 250°F to 300°F • Finish Coat and Final Bake – 1-1/2 hours at 350°F to 400°F • Final Bake at 400°F for sulfuric acid service



The OPW 764 Floating Suction Assembly does not include the vertical pipe. May be mounted with the swivel connected to a vertical pipe or with the swivel mounted directly to the tank wall.

SIZE	NUMBER OF FLOATS REQUIRED
2″	ONE
3″	TWO
4″	TWO
6″	THREE

DIMENSIONS								
SIZE	A		D		R		W	
	IN.	MM.	IN.	MM.	IN.	MM.	IN.	MM.
2″	5½	140	121¼	3080	18⅜	467	6½	165
3″	5	127	121¼	3080	18⅜	467	6¼	159
4″	6¹⁄₁₆	154	121½	3086	23⅜	594	6½	165
6″	7¾	197	120⅛	3051	23⅜	594	6¾	171

Figure 17. Accumulation tank floating suction.

0.41 mm (0.016 inch) thick aluminum and secured with aluminum bands. In order to reduce the heat loss from the bottom of the tank, an insulating pad will be installed under the tank.

3.2.2 Transfer Pump

The transfer pump circulates water from the accumulator tank through the heat exchanger to the can washer nozzles. The required pressure at the can washer nozzle is 42.44 kg/cm² (60 psi) minimum. At this pressure the flowrate per nozzle is 5.68 liters/m (1.5 gpm) and the total flow for the eight nozzles is 45.4 liters/m (12 gpm). Table 6 shows the pressure versus flow for the can washer nozzles. An engineering study of the pump requirements and operation was made to determine the best type and the size of pump required.

A centrifical pump was selected for this service. The centrifugal pump is the type most widely used in the chemical industry for transferring liquids of all types including general service of water supply, boiler feed, condensate return, etc. The primary advantages of a centrifugal pump are simplicity, low first cost, uniform (nonpulsating) flow, small floor space, low maintenance expense, pumps nonlubricating fluids, and quiet operation. Pump motor horsepower was an important consideration in the study because use of electrical energy lowers the overall efficiency of the system and increases the cost per Btu of collected energy. After the requirements for the pump were established, quotes from several manufacturers were obtained and the final selection was made. The pump selected was a bronze fitted Fairbanke Morse Wesco Model Number CK610 regenerative turbine pump with a separate 3 horsepower motor and steel mounting base. A separate pump/motor combination was selected so that the pump could be insulated to minimize heat loss from the system.

3.2.3 Associated Equipment and Piping

The piping run from the accumulator tank to both lines U and V shown on Drawing 7234-030, sheet 1, was designed for convenient simple installation requiring a minimum of rework to the building. The line is routed along the outside wall of Building 4, through the top of the window on the second floor, up to the ceiling, and over to the can lines. This routing keeps the line away from working areas where people could contract it or it could be damaged by moving equipment.

The material for the pipe, and insulation for both the water lines and steam lines was specified in Campbell Soup specifications. The pipe size was selected after an engineering analysis was conducted on each system. The pressure drop in the hot water line was an important consideration since it influenced the pump motor horsepower. The pipe size selected for the potable water line was 3.81 cm (1-1/2 inch) schedule 40 pipe. The steam line was sized based on available steam pressure and the maximum steam use rate.

TABLE 6. EMPTY CAN WASHER NOZZLE FLOWRATE AT VARIOUS PRESSURES

Pressure		Flowrate	
$\frac{kg}{cm^2}$	(psi)	liter/mm	(gpm)
10.61	(15)	2.95	(.78)
14.14	(20)	3.37	(.89)
21.21	(30)	4.16	(1.1)
28.29	(40)	4.92	(1.3)
42.44	(60)	5.67	(1.5)
56.58	(80)	6.43	(1.7)
70.73	(100)	7.19	(1.9)
Fulljet nozzle 1/4 G 6.5			

3.3 CAN WASHER INTERFACE

The can washer interface section consists of the heat exchanger and associated steam line and the details of the connection to can lines U and V. Can line U is the line that will normally be operated with solar heated water. Can line V is connected in case something happens to can line U during Phase III of the program to render it inoperable for a period of time. Having both lines piped in at the same time will also save money and avoid program delays in the future.

3.3.1 Heat Exchanger

The heat exchanger was designed using the following parameters:

- Fluid heated – potable water
- Temperature rise – 21.1°C to 93.3PC (70°F to 200°F)
- Flowrate – 56.77 liters/m (15 gpm)
- Pressure drop – 0.707 kg/cm^2 (1 psia)
- Heating fluid – steam 14.14 kg/cm^2 (20 psig)
- Fouling resistance – 0.001 shell side
0.005 tube side

The surface area was calculated using on overall heat transfer coefficient (U) of 1181 watt/m^2°K (208 Btu/hr-ft^2°F) clean and the fouling factors shown above. The calculated surface area was 3.81 m^2 (41 sq. ft.). The materials of construction for the heat exchanger were selected based on compatibility with potable water and steam service. Admiralty red brass tubes and shell was selected based on copper for the tube side at the suggestion of Campbell Soup Company, because of the possibility of green discoloration of the food products. Table 7 is the data sheet on the unit.

The heat exchanger will be located near the ceiling on the second floor of building 4, as shown on Drawing 7234-025. This location was selected because of the proximity to lines U and V and the main structure to mount the unit already existed. Also, there is an existing steam line close to the installation site and there is enough room so that the tubes of the heat exchanger can be cleaned. Drawing 7234-028 shows the heat exchanger installation details.

3.3.2 Interface with Line U

The can washing device used on line U is a sheet metal enclosure, approximately 2.44 meters (8 feet) long and it has a water supply tube with a row of eight 1/4 G6.5 nozzles located along the lower edge. During the travel through the washer the empty cans rotate so that all surfaces are

HEAT TRANSFER DIVISION
AMERICAN-STANDARD
POWER & CONTROLS GROUP
BUFFALO, N.Y. 14240

TABLE 7. HEAT EXCHANGER SPECIFICATION SHEET

1			JOB NO.	RFQ 0291
2	CUSTOMER	Acurex Corporation	REFERENCE NO.	
3	ADDRESS	Mountain View, Calif.	INQUIRY NO.	SF76-8-24-288
4	PLANT LOCATION		DATE	
5	SERVICE OF UNIT	Potable Water Heater	ITEM NO.	01
6	SIZE 08024	TYPE HCE-C	(HORIZ.) (VERT.)	CONNECTED IN
7	SQ. FT. SURF./UNIT (GROSS) (EFF.) 41	SHELLS/UNIT 1	SQ. FT. SURF./SHELL (GROSS) (EFF.)	41
8	**PERFORMANCE OF ONE UNIT**			
9		SHELL SIDE		TUBE SIDE
10	FLUID CIRCULATED	Steam		Potable Water
11	TOTAL FLUID ENTERING #/hr	1022		7386
12	VAPOR			
13	LIQUID GPM			15
14	STEAM #/hr	1022		
15	NON-CONDENSABLES			
16	FLUID VAPORIZED OR CONDENSED			
17	STEAM CONDENSED			
18	GRAVITY			
19	VISCOSITY			
20	MOLECULAR WEIGHT			
21	SPECIFIC HEAT		BTU/LB-°F	BTU/LB-°F
22	THERMAL CONDUCTIVITY		BTU/HR-FT-°F	BTU/HR-FT-°F
23	LATENT HEAT	939.4	BTU/LB	BTU/LB
24	TEMPERATURE IN	259	°F	70 °F
25	TEMPERATURE OUT	259	°F	200 °F
26	OPERATING PRESSURE	20	PSIG	100 PSIG
27	NO. PASSES PER SHELL	1		4
28	VELOCITY		FT/SEC	1.1 FT/SEC
29	PRESSURE DROP	NEG	PSI	0.14 PSI
30	FOULING RESISTANCE (MIN.)	.0005		.001
31	HEAT EXCHANGED-BTU/HR	960,200	MTD CORRECTED-°F	112
32	TRANSFER RATE-SERVICE	208	CLEAN	
33	**CONSTRUCTION OF ONE SHELL**			
34	DESIGN PRESSURE	200 *	PSI	150 PSI
35	TEST PRESSURE	300	PSI	225 PSI
36	DESIGN TEMPERATURE	300 *	°F	300 °F
37	TUBES Admiralty	NO. 210 O.D. 3/8 BWG. 24	LENGTH 24	PITCH 29/64 TRI
38	SHELL Red Brass	I.D. O.D.	SHELL COVER	(INTEG) (REMOV)
39	~~XXXXXXXX~~ OR BONNET	Cast Iron	CHANNEL COVER	
40	TUBESHEET-STATIONARY	Forged Brass	TUBESHEET-FLOATING	
41	BAFFLES-CROSS Brass	TYPE SEG	FLOATING HEAD COVER	
42	BAFFLES-LONG	TYPE	IMPINGEMENT PROTECTION	
43	TUBE SUPPORTS			
44	TUBE TO TUBESHEET JOINT	Rolled		
45	GASKETS	Asbestos		
46	CONNECTIONS-SHELL SIDE	IN 3"	OUT 3"	RATING N.P.T.
47	CHANNEL SIDE	IN 2"	OUT 2"	RATING N.P.T.
48	CORROSION ALLOWANCE-SHELL SIDE		TUBE SIDE	
49	CODE REQUIREMENTS	ASME Sec. VIII		TEMA CLASS
50	WEIGHTS-EACH SHELL		BUNDLE	FULL OF WATER
51	NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)			
52	REMARKS: * Maximum steam pressure on the shell side is 100 psig at 350°F. Unit not suitable for steam in the tube.			

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exposed to the fixed streams of hot water. The water is supplied to the empty can washer through a 1.91 cm (3/4 inch) schedule 40 pipe. The hot water supplied to the can washing line must meet the following requirements:

- Flowrate — 47.31 liters/mm (12.5 gpm) in demand
- Pressure — 42.44 kg/cm² (60 psi) at nozzle
- Temperature — 82.2 - 90.5°C (180-195°F)
- Duty cycle — continuous during two week day shifts. Shuts off when the can line stops.

The interface with line U shown on Drawing 7234-030 is designed to be simple and fast. All that is required is removing a section of 3/4 inch line between two unions and replacing it with a new section of line containing the solar hot water connection, temperature sensor, flow switch, and a pressure gage.

Acurex proposes to plumb the drain line from the empty can washer into a sump under the full can washer. This water will be used as the second rinse in the full can washer. The water will then be collected in a second sump mixed with detergent and pumped into the first section of the full can washer. This design would utilize the heat contained in the hot water from the empty can washer and eliminate the need for supplying new water to the full can washer. Drawing 7234-030 shows this design.

3.4 CONTROL SYSTEM

The control system performs three major functions. It controls the collection and storage of solar energy, it controls the supply of hot water to the canning line at the proper temperature and it protects the collector field from environmental damage.

The control philosophy is predicated on a maximum amount of local autonomous control in each of the three major equipment areas. Those functions which can be controlled completely within the field or other areas are handled there with only status or analog information passed to the central console. Example, the wind velocity sensor is mounted at the collection field. A high wind velocity will trigger the "stow" function of the tracking concentrators without action of the central console. Similarly the use of process steam for additional water heating in the heat exchanger does not involve any central control action other than turning on the steam supply. Drawings 7234-027 to 030 and 045 shows the control system components.

Since the three major operating areas are separated by some distances, all control and analog signals are exchanged at high levels (1 volt or greater).

3.4.1 Field Control Components

The field junction box is the connection point for all field data and control signals. The Resistance Temperature Detector (RTD) temperature sensors are conditioned to 0-1 volt signals representing -17.8 to 121°C (0 to 250°F) temperatures. Each sensor has one or more alarm sensors connected to it to signal local freezing dangers, overtemperature or normal operating conditions. The wind velocity indicator is also equipped with upper limit alarms so that in the event of high winds the movable concentrator panels will move to the "stowed" position. Similarly a "concentrator overtemperature" indication will cause that concentrator to "desteer" to eliminate the possibility of boiling in the concentrators.

When a possible field freezing condition exists with any local panel temperature below 1.1°C (34°F), a signal is sent to the central control console which will trigger a controlled water flow through the panels to keep them from freezing.

3.4.2 Storage Tank Control Components

The storage tank area contains the majority of the active system control elements. The major active control loop is the collector field flow control. This loop consists of a Digital Dynamic Incorporated digital flow control valve, a Barton 306 FLOTRAC water flow meter and a DDI M-100 controller.

The Model 500 FLOTRAC Meter is an accurate, high pressure water meter. The FLOTRAC, employs a "constrained vortex" principle to provide an accuracy of ±1.0 percent over a broad range. The meter has but one moving part which comes in contact with the process media, the rotor. The rotor assembly includes bearings and an integral magnet, and can be removed and replaced quickly and easily in the line.

The register assembly is magnetically coupled to the rotor assembly. This eliminates friction and leakage from packing glands.

The Model 100 is a single setpoint electronic analog controller with integral A/D converter and solid-state relays for driving 4 to 7 bit digital binary control valves. It uses the PID algorithm to provide proportional, integral (reset), and derivative (rate) response. Individual gain controls are provided for the 3 modes. All field wiring is connected via a heavy-duty terminal strip mounted on the circuit board.

The process variable and setpoint inputs respond to standard voltage or current mode industrial control signals. The setpoint is provided by the central control console according to the mode of operation. Interchanging the input signals converts the controller to reverse-acting.

The control valve is driven by an analog/digital converter and integral solid-state relays. The valve update interval is adjustable to allow optimization of system performance. Individual, easily replaced fuses protect the relays. The valve setting is indicated in binary by light-emitting diodes on the circuit board. A valve disable line is provided to override the controller function by de-energizing the solid-state relay outputs. With the controller disabled, the solenoid outputs may be individually switched for maintenance purposes.

The D.D.I. 607D series digital control valve is a general purpose device suitable for water.

The standard valve contains eight internally piloted diaphragm type ASCO^{tm} solenoid valve actuators. Associated with each solenoid actuator is a metering flow restrictor. By selectively energizing the coils of the solenoids controlling these flow restrictors, any discrete flow restriction can be set on the valve in increments of the smallest restriction The valve orifices are sized in a binary progression so that by selecting various combinations of valves, flow may be controlled to a resolution of 1 part in 31 or 3 percent. The reliability of an on-off valve is many times greater than a proportioning type control valve.

Other sensing equipment located at the tank includes the tank level and temperature sensors. The tank level is sensed by several DeLaval float type switches located on a support frame which is inserted from the top of the tank. These flat switches signal tank level high or full, low, and tank empty. The switches used on hermetically sealed and actuated magnetically for maximum reliability and lifetime.

The tank also contains two temperature sensors which measure the temperature of the top and bottom of the tank and the differential between them. If the tank is full, but the temperature differential between top and bottom indicates that useful energy may still be added, the control system will allow replacement of cooler water at the tank bottom with hotter water from the field. However, in this mode, the field flow is controlled to add high temperature water while minimizing the amount of water which is dumped.

The remaining tank control components consist of a pair of flow switches to detect flow stoppages in supply from the field or flow to the canning line.

3.4.3 Can Washer Control Components

The can washer area has only two control components. The temperature of the water leaving the heat exchanger is measured by a liquid filled thermal bulb which directly actuates a control valve on the steam line into the heat exchanger. A LESLIE "Eventemp" GICK valve is used which has been in commercial use for 10 years.

A water flow switch is used to detect when the can line is shut off for some reason. Its signal will cause the central control console to shut off the steam and pump after a short time period.

3.4.4 Central Control Console

The central control console contains the main operating and control components, the data logging system and the control panel.

The control console is shown pictorally in Drawing 7234-045. It contains indicator lights to indicate various modes, the status of system components, various possible malfunctions and several operating controls.

The "mode" control switch can be used to select the four operating modes of the system (Figure 18). In the "solar supply" position, the system is activated each morning by a reset timer and operates normally. The field flow is controlled by a preset flow program drawn on the chart of a Leeds & Northrup Trendtack controller. The normal flowrate as a function of time is drawn on the chart and the controller will connect this to a DC signal which is sent to the flow controller at the tank. Thus the flow may be programmed for maximum flow during the hours of highest solar insolation. As the system starts each morning, the control system checks for a positive temperature rise across the field. If no useful energy is being added to the water, or if energy is being lost, the field is bypassed.

In the "Boiler Supply" mode, the canning line is supplied by the normal company hot water supply and the control system will act only to protect the field components from freeze or overtemperature damage.

The "Overtemperature Protect" mode may be signaled by a full tank of hot water, a hot collector or the manual mode switch. In this mode the field flow control is switched to temperature control and the minimum amount of water necessary to keep the field below 96°C (205°F) is run through the field. In this condition, the concentrators are "stowed".

The "Freeze Protect" mode operates in a similar manner in that the field water flow is set to a minimum flowrate through the field and a drain valve is opened. This mode activiates when the temperature of any field sensor is below 1.1°C (34°F) and deactivates at 10°C (50°F).

If the storage tank is full but the tank bottom temperature is below that of the field outlet, then useful energy can still be added to the tank. In this case the field water flow control is switched from flowrate to temperature control and the system will produce as much as 93°C (200°F) water as it can to add to the tank. A tank overflow will dump cooler water from the bottom of the

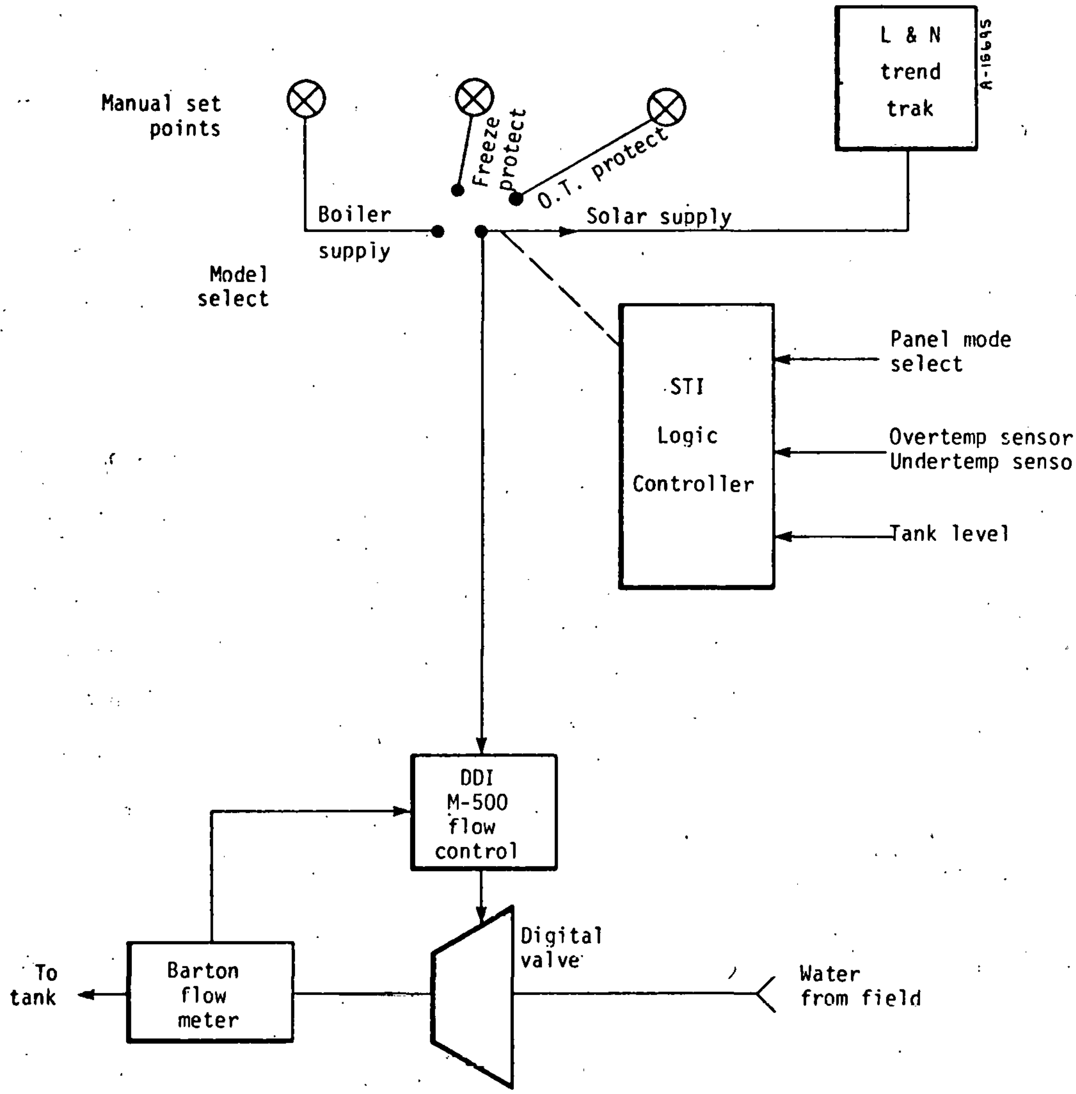

Figure 18. Collector panel flow control.

tank until the entire tank reaches 93°C (200°F). At this point the control system will switch to the "Field Overtemperature Protection" mode, until the tank cools or water is used and must be replaced. The flow control setpoints for these various modes may be adjusted inside the control panel. The front panel also contains manual flow controls.

Logical control functions will be done with a Texas Instruments Programmable Logic Controller. These units are rapidly replacing the older type of relay logic whenever complex logical functions are required. During the setup phase, the programmable nature of the controller will be used to modify the operation of the system as necessary. After the system is on-line, the program is transferred to permanent read only memory. The Texas Instruments STI system has been in widespread industrial usage for two years and similar units are available from almost all industrial control manufacturers.

The overall control scheme with all contingencies is detailed in Table 8.

3.5 DATA ACQUISITION SYSTEM

3.5.1 Field Data Components

The collector field instrumentation is summarized in Table 9. The field temperature sensors are RTD with Action Pak signal conditioners. These signal conditioners produce a 0 to 1 volt signal representing temperatures of -18°C to 121°C (0°F to 250°F). The ambient temperature is measured using a mast mounted Weather-Measure model T621 thermosensor with a radiation shield. Wind speed and direction are sensed by a Weather Measure W101-P-DC/540 Skyvane I system mounted on a 10 ft mast.

Also mounted in the field are an EPPLEY PSP pyranometer and an EPPLEY SBS pyranometer.

All sensor outputs are conditioned to 0-1 volt signals for transmission to the data system.

3.5.2 Storage Tank Data Components

The storage tank area is equipped with RTD thermometers and the Barton flowmeter as shown in Table 10. All signals are conditioned to 0-1 volt DC for transmission to the data system.

3.5.3 Can Washer Data Components

Both canning lines "U" and "V" are equipped with temperature and water flow sensors in order to compare the performance of the solar and reference can lines (Table 11).

The temperature sensors are RTD's and the water flowmeters are Barton model 306 FLOTRACs. All signals are conditioned to 0 to 1 volt DC levels by Action Pak model 1400 or 7050 signal conditioners.

TABLE 8. SOLAR HOT WATER CONTROL

Condition	Action
Function switch set to "SOLAR SUPPLY"	NORMAL OPERATING MODE • Programmed flow controller operates flow control valve. Start up in bypass mode • Pump operates and steam supply solenoid valve opens on demand • Solar supply valve open. Plant supply valve closed
Surface of flat plate collectors is below 72°F (adjustable) AND Tube surface of concentrators is below 70°F (adjustable)	INADEQUATE TEMPERATURE BYPASS • Switch valves to allow flow to bypass field • Light "INADEQUATE TEMPERATURE BYPASS", record on logger
Field outlet temp. exceeds 205°F (adjustable)	OVER TEMPERATURE Augment programmed flow by small increment (to be determined)
OVER TEMPERATURE mode is active AND $T_{FIELD\ OUTLET} < 195°F$	Deactivate OVER TEMPERATURE mode
Power supply fails	POWER FAILURE Normally open solenoid valve opens. Flow circulates through field to drain (10 GPM)
Function switch set to "BOILER SUPPLY"	• Pump turned off • Steam supply solenoid valve shut • Plant hot water supply valve is open to canning line, solar system valve shut • Light "BOILER SUPPLY", record on logger

TABLE 8. Continued

Condition	Action
Function switch set to "SOLAR SUPPLY" AND Tank is empty (Dead band on bottom level switch to be approx. 1 foot to 2 feet in height)	EMPTY TANK • Pump turned off • Steam supply solenoid valve shut • Plant hot water supply valve is open to canning line, solar system valve shut • Light "EMPTY TANK" (red light), record on logger
Outlet water temp. from H.X. falls below 170°F (adjustable) (delay 5 minutes) AND Canning line solar supply valve is open Use reset button for restart	HEATING MALFUNCTION Same as EMPTY TANK mode, only • Light "HEATING MALFUNCTION" (red light), record on logger
Canning line water demand switch opens	SHUTDOWN • Pump is shut off • Steam supply solenoid valve is closed • Light "CAN WASH SHUTDOWN", record on logger
Storage tank is full AND $T_{TANK\ BOTTOM} < T_{TANK\ INLET}$	FULL TANK, NORMAL OPERATION • Light "FULL TANK", record on data logger
Storage tank is full AND $T_{TANK\ BOTTOM} > T_{TANK\ INLET}$ AND $T_{TANK\ BOTTOM} <$ 190°F (adjustable)	Initiate: "FULL-TANK, TEMPERATURE CONTROLLER" • Disable flowrate programmer • Enable set point controller for control valve. $T_{TANK\ INLET_{SET}}$ = 200°F • External standpipe allows tank to drain • Light "FULL TANK, TEMPERATURE CONTROLLER", record on data logger • Disable FULL TANK, NORMAL OPERATION mode

TABLE 8. Continued

Condition	Action
Storage tank is full AND $T_{\text{TANK BOTTOM}} > 190°F$ (adjustable)	• Steer concentrators away from sun • In addition, light "TANK TEMP > 190°F", record on logger
$T_{\text{SURFACE}_{\text{F.P.}}} < 34°F$ (adjustable) OR $T_{\text{SURFACE}_{\text{CONC.}}} < 34°F$ (adjustable) OR $T_{\text{MANIFOLDS}} < 34°F$ (adjustable)	FREEZE PROTECT • Disable flow rate program • Light "FREEZE PROTECT", record on logger • Drain valve opens for 10 GPM flow • Field bypass valves are in field flow position
FREEZE PROTECT mode is operative AND $T_{\text{TANK INLET}} > 40°F$ (adjustable)	Deactivate "FREEZE PROTECT" mode
FREEZE PROTECT mode is operative AND Flow switch in drain line indicates inadequate drainage flow.	DRAIN FAILURE • Main flow control valve opens to allow 10 GPM flow into tank • Light "DRAIN FAILURE" red, record on logger • Field bypass valves are in field flow position
Any control mode is operative AND No signal exists for opening control valve AND $T_{\text{SURFACE}_{\text{F.P.}}} > 205°F$ (adjustable) OR $T_{\text{SURFACE}_{\text{CONC}}} > 205°F$ (adjustable)	FIELD OVERHEAT PROTECT Maintain all conditions of operating mode, but • Steer concentrators from sun • Enable set point controller for control valve: $T_{\text{TANK INLET}_{\text{SET}}} = 200°F$ (Reverse Action) • Initially provide signal to open valve for at least 10 minutes with minimum flow setting • Allow this mode to self deactivate if flow required is less than the lowest discrete flow setting, i.e., if control valve shuts, deactivate mode. • Light "FIELD OVERHEAT PROTECT", log on logger

TABLE 8. Continued

Condition	Action
Daily timer identifies nighttime	Concentrator turns to face downward
Temperature of any concentrator outlet (as measured by thermal switch located on concentrator) exceeds 215°F	EXCESSIVE OVERHEAT • Concentrators steered away from sun • Light "EXCESSIVE FIELD OVERHEAD" red, record on logger
Flow control valve should be open AND No flow is measured flowing into tank	NO FIELD FLOW TO TANK Light "NO FIELD FLOW TO TANK" red, record on logger
Solar supply canning line valve is signalled to be open AND No canning line flow exists	FAILURE IN CANNING LINE SUPPLY • Light "FAILURE IN CANNING LINE SUPPLY" red, record on logger • Switch to boiler supply • Shut steam supply solenoid valve • Turn off pump • Disable solar supply until reset button pushed

<u>Additional Manual Controls</u>

- Activate/deactivate tracking, divert concentrators from sun
- Select any flow with control valve (we can do this with a hand valve if control valve override is too difficult or costly)
- Open/close steam solenoid
- Bypass field with flow
- Open/close drain valve

TABLE 8. Concluded

Alarm and Information Lights, Records	
• For all active modes identified: Green or yellow lights	
– HEATING MALFUNCTION – TANK EMPTY – EXCESSIVE FIELD OVERHEAT – FAILURE IN CANNING LINE SUPPLY – NO FIELD FLOW TO TANK – DRAIN FAILURE	Red light, and record on paper printer along with time started and stopped

TABLE 9. COLLECTOR FIELD SENSORS

Location	Variable	Sensor
Field	Ambient air temperature	Weather-measure T621
Field	Wind Direction	Weather-measure Skyvane I
Field	Wind Velocity	Weather-measure Skyvane I
Field	Total Radiation	EPPLEY PSP pyranometer
Field	Diffuse Radiation	EPPLEY SBS pyranometer
Manifold	Water temperature	Resistance thermometer (RDF 21B10A4B)
Plate Surface	Surface temperature	Resistance thermometer (Mical RTX-4568-D2-F72)

TABLE 10. TANK SENSORS

Location	Variable	Sensor
Field outlet manifold	Temperature	Resistance thermometer
Field outlet manifold	Water flow	Barton 500 flowmeter
Field outlet manifold	Water flow	FLOTEC V4 flow switch
Tank Top	Temperature	Resistance thermometer
Tank bottom	Temperature	Resistance thermometer
Tank bottom	Water level (2)	Delonal 24579 level switch
Tank top	Water level (1)	Delonal 24579 level switch

TABLE 11. CAN WASHER SENSORS

Location	Variable	Sensor
Line "U"	Water temperature	Resistance thermometer
Line "U"	Water flowrate	Barton 306 FLOTRAC
Line "V"	Water temperature	Resistance thermometer
Line "V"	Water flowrate	Barton 306 FLOTRAC
Heat Exchanger	Water temperature in	Resistance thermometer
Heat Exchanger	Water temperature out	Resistance thermometer

3.5.4 Data Logger-Printer

The system will be equipped with a 40 channel Autodata Nine data logger for local data logging and display purposes. The Autodata Nine is a microprocessor based system which periodically samples, converts, and logs data in response to preset time commands or external events. For diagnostic purposes the system is equipped with an optional alarm system which will print one complete data scan whenever any analog value exceeds high or low alarm limits. Thus, a complete onsite record is immediately available to the inspection or service personnel during operation. This capability of immediate data display will be used extensively during the setup and adjustment phases. Local data will be printed on a Decwriter II 30 CPS terminal. Data will also be recorded on a 9 track magnetic tape for analysis at Aerotherm's facilities.

3.5.5 Data Display System

There are three methods of displaying data available to the system operator. In each junction box (collector field, tank, can line) there is a selector switch and a plug jack for a portable meter. By plugging in a hand held meter, service personnel can read any temperature, flowrate, etc., which is measured in that portion of the system. This will be very useful in balancing the collector field or performing maintenance.

At the control console, the operator has five panel meters which can display selected variables. Four of the meters continuously display field outlet flow and temperature and canning line flow and temperature. The fifth meter may be switched to any variable in the system.

The third data display is available via the data logger and printer combination. By manipulation of the front panel controls (which may be locked out) the data logger can print out the current values of all data channels.

3.5.6 Data Interface to ERDA System

To facilitate the interface to the ERDA supplied data acquisition system, various sensors (temperature and flow) are available as 0 to 1 VDC signals at a terminal strip at the back of the control cabinet. The signals will be single ended with a common signal and chassis ground.

The signals available at the terminal strip are detailed in Table 12.

3.6 INSTALLATION DETAILS

The solar heated hot water system was designed for simple installation using methods and materials currently used in construction, chemical processing, and solar heating industries. Required modifications to the existing Campbell Soup facility will be kept to a minimum and there will be no

TABLE 12. SENSORS TO ERDA DATA SYSTEM

Location	Variable	Sensor
Field	Ambient temperature	Weather-measure T621
Field	Wind direction	Weather-measure Skyvane I
Field	Wind speed	Weather-measure Skyvane I
Field	Total radiation	EPPLEY PSP pyranometer
Field	Diffuse radiation	EPPLEY SBS pyranometer
Field inlet	Water temperature	Resistance thermometer
Field outlet	Water flowrate	Barton 500 FLOTRAC
Field outlet	Water temperature	Resistance thermometer
Heat exchanger inlet	Water temperature	Resistance thermometer
Heat exchanger outlet	Water temperature	Resistance thermometer
Can line "U" inlet	Water flowrate	Barton 306 FLOTRAC
Can line "U" inlet	Water temperature	Resistance thermometer
Can line "V" inlet	Water flowrate	Barton 306 FLOTRAC
Can line "V" inlet	Water temperature	Resistance thermometer

interference with their production schedule. (For the most part, the installation of the system will be done by a general contractor per the specifications shown in Appendix A-1 under the guidance of Acurex.)

3.6.1 Solar Collector Field

3.6.1.1 Concentrating Collectors

The tracking concentrating collectors will be mounted on the roof of Building W8 in three rows, each row consisting of two arrays. Each array will consist of 8 each 3.05 meter (10 feet) long interconnected sections of parabolic reflectors with a support at each end of the row and between each section. The field layout and electrical schematic are shown on Drawings 7234-030, sheet 2 and 7234-031, sheet 2.

The first row of concentrating collectors will be installed parallel to the south wall of the building, as shown in Drawing 7234-030, sheet 2. The collectors will be supported on a triangular base as shown in Drawing 7234-030, sheet 3. One leg of the triangular structure will be mounted to the parapet wall and the other leg will be mounted on the wood roof above the P4 I beam. All the support footings (tees) except for the first one (west wall) will be mounted on the roof and south parapet wall. The first supports will be mounted to the west parapet wall. After all the tees are in place the three legs of the triangle will be clamped in place to the tee and the concentrator yoke. After the supports are lined up and leveled, the supports will be welded together as shown on the drawing. Rows 2 and 3 will be located as shown on Drawing 7234-030, sheet 2.

The procedure for building up the supports will be the same the second two rows.

Rows 2 and 3 are shown on Drawings 7234-030, sheet 4 and sheet 5. All the nuts and bolts for the tees on the roof will be inserted from below the roof and the retaining nuts put on from the roof side. This will allow adjustment of the structure during installation of the concentrators. The threaded end of the bolt will have a wrenching surface so it can be held while the bolt is being loosened or tightened.

After the structures are all in place, the concentrating collector will be assembled into the supports as shown on the drawing. During the assembly operation, adjustment of the position of the supports can be accomplished as required by loosening the nuts in the retaining bolt. After the collectors have been installed, all the nuts will be checked to make sure they are tight.

The motor and worm gear drive will be installed as shown in each array. After the motor is installed the rotation of the concentrator will be checked. Then the pitch pockets per the detail shown on Drawing 7234-030, sheet 3 will be completed. The metal flashing for the pitch pocket will normally be installed before the support legs are clamped to the tees.

3.6.1.2 Flat Plate Collectors

The flat plate collectors will be mounted on the first two rows of monitors (Reference South Wall) starting from the west wall. Fifty-eight flat plate collectors 0.91 meters (3 feet) wide by 5.03 meters (16.5 feet) long will be installed in the first row and 58 flat plate collectors 0.91 meters (3 feet) wide x 3.2 meters (10.5 feet) long will be installed in the second row. The layout of the collector is shown on Drawing 7234-030, sheet 2.

In order to accomodate the flat plate collectors, a supporting structure will be constructed from the parapet wall to the first monitor on both sides of each row and between the monitors. In the first row the supporting structure will be constructed as follows.

- Mount the support columns on the east and west parapet walls
- Install 5 each 6.1 meter (20 feet) length 8 x 4 x .25 inch thick rectangular structural steel tubing as shown on Drawing 7234-048, sheet 3, detail E
- Install 5 each 6.1 meter (20 feet) lengths of 10 LB 15 I beam as shown in View B-B of the same drawing
- Install the 12 LB 16.5 support I beam on the top of ST4 WF 13.5 tee under the roof on both sides of each monitor (8 places) as shown
- Install the metal bearing plates on the monitor and bolt them into the support beam as shown. After the plates are installed, install flashing to prevent water leakage through the roof
- After the bearing plates are in place install the 4WR13 beam the entire width of the roof, from the east to the west parapet wall, and secure it at both sides and three places on each monitor. The I beam will be installed in even lengths and each length will be tied together with a bolted steel plate
- Install the 4C 5.4 channel the entire length of the roof. Attach the channel to the bearing plates and the 10 LB 15 beam as shown

The support structure for the second row of collectors will be the same as above, except that the lower structure will not be used and the 4 WF 13 beam will be used in place of the 4C 5.4 channel above the 10 LB 15 beam as shown on Drawing 7234-048, sheet 3.

After the support structure is in place the flat plate collectors will be installed. In the first row the 5.03 meter (16.5 foot) long collectors will be installed as shown on Drawing 7234-048, sheet 1. On the lower end of the monitor each collector will be held in place with a 1 1/2 x

1 1/2 x 1/8 angles as shown in View C-C. At the top the collectors will be held down and at the same time bolted together, using steel straps as shown in View A-A. After the collectors are in place the space between the monitors will be closed off on both sides using galvanized corrugated siding that matches that presently used to close off the sides of the monitor. The new siding is attached as shown on Drawing 7234-048. Galvanized flashing will be installed over the high end of the collector as shown.

Installation of the second row of collectors is the same as the first row except the space between the monitors will not be closed off. The installation is shown on Drawing 7234-048, sheet 4.

3.6.1.3 Field Equipment and Piping

The field equipment and piping layout Drawing 7234-030, sheet 2 shows component locations, valves, fittings, pipe runs, and pipe sizes. The plumbing will be done in accordance with the specification outlined in Appendix A-1. The electrical wiring is shown on Drawing 7234-031, sheet 2. The environmental instrumentation consisting of wind gauge, pyranometers, and ambient temperature guage will be mounted on a 10 foot high tower as shown on Drawing 7234-031, sheet 2. All electrical work will be done in accordance with Appendix A-1.

3.6.2 Storage

The accumulator tank and pump will be installed on a reinforced concrete pad in the patio area between Building 2 and Building 4 as shown on Drawing 7234-029. The hot water piping will be routed up the wall of Building 4, through the top of the window on the second floor, up to the ceiling, through the heat exchanger, then to canning lines U and V. Drawing 7234-030, sheet 1 shows the actual pipe routing with all valves and fittings.

3.6.3 Can Washing Interface

The heat exchanger will be installed on the ceiling of Building 4 on an existing structure as shown on Drawing 7234-026. The installation details including brackets, fittings, valves and controls are shown on Drawing 7234-028. The installation details for the solar hot water system to can lines U and V are shown on Drawing 7234-030, sheet 1.

3.6.4 Control System Installation

Since the control system is divided into a number of modular sections, it can be completely prefabricated and checked out at Aerotherm before shipment.

Field installation will consist of connecting the sensors to cables installed by the electrical contractor and connecting these cables to labeled terminal strips.

All wiring between the three junction boxes and the control console is on a terminal block to terminal block basis. Wires will be installed in the conduit by the electrical contractor. Table 13 shows a typical wiring list for the analog signal cables from the field junction box to the control console.

3.7 SYSTEM PERFORMANCE

3.7.1 System Performance Calculations

Methods for predicting the flat plate collector and the trackable concentrator performance have been described by Liu and Jordan (Reference 1) and Duffie and Beckman (Reference 2). In this section, the salient points necessary to predict the collector system performance are briefly discussed. It is important to know the hourly amount of the direct and diffuse solar radiation throughout the year since for a concentrating collector only the direct component is used and for a flat plate collector, the amount of incident beam radiation is a function of the angle between the collector normal and the sun line and (to a first approximation) the diffuse component is not. This relationship for a flat plate collector is given as Equation 1:

$$q_i = q_B R_B + q_d \qquad (1)$$

where

q_i = total incident energy rate per unit area

q_B = diffuse component to a horizontal surface

R_B = $\cos \theta_T / \cos \theta_Z$

θ_T = angle between collector normal and line to the sun

θ_Z = angle between normal to a horizontal surface and line to the sun

Similarly, for a concentrator, the incident solar radiation can be written as:

$$q_{i,conc} = q_B R_{conc} \qquad (2)$$

$$R_{conc} = \cos \theta_i / \cos \theta_z \qquad (3)$$

where

θ_i = angle of incidence of beam radiation on the concentrator

TABLE 13. TYPICAL WIRING LIST

Terminal Block 101 Location Field Junction Box

Term	Field I.D.	Wire Size	Signal	Level	To Term Block	Term
-1		#22	Wind Direction	1 VDC	TB 401	-1
-2		#22	Wind Velocity	1 VDC	TB 401	-2
-3		#22	Total Radiation	1 VDC	TB 401	-3
-4		#22	Diffuse Radiation	1 VDC	TB 401	-4
-5		#22	Ambient Temp.	1 VDC	TB 401	-5
-6		#22	Water Inlet Temp.	1 VDC	TB 401	-6
-7		#22	Field Outlet Temp.	1 VDC	TB 401	-7
-8		#22	Collector Temp.	1 VDC	TB 401	-8
-9		#22	Collector Temp.	1 VDC	TB 401	-9
-10		#22	Collector Temp.	1 VDC	TB 401	-10
-11		#22	Collector Temp.	1 VDC	TB 401	-11
-12		#22	Collector Temp.	1 VDC	TB 401	-12
-13		#22	Collector Temp.	1 VDC	TB 401	-13
-14		#22	Collector Temp.	1 VDC	TB 401	-14
-15		#22	Collector Temp.	1 VDC	TB 401	-15
-16		#22	Collector Temp.	1 VDC	TB 401	-16
-17		#22	Collector Temp.	1 VDC	TB 401	-17
-18		#22	Collector Temp.	1 VDC	TB 401	-18
-19		#22	Collector Temp.	1 VDC	TB 401	-19
-20		#22	Collector Temp.	1 VDC	TB 401	-20
-21		#22	Collector Temp.	1 VDC	TB 401	-21
-22		#22	Spare	1 VDC	TB 401	-22
-23		#22	Spare	1 VDC	TB 401	-23
-24		#16	Signal Common	Ground	TB 401	-24

For a concentrator rotating about a horizontal east-west axis with continuous adjustment, from Reference 2:

$$\cos\theta_i = (1-\cos^2\delta\ \sin^2 W)^{1/2} \tag{4}$$

where

δ is the declination and W is the solar low angle

The solar insolation quantities q_B and q_d are referred to a horizontal surface since most insolation data are taken with instruments whose normal is vertical. Data on q_B and q_d on an hourly basis is needed since q_B and q_d vary strongly during the day and collector efficiency is a function of the magnitude of q_i. Hence to arrive at a correct daily efficiency, a daily average must be formed using estimates or data for q_B and q_d on an hourly basis.

Only a few locations in the United States make hourly direct and diffuse solar insolation measurements. For the three locations considered in this report, only daily average solar radiation data are available. For estimating the hourly radiation from the available daily radiation data, the correlation developed by Liu and Jordan is utilitzed. The ratio of hourly to daily total radiation is denoted by r_t and the ratio of hourly to daily diffuse radiation is called as r_d. Values of r_t and r_d are generated, by Liu and Jordan, as a function of sunset hour angle W_s. Figure 19 shows the relationship between the daily radiation and hourly radiation on a horizontal surface.

In general, for either a flat plate or a concentrating collector, the useful energy collected can be cast into:

$$q_u = F\left[\rho\gamma\zeta\alpha q_i - \frac{U_L}{c}(\overline{T} - T_A)\right] \tag{5}$$

where

q_u = useful energy rate absorbed per unit area

q_i = incident energy rate

F = collector heat removal efficiency factor

ρ = specular reflectivity

γ = intercept factor

ζ = transmittance

α = solar absorptance

U_L = overall loss coefficient

c = concentration ratio

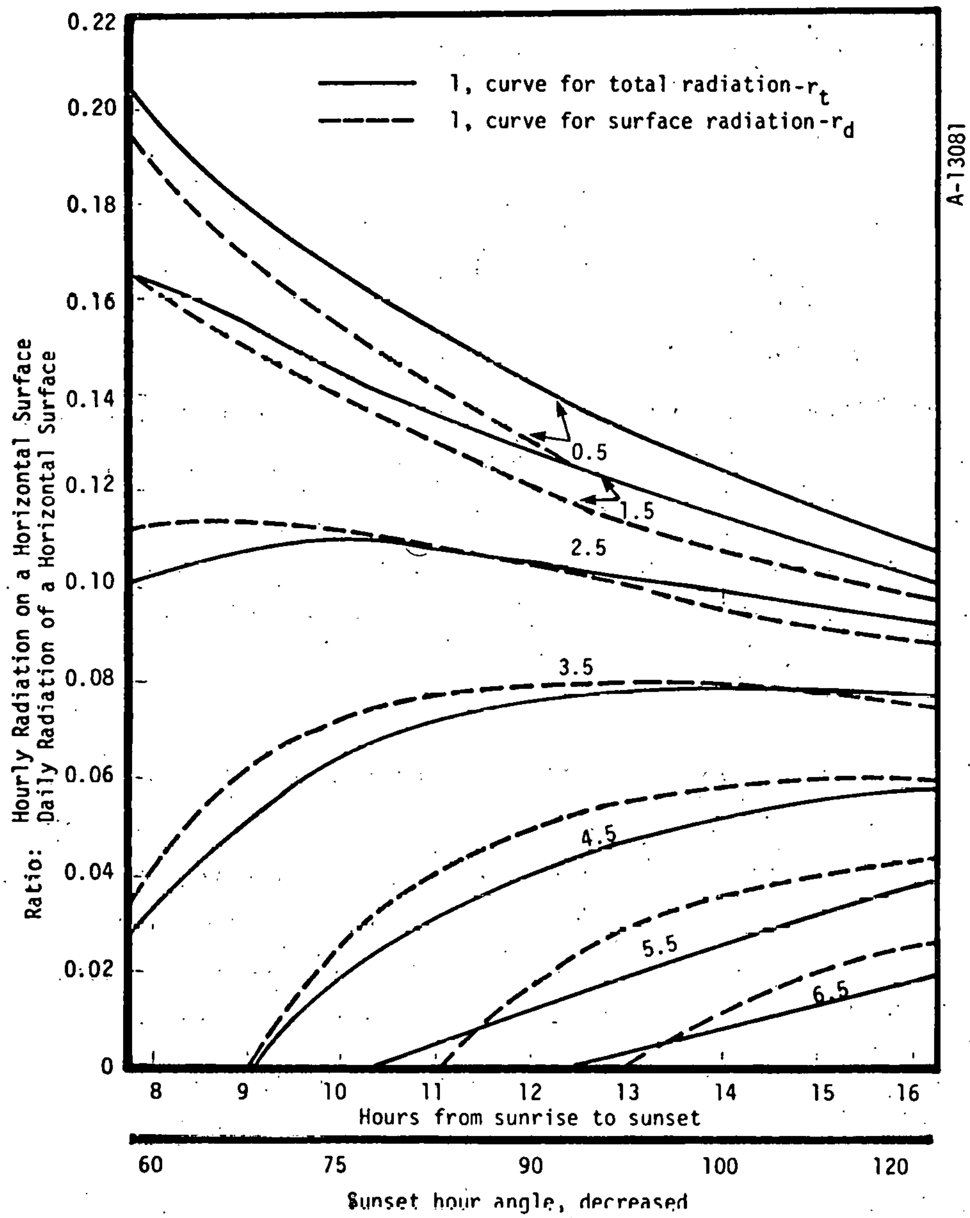

Figure 19. Correlation for estimating hourly radiation from daily radiation.

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C = 1 for flat plate collector

$\overline{T}$ = average fluid temperature

T_A = ambient temperature

In terms of efficiency, Equation (5) can be rewritten as:

$$\eta \equiv \frac{q_u}{q_i} = F(\rho\gamma\zeta\alpha - \frac{U_L}{C} F) \qquad (6)$$

where $$F = (\overline{T} - T_A)/q_i \qquad (7)$$

3.7.2 Specific System Performance Computation

Equations (1) through (7) are used in generating the hourly useful heat rates. Three representative locations are selected. The three locations are Sacramento, California; Omaha, Nebraska; and Albuquerque, New Mexico. Calculations are performed for six representative days.

The Solargenics flat plate collector has been selected for the design. For the particular flat plate collector design with an unselective, single glazed surface, the efficiency relation is:

$$\eta_{f \cdot p} = 0.7719 - 1.4325\ F \qquad (8)$$

(This efficiency relationship is lower than what has been guaranteed by the manufacturer. However, since data only exist for the Solargenics collector with a selective coating Aerotherm estimated the performance equation stated above. The quoated Solargenics curve is about 6 to 10 percent higher than the estimated curve. In order to be on the safe side, the lower of the two curves is being used here. Solargenics is in the process of testing their nonselective flat plate collection at Desert Sunshine and these data will be available before the collector is purchased.)

The concentrating collector selected is the Acurex/Aerotherm design. The measured efficiency relation for the concentrating collector is:

$$\eta_{conc} = 0.635 - 0.1125\ F \qquad (9)$$

In the preliminary design optimization, it was determined that the annual total incident energy is maximized when a surface is tilted at 10° less than the local latitude. Also, for the hot water yearly demand, an east-west tracking concentrator provides the most uniform energy supply.

Thus, for the proposed solar hot water system, the flat plate will be tilted at 10° less than the local latitude, and the axis of the concentrators will be oriented east-west.

The steps involved in computing hourly useful rates are as follows.

For the particular location of interest, latitude, L, and for the particular day of interest decliniation δ are known. Then:

- Sunset hour angle is calculated from

$$W_s = \cos^{-1}(- \tan L \tan \delta)$$

- Using W_s, values of r_t and r_d are obtained from Figure 1, as a function of hour angle from solar noon W, to estimate the hourly radiation from average daily radiation. Table 14 presents the average daily solar insolation values that are used in the calculation. Note that these values are the total and diffuse radiation on a horizontal surface. From the values of r_t and r_d, hourly values of insolation are estimated.
- Using hour angle from solar noon W, latitude L, declination δ, and tilt angle β, incidence angles on horizontal surface θ_z , and incidence angle on tilted surface θ_t are calculated.
- Using Equations (1) and (2), hourly values of $q_{f \cdot p}$ and q_{conc} are obtained.
- Using different assumed values of temperature difference ΔT, quantity F and hence the efficiency η for the flat plate and the concentrator are obtained with the aid of Equations (8) and (9).
- Using the calculated values of efficiency η, the hourly useful heat rates, q_u are obtained.
- For each selected day, the summation of these hourly useful heat rates, gives the daily useful heat rates, q_u, as a function of $(\bar{T} - T_A)$.
- For the known collector field size and inlet fluid temperature, the daily useful heat rates are obtained.

Table 15 presents the daily useful energy obtainable from the flat plate and concentrating collector fields at the three locations of interest.

TABLE 14. AVERAGE DAILY TOTAL AND DIFFUSE RADIATION DATA
($\overline{q}$ in MJ/m^2 day)

Day	Location					
	Sacramento, CA[a] (Latitude = 38.5°)		Omaha, NE[b] (Latitude = 40°)		Albuquerque, NM[b] (Latitude = 35°)	
	$\overline{q}_{total}$	$\overline{q}_{diff}$	$\overline{q}_{total}$	$\overline{q}_{diff}$	$\overline{q}_{total}$	$\overline{q}_{diff}$
Feb 21	10.73	4.12	11.3	5.5	15.1	3.3
Apr 21	22.24	6.20	18.2	9.0	22.5	6.2
Jun 21	29.73	6.36	23.3	9.3	26.1	4.3
Aug 21	25.97	3.71	19.9	8.1	22.8	6.8
Oct 21	14.63	4.26	13.3	5.2	16.3	4.6
Dec 21	6.25	2.76	7.3	2.7	11.1	0.9

[a]Data obtained from Liu and Jordan (Reference 1). Values reported for Davis, California are used.

[b]Data obtained from "Solar Radiation Availability to Various Collector Geometries: A Preliminary Study," SAND 76-009, February 1976. Author — Dr. Eldon Boes of Sandia Albuquerque Laboratories

TABLE 15. SYSTEM USEFUL ENERGY
Effective Flat Plate Collector Field = 4134 ft² (384.1 m²)
Concentrator Field = 2880 ft² (267.6 m²)

Day	Location					
	Sacramento		Omaha		Albuquerque	
	q_u		q_u		q_u	
	MBtu/Day	MJ/Day	MBtu/Day	MJ/Day	MBtu/Day	MJ/Day
Feb 21	3.57	3765	2.63	2773	5.59	5895
Apr 21	6.57	6928	4.54	4787	6.44	6791
Jun 21	9.17	9670	6.49	6844	8.55	9016
Aug 21	8.79	9269	6.29	6633	7.63	8046
Oct 21	6.29	6633	4.86	5125	6.93	7308
Dec 21	2.59	2731	3.20	3374	5.83	6148
Annual Average Daily	6.16	6496	4.67	4925	6.83	7201
Average Total Yearly (Average Daily x 365)	2.25×10^9 Btu	2.37×10^6 MJ	1.70×10^9 Btu	1.79×10^6 MJ	2.49×10^9 Btu	2.63×10^6 MJ

REFERENCES

1. Liu, B. Y. H. and Jordan, R. C., "The Long-Term Average Performance of Flat Plate Solar-Energy Collectors," Solar Energy, Vol. 7, No. 2, 1963.

2. Liu, B. Y. H. and Jordan, R. E., "The Interrelationship and Characteristic Distribution of Direct, Diffuse, and Total Solar Radiation," Solar Energy, July 1960, pp. 1-19.

3. Klein, S. A., "TRNSYS, A Transient Simulation Program," Engineering Experiment Station Report 38, Solar Energy Laboratory, University of Wisconsin, March 1976.

4. "Solar Industrial Process Hot Water Program," Aerotherm Proposal 2307-76-A, prepared for ERDA RFP PMEP 1, January 1976.

5. Hoerner, Fluid-Dynamic Drag, Hoerner, Midland Park, N. J., 1958, pp. 3-16 to 3-18.

6. Communication to Aerotherm by Bob Alvis, Sandia Laboratories, June 18, 1976.

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ATTACHMENT A

REQUEST FOR PROPOSAL TO INSTALL SOLAR COLLECTION SYSTEM AT CAMPBELL SOUP COMPANY SACRAMENTO, CALIFORNIA

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REQUEST FOR PROPOSAL REQUIREMENTS

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REQUEST FOR PROPOSAL REQUIREMENTS EXHIBIT B

SECTION 1

GENERAL CONDITIONS & SCOPE OF WORK

1.1 GENERAL

The specifications, together with the accompanying drawings, are intended to cover all the work (except such work as will be done by Acurex) to be done in connection with the construction of a Solar Hot Water Collection System at Campbell Soup Company, Sacramento, California.

The entire work when finished is to be delivered to Acurex in perfect condition to the satisfaction of the Senior Project Engineer (SPE).

The term "SPE" refers to Mr. Jorgen Vindum, of Acurex, located at 485 Clyde Avenue, Mountain View, California.

The term "Approved Equal" means approved by Acurex.

The term "Contractor" refers to the general contractor, or firm, or individual to whom the work has been awarded under the terms of the accompanying contract.

The law of the place of building shall govern the construction of this contract.

The Contract is formed by the following documents: The Contract Proposal, the General Conditions, the Drawings and the Specifications, including all modifications thereof incorporated in the documents before their execution.

The term "Work" in the contract includes labor or materials, or both.

All time limits stated in the Contract Documents are of the essence of the Contract.

The work items listed on the following pages and/or shown on the Drawings, including all work incidental thereto, shall be performed in accordance with the Drawings and the Contract for this work, of which the General Conditions and these Specifications form a part thereof.

The work to be performed under these Specifications will be interdependent with work of the other contractors. The Contractor will, therefore, properly conduct, cooperate and coordinate his work with theirs. Where any part of the Contractor's work depends, for proper execution or results, upon the work of another contractor, the Contractor shall inspect and promptly report to the SPE any defects in such work that renders it unsuitable for such proper execution and results. His failure to inspect and report shall constitute an acceptance of the other contractor's work as fit and proper for the reception of his work, except as to defects which may develop in other contractors' work after the execution of his work.

A predetermined schedule will be worked out for the modification of existing facilities. Contractor shall adhere to schedule and perform such work as necessary to construct footings and foundations for others to install structures thereon as hereinafter specified.

1.2 SCOPE OF WORK

The work items listed on the following pages and/or shown on the drawings, including all work incidental thereto, shall be performed in accordance with the drawings and the contract for this work, of which the general conditions and these specifications form a part thereof.

The wording "install" or "construct" where used above or hereafter in these specifications is all inclusive and is to mean furnishing labor, equipment, materials, etc., for a complete and finished job — except for equipment as specifically stated in these specifications and related drawings as being furnished by Acurex, however, Contractor will install the equipment being furnished by Acurex.

Contractor shall remove, modify, install erect and do all necessary work to complete all work called for on the drawings and/or these specifications.

1.3 CORRELATION AND INTENT OF DOCUMENTS

The Contract Documents are complementary and what is called for by any one shall be as if called for by all.

The intention of the documents is to include all labor and materials, equipment and transportation necessary for the proper execution of the work.

The Contractor shall carefully study all drawings, specifications and other instructions and shall report to the SPE any error, inconsistency or omission.

1.4 DRAWINGS & SPECIFICATIONS

Where variations from standard drawings of Acurex are indicated by special drawings, these shall be used jointly in the performance of the work as shown assembled in the General Arrangement Plan.

The SPE shall furnish, with reasonable promptness, necessary additional instructions, drawings, etc. All such drawings and instructions shall be consistent with the contract drawings and specifications and true developments thereof, and reasonably inferable therefrom. The work shall be executed in conformity therewith and the Contractor shall do no work without proper drawings or instructions.

After Acurex's acceptance of the Contractor's bid, the Contractor will be held to the performance of the work as interpreted by Acurex where any conflict between the drawings and specifications exists.

The Contractor shall keep one copy of all drawings and specifications on the work, in good order, available to the SPE.

All drawings and specifications furnished by Acurex are his property and are not to be used on other work, and are to be returned upon the completion of the work.

1.5 SHOP DRAWINGS

The Contractor shall submit with such promptness as to cause no delay in the work all necessary copies of shop or setting drawings, and the SPE shall pass on them with reasonable promptness. Acurex's approval of such drawings does not relieve the Contractor from responsibility for deviations from drawings or specifications or for errors of any sort.

1.6 MATERIALS, APPLIANCES, ETC.

Unless otherwise specified, all materials shall be new and of good quality.

The Contractor shall provide and pay for all materials, labor, water, tools equipment, light, power, transportation, concrete forms and other appliances necessary for the full performance of the work herein specified, except as any be otherwise specifically noted, and it is understood that Acurex may consider the submission of a bid hereon as assurance that the Contractor has determined, after careful investigation, that everything he is to provide will be readily available to him as when needed in the performance of the work.

1.7 EMPLOYEES

The Contractor shall not employ on the work any unfit person or anyone not skilled in the work assigned to him to perform.

The Contractor shall keep a competent foreman on this work during its entire progress.

1.8 SURVEY LINES & LEVELS

The General Arrangement Plan shall govern the staking out of the work. The Contractor shall establish all construction lines and grades in accordance with the information as shown on the Drawings or as instructed by the SPE in lieu of such information.

1.9 PERMITS, ORDINANCES, ETC.

The Contractor shall obtain all necessary building permits, temporary licenses, certificates of final tests, including certificates of occupancy where such certificates are prescribed by local or state ordinances, rules or regulations. He shall also secure all permits and make all necessary arrangements with city and public utility concerns for the removal or relocation of poles, trees, traffic signals, hydrants, catch basins and all other obstructions required by the new construction. He shall pay all lawful fees for such permits, certificates, etc., the cost of all such fees being included in the cost of the work.

He shall be responsible for failure to secure all permits and shall be responsible for any violations of Federal, State, local or other laws, ordinances and fire insurance regulations. If the drawings and specifications are at variance therewith, he shall notify the SPE in writing of any differences so that necessary changes may be made before the work is installed.

Copies of all permits shall be furnished Acurex before any work is started.

1.10 SUPERVISION

The SPE or his representative shall at all times have access to and power of inspection over the work, to accept materials and workmanship in his judgment satisfactory, or reject work and material not in accordance with the drawings and specifications. The Contractor shall provide proper facilities for such access and for inspection.

All directions given to the foreman shall be as binding as if given to the Contractor. Important directions shall be confirmed in writing to the Contractor.

1.11 INSPECTION AND TESTS

If the specifications, the SPE's instructions, laws, ordinances or any public authority require any work to be specially inspected, tested or approved, the Contractor shall give the SPE timely notice of its readiness for inspection, and if the inspection is by an authority other than the SPE, of the data fixed for such inspection.

He shall also arrange for all the necessary inspections of the work by all the interested departments or authorities and shall pay for all lawful fees for same.

If any such work shall be covered up without the consent of the SPE or interested public authority it must, if required by the SPE or interested authority, be uncovered for inspection at the Contractor's expense.

Copies of all certificates of inspection shall be furnished to Acurex at the completion of the work.

1.12 PROTECTION OF THE PUBLIC AND OF THE PROPERTY, RISKS, LIABILITIES, ETC.

The Contractor shall erect and maintain during the construction such temporary guard rails and other safety appliances as the laws or construction conditions require – all shall be securely constructed and meet with the requirements of the SPE.

The contractor shall continuously maintain adequate protection of all his work from damage and shall protect Acurex's property from injury arising in connection with this work.

He shall perform all work required to protect adjoining properties, streets, alleys, sidewalks, curbs, trees, shrubs, lawns, etc.

He shall provide and place all shoring and bracing needed to protect all work against settlement and shoreup all adjoining buildings as requried. All shoring to be left in place until need for same has passed.

The Contractor is to assume full responsibility for accidents to persons or damage to property, due to negligence by himself, his subordinates or sub-contractors; for encroachment on adjacent property; for loss by theft during the prosecution of the work and for authorized use of patented articles or processes.

He shall assume and agree to indemnity Acurex against all such losses.

1.13 CHANGES IN THE WORK

Acurex, without invalidating the contract, may order extra work, or make changes, by adding or deducting from the work, the contract sum being adjusted accordingly. All such work shall be executed under the conditions of tbe original contract, except that any claim for extension of time caused thereby shall be adjusted at the time of ordering such change.

No additions to or omission of work of any nature whatever shall be performed by the Contractor without written notice from the SPE.

Should additional work be necessary beyond that included in the contract or certain work omitted therefrom then the Contractor shall immediately submit a written bid in triplicate for the extra work or a credit for the work omitted and must not proceed without the written acceptance of the SPE.

1.14 DELAY

Neither Acurex nor Contractor shall be liable in damages or otherwise when the performance of its obligations hereunder is delayed by fire, storm, flood, war, rebellion, insurrection, riot, strike, failure of carriers to transport or furnish facilities for transportation, or for delay in delivery of materials to be furnished hereunder, when the supply of such materials or the facilities of production, manufacture, transportation, or distribution of them which otherwise would be available to the party in default are impaired by the order, requisition or necessity of any government or governmental authority, or when such delay is due to any cause whatsoever beyond the control of the party in default, whether similar to or dissimilar from the causes here enumerated. In the event of such delay in performance or delivery, the time in which to complete such performance or make such delivery shall be extended for the period of 60 days after the cause of such delay has ceased to exist.

1.15 CORRECTION OF WORK BEFORE FINAL PAYMENT

The Contractor shall promptly remove from the premises all materials condemned by the SPE or public authority as failing to conform to the contract, whether incorporated in the work or not, and the Contractor shall promptly replace and re-execute his own work in accordance with the contract and without expense to Acurex and shall bear the expense of making good all work of other contractors destroyed or damaged by such removal or replacement.

1.16 FAULTY MATERIALS OR WORKMANSHIP

Neither the final certificate nor payment nor any provisions in the Contract Documents shall relieve the Contractor of responsibility for faulty materials or workmanship, and, unless otherwise specified, he shall remedy any defects due thereto and pay for any damage to other work resulting therefrom, which shall appear within a period of 1 year from the date of completion. Acurex shall give notice of observed defects with reasonable promptness.

1.17 ACUREX'S RIGHT TO DO WORK

If the Contractor should neglect to prosecute the work properly or fail to perform any provision of this contract, Acurex, after 3 days written notice to the Contractor, may, without prejudice to any other remedy he may have, make good such deficiencies and may deduct the cost thereof from the payment then or thereafter due the Contractor.

1.18 ACUREX'S RIGHT TO TERMINATE CONTRACT

If the Contractor should be adjudged a bankrupt, or if he should make a general assignment for the benefit of his creditors, or if a receiver should be appointed on account of his insolvency, or if he should persistently or repeatedly refuse or fail to supply enough properly skilled workmen or proper materials, or if he should fail to make prompt payment to sub-contractors or for material or labor, or persistently disregard laws, ordinances or the instructions of the SPE, or otherwise be guilty of a substantial violation of any provision of the contract, then Acurex may, without prejudice to any other right or remedy and after giving the Contractor 7 days written notice, terminate the employment of the Contractor and take possession of the premises and of all materials, tools and appliances thereon and finish the work by whatever method he may deem expedient. In such cases the Contractor shall not be entitled to receive any further payments until the work is finished. If the unpaid balance of the Contract price shall exceed the expenses of finishing the work, such excess shall be paid to the Contractor. If such expense shall exceed such unpaid balance, the Contractor shall pay the difference to Acurex. The expense incurred by Acurex as herein provided, and the damage incurred through the Contractor's default, shall be certified by the SPE.

1.19 APPLICATIONS FOR PAYMENTS

The Contractor shall submit to the SPE an application for each payment and, if required, receipts or other vouchers showing his payments for materials and labor, including payments to subcontractors.

If payments are made on valuation of work done, such application shall be submitted at least 10 days before each payment falls due, and, if required, the Contractor shall, before the first application, submit to the SPE a schedule of values of the various parts of the work, including quantities, aggregating the total sum of the contract, divided so as to facilitate payments to subcontractors, made out in such form and, if required, supported by such evidence as to its correctness as the SPE may direct. This schedule, when approved by the SPE, shall be used as a basis for certificates of payment, unless it be found to be in error. In applying for payments, the Contractor shall submit a statement based upon this schedule and, if required, itemized in such form and supported by such evidence as the SPE may direct, showing his right to the payment claimed.

If payments are made on account of materials delivered and suitably stored at the site but not incorporated in the work, they shall, if required by the SPE, be conditional upon submission by the Contractor of bills of sale or such other procedure as will establish Acurex's title to such material.

1.20 PAYMENTS

The payments for work done under the contract effected by acceptance of this bid by Acurex shall be made in the following manner:

a. On the first day of each month Acurex shall pay to the Contractor a sum equivalent to 80 per centum of the value of the work completed by the Contractor and of materials suitably stored at the site, since the date of the last prior payment. At no time, however shall the total payments exceed 80 per centum of the entire value of the work completed in place. The above mentioned value of the work so completed shall be based on an estimate survey made by the SPE or covered by a statement rendered to the SPE by the Contractor, and checked and approved by the SPE.

b. Final payment of all sums then due the Contractor shall be made by Acurex within 30 days after:

   1. The completed work has been accepted by the SPE, the contract fully performed, and

   2. The Contractor has furnished satisfactory proof that he has paid all outstanding bills incurred by him for materials furnished or services performed.

1.21 PAYMENTS WITHHELD

The SPE may withhold or, on account of subsequently discovered evidence, nullify the whole or part of any certificate for payment to such extent as may be necessary to protect Acurex from loss on account of:

a. Defective work not remedied.

b. Claims filed or reasonable evidence indicating probable filing of claims.

c. Failure of the Contractor to make payments properly to sub-contractors or for materials or labor.

d. A reasonable doubt that the contract can be completed for the balance then unpaid.

When all the above grounds are removed certificates shall at once be issued for amounts withheld because of them.

1.22 INSURANCE PREMIUMS

The Contractor shall maintain such insurance as will protect him from claims under workmen's compensation acts and from any other claims for damages for personal injury, including death, and damage to property which may arise from operations under this contract, whether such operations be by himself of by any sub-contractor or anyone directly or indirectly employed by either of them. Certificates of such insurance shall be filed with Acurex, if they so require, and shall be subject to their approval for adequacy of protection.

Contractor agrees to and does hereby accept full and exclusive liability for the payment of any and all premiums, contributions and taxes for workmen's compensation insurance, unemployment insurance and for old age pensions, annuities and retirement benefits, now or hereafter imposed by or pursuant to federal and state laws, which are measured by the wages, salaries or other renumeration paid to persons employed by Contractor in connection with the performance of this contract and Contractor further agrees to indemnify and hold Acurex harmless against any liability for any such taxes or contributions which may be assessed against Acurex. Contractor further agrees to enter into any agreement that has been or may hereafter be prescribed by any federal or state governmental body or authority in order to effectuate the foregoing purposes.

1.23 GUARANTY BOND

Contractor will be required to furnish a financial statement and qualify to make surety bond or satisfy Acurex requirements as to the Contractor's ability to successfully complete the contract. At Acurex's option a surety bond will be executed and all premiums paid by Acurex.

1.24 LIENS

No installment payment or the final payment nor any part of the retained percentage shall become due until the Contractor shall deliver to Acurex a complete release of all liens arising out of this contract, or receipts in full in lieu thereof and, if required in either case, an affidavit that as far as he has knowledge or information the releases and receipts include all the labor and material for which a lien could be filed; but the Contractor may, if any sub-contractor refuses to furnish a release or receipt in full, furnish a bond satisfactory to Acurex, to indemnify them against any lien. If any lien remains unsatisfied after all payments are made, the Contractor shall refund to Acurex all monies that the latter may be compelled to pay in discharging such lien.

1.25 ASSIGNMENT

Neither party to the contract shall assign the contract without written consent of the other, nor shall the Contractor assign any monies due or to become due to him hereunder, without the previous written consent of Acurex.

1.26 SEPARATE CONTRACTS

Acurex reserves the right to let other contracts in connection with this work. The Contractor shall afford other contractors reasonable opportunity for the introduction and storage of their materials and the execution of their work and shall properly connect and coordinate his work with theirs.

1.27 SUB-CONTRACTORS

The Contractor shall, as soon as practicable after the signing of the contract, notify the SPE in writing of the names of his sub-contractors, and shall not employ any that the SPE may, within a reasonable time, object to as incompetent or unfit.

The Contractor agrees that he is fully responsible to Acurex for the acts and work of his sub-contractors and of persons either directly or indirectly employed by them.

Nothing contained in the Contract Documents shall create any contractual relation between the sub-contractor and Acurex.

1.28 RELATIONS OF CONTRACTOR & SUB-CONTRACTOR

The Contractor agrees to bind every sub-contractor and every sub-contractor agrees to be bound by the Terms of the Agreement, the General Conditions and the Drawings and the Specifications as far as applicable to his work.

1.29 SPECIAL GUARANTEES

The contractor shall obtain from the respective sub-contractors such guarantees as are particularly called for under the separate trades of the specifications. These guarantees shall extend to Acurex direct and shall be accompanied by similar guarantees from the Contractor, all in form and substance satisfactory to the SPE.

1.30 USE OF AND CLEANING UP OF THE PREMISES

The Contractor shall confine his apparatus, materials and operations of his workmen to limits indicated by law, ordinances, permits or directions of the SPE and shall not unreasonably encumber the premises.

He shall not load or permit any portion of the structure to be loaded with a weight that would endanger its safety, and he shall enforce the SPE instructions regarding signs, advertisements, fires and smoking.

The Contractor shall at all times keep the premises free from the accumulation of waste materials or rubbish no matter by whom caused and upon completion shall remove all debris, rubbish, tools scaffolding and surplus materials, repair any damage done to the work no matter how or by whom caused, leaving the premises clean and in perfect order and repair at the termination of his work.

1.31 MATERIALS FURNISHED BY ACUREX

It is agreed that the attached list of construction materials and equipment will be furnished by Acurex, delivered to the Contractor's Yard free of cost to the Contractor: (See Section 2).

The Contractor shall, however,

a. Install same or use same in the work in accordance with the intent and purpose of the drawings and these and/or the manufacturer's specifications.

b. Promptly inspect all such materials and equipment upon delivery to him and give prompt notice to Acurex of any shortages therein or damage or breakage thereto and assume entire responsibility for any such shortage or damage or breakage if such notice is not promptly given.

c. Assume entire responsibility for the safety of all such materials and equipment against loss by theft or otherwise or breakage or damage after same has been delivered at the site.

d. Make good at his own expense any such loss or breakage or damage occurring before the work is accepted by Acurex.

The Contractor shall notify the SPE or his local representative in cases of non-delivery of any part of the materials or equipment listed as furnished by Acurex, at least 2 weeks before he expects to use or install same.

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SECTION 2

EQUIPMENT

2.1 EQUIPMENT

Equipment to be furnished by Acurex and installed by the General Contractor, numbers coded according to Drawing Number 7234-030.

2.1.1 Control Valves

1	Solenoid Valve	1-inch Magnetrol Number 16L44 normally closed
5	Digital Valve	1-1/2-inch Digital Dynamics Inc. Number DD1 5-607 D-14
6	Flow Meter	1-inch Barton Series 500 w/308 Pulse Action Pak Number 7000
7	Thermal Element	1-1/2-inch RDF Corporation Type 21A 10A4A4B
15	Temperature Control Valve	1-inch Johnson Number 1550 D4
16	Solenoid Valve	1-1/2-inch Johnson Number 1550 D4
17	Local Pressure Indicator	Marshalltown Pressure Gauge P-500
21	Solenoid Valve	3/4-inch Johnson Number 250 D-3 normally closed
24	Solenoid Valve	2-inch Magnetrol Number 36L47 normally closed
25	Solenoid Valve	3/4-inch Magnetrol Number 14 LR43 normally open
26	Flowswitch	3/4-inch W. E. Anderson Flotec V6-EPB-B-S-2-D
27	Flowmeter	1-inch Morel Number 306
29	Flowswitch	2-inch W. E. Anderson Flotec V4-2
30	Flowswitch	1-1/2-inch W. E. Anderson Flotec V4-1-1/2
32	Tank Level Gauge	"Gems" Fibra Level 24550 Switch Kit (furnished and installed by Acurex).

2.1.2 Steam Trap

(See drawings)

2.1.3 Heat Exchanger

(See drawings)

2.1.4 Pump

(See drawings)

2.1.5 Accumulator Tank

(See drawings)

2.1.6 Floating Suction

(See drawings)

SECTION 3

SPECIFICATIONS FOR ASPHALTIC CONCRETE DRIVEWAYS AND SERVICE AREAS

3.1 GENERAL

Pavements shall be installed by a competent asphalt paving contractor, using skilled personnel.

Compaction of the subgrade shall be accomplished with a sheepsfoot or other approved tamping roller; a three wheel or tandem power roller weighing approximately 8 tons shall be used to compact the base courses and wearing surface. Areas adjacent to fill boxes, drains or other fixed objects, inaccessible to a roller, shall be compacted with hand tampers of the pneumatic or vibratory type on subgrade and base courses; with hand tampers weighing not less than 25 pounds on wearing surface.

All fill and backfill as hereinafter required shall be good clean earth, sand or gravel, free from rubbish or other foreign or organic matter, meeting the approval of the SPE.

3.2 PREPARATION OF SUBGRADE

All top soil shall be removed together with all unstable materials such as saturated subgrade soils, roots, logs, organic matter or other foreign undesirable materials and the area shall be brought to grade by excavation and/or filling as required.

All drains, catch basins, concreted areas, valve boxes, etc., as called for, shall be carefully set so that their finished elevation will be in proper relation with the given finished elevation of the top of the surrounding pavement. Small isolated concrete areas such as round gauge and fill boxes shall not be installed until after pavement is completed. This shall be the responsibility of the general contractor and if any changes must be made after the paving work is started, the expense must be borne by the general contractor whether paving work was sublet by him or let under separate contract.

The subgrade shall be thoroughly rolled and tamped, soft and weak spots shall be dug out and backfilled, depressions shall be filled and the subgrade re-rolled and retamped as required to obtain 95 percent of optimum compaction. Checks shall be made with a pneumatic or vibratory tamper to insure specified compaction in areas around underground tank holes, trenches and other filled areas.

Upon completion the subgrade shall present a firm, even surface free from weak spots, depressions or high spots compacted and finished within a tolerance of ± 1/2" to a depth below finished grade equal to the sum of the specified thicknesses of base courses and wearing surface.

There shall be no loose or uncompacted subgrade soils in the subgrade prior to placing the sub-base material.

3.3 ASPHALTIC CONCRETE (A.C.) DRIVEWAY

Pavement shall consist of a sub-base and/or base course and a wearing surface of compacted thickness as designated below:

Conditions	Sub-base	A.C. Base	Wearing Surface
All Paved Areas	4"	2"	1"

Before priming and before placing the sub-base, the sub-grade shall be stabilized to a depth of 6". The soil shall scarified to the 6" depth and be free from vegetation, large lumps or other objectionable matter and may be either existing material, material secured from other sources or a combination of the two. MC-3 asphalt shall be applied to the scarified area at the rate of 1-1/2 gallons per square yard and thoroughly mixed into the soil and aerated prior to compaction. The stabilized material shall then be rolled as required to obtain 95 percent optimum compaction. The same air temperature restrictions apply for MC-3 as given below for MC-1 prime coat.

3.4 SUB-BASE COURSE

The sub-base course shall be constructed of crushed stone, broken gravel or slag of uniform quality and acceptable to local highway departments in the area of the work, or combinations thereof meeting the following gradations:

Sieve Size	Percent Passing
2"	100.0
1"	70-100
No. 4	35-70
No. 200	3-12

The fraction passing the No. 40 sieve (soil binder) shall have a plasticity index not greater than 6 or the total aggregate shall have a Sand Equivalent Value of not less than 30.

Other similar materials which are approved and used by local highway department, city or town specifications or highway type base construction in the area of this installation may be substituted for those shown above. Also, clean bank run sand and gravel or other approved material having a bearing value of 75 psi or better may be used fo the sub-base.

The aggregate shall be thoroughly blended prior to placing. It shall be spread to uniform thickness in layers not exceeding 3" (when compacted) and shall be rolled and thoroughly compacted at the proper moisture content until material does not creep or wave ahead of roller and it is firm enough to support material trucks without displacing or shifting. Depressions and poorly compacted areas must be corrected by filling with the same type materials and re-rolling.

The finished surface of the sub-base must be firm, free from loose material and to grade a depth below finished grade equal to the specified thickness for the base and wearing course.

3.5 PRIME COAT

A prime coat of MC-1 Asphalt (0.2 to 0.4) gallons per square yard) shall be applied to the finished sub-base and allowed to cure prior to placement of the base course.

Prime coat shall not be applied when the air temperature is below 60°F and falling, but may be applied when the temperature is above 50°F and rising. Air temperature to be determined in the shade away from artificial heat.

3.6 ASPHALTIC CONCRETE BASE

The base or level-up course shall be hot plant mix asphaltic concrete from an approved plant capable of furnishing specification materials. The grade of asphalt shall be 85-100 penetration and the mix shall be in accordance with local State Highway specifications for fine graded level-up course. The asphaltic material shall be from 3.5 to 7 percent of the mixture by weight.

The base or level-up course shall be placed only when weather conditions are suitable. It shall be rolled and thoroughly compacted to 95 percent density. The thoroughly compacted and dry hard surface shall be given a tack coat of RC-2 Asphalt not to exceed 0.1 gallons per square yard. The tack coat shall be rolled with a pneumatic tire roller and allowed to cure prior to placement of hot mix asphaltic concrete wearing surface.

3.7 WEARING SURFACE

The wearing surface shall be hot plant mix asphaltic concrete form an approved plant capable of furnishing specification materials. The grade of asphalt shall be suitable for local climatic conditions (85-100 penetration or as required by local highway specifications). The mix shall be dense graded where available and shall be in accordance with the State Highway or City specification for hot mix wearing surfaces in the state or area where this installation is to be made. The number of the applicable specification will be furnished by the SPE.

All concrete surfaces against which the wearing surface will be placed shall be lightly coated with an RC-2 asphalt tack coat and the wearing surface rolled toward the concrete to insure a tight seal at the joint. The wearing surface mixture shall be placed uniformly high adjacent to all concrete driveway areas so that after compaction it will be 1/2" high above such adjoining concrete surfaces.

The wearing surface shall be installed only when weather conditions are suitable. It shall be rolled and thoroughly compacted to 95 percent density and uniform texture conforming to specified finished elevations with no irregularities exceeding 1/4-inch in 10 feet. Any irregularities or defects remaining after final compaction shall be corrected by complete removal and replacement of the surface course in the affected area.

At the direction of the SPE and as necessary to check the thickness, the contractor shall cut test holes not more than one per 1000 square feet (unless defects are found) and shall refill the test holes with acceptable materials properly compacted.

SECTION 4

HOT AND COLD WATER PIPING

4.1 SCOPE

This specification covers the conditions and requirements for fabricating and erecting hot and cold water piping systems and of piping materials as hereinafter stated.

4.2 GENERAL DESCRIPTION

This specification covers piping for hot and cold water systems, above ground only, including raw, filtered, carbon filtered, and reclaimed potable water. (Spinkler systems for fire protection and underground potable water systems must meet Associated Factory Mutual requirements, and are not covered by this Specification.)

Contractor shall furnish all equipment, labor and materials required to complete the pipework installation as shown on the Drawings, and as herein specified with the exception of the material furnished by Acurex. Contractor's equipment shall be adequate and servicable for the work required. In the event the condition of any of the Contractor's equipment is such that it would adversely affect the workmanship of the completed job or retard its progress, the equipment must be immediately repaired or replaced with equipment satisfactory to Acurex.

Where valves or fittings are furnished by Acurex, some will not include bolts, nuts, gaskets, or other materials related thereto.

Except where flanges occur in 4-inch or larger diameter piping, all fittings and pipe shall be connected by welding. Three inch diameter or small diameter piping and fittings shall be made up with screwed fittings and connections, except as may be noted or shown on the drawings and on the approval of the SPE.

Contractor shall promptly repair, to the satisfaction of Acurex, property damaged by him in the progress of his work. He shall provide safe and convenient temporary crossings over pipeline ditches where same is necessary.

4.3 JOB SITE DRAWINGS AND SPECIFICATIONS

Contractor will be furnished a sufficient number of complete Plans and Specifications to supply all sub-contractors with a minimum of one set. All sub-contractors must be furnished one complete set with specifications. Contractor shall require of his sub-contractors that they have this one set of plans and specifications with them on the job, together with any revised drawings at any time they are performing work.

In addition, contractor shall keep one working set of drawings and specifications with any revised drawings on job site at all times for SPE review. Also, contractor shall keep one set of drawings with any revised drawings on job site marked currently for as-built conditions.

Acurex will furnish all the sets of plans and specifications needed by contractor on written request.

4.4 DITCHING AND BACKFILLING

Contractor shall do all necessary ditching and backfilling and other excavating to install lines at the required depth.

Pipe shall be installed in ditch no closer than 6 inches to any other parallel line or cross line, whether said other parallel line is installed in the same ditch or otherwise. No extra payment will be allowed by reason of having to excavate the ditch to depths greater than required to meet the above specifications so that pipeline will pass under all other pipelines, drain lines, conduits, telephone cables, etc., encountered along the buried pipelines.

Contractor shall maintain all ditches and excavations clear and free from fall material, loose rock, etc. and/or obstructions caused by cave-ins, washes, slide or otherwise until the pipe is lowered and the ditch is ready for backfilling. Welding rod stubs shall not be discarded in the ditch nor in such a manner that they might be placed in the ditch during backfilling operations.

In the case where rocks, stones, or other hard materials are encountered in the bottom of the ditch, contractor shall excavate 3-inch deeper than otherwise required and shall place 3-inches of loose dirt, free from rock, stones or other hard materials, in the bottom of the ditch before installing the pipe.

The buried pipe shall be covered to a minimum depth of 6-inches with dirt that is free of rocks, stones, or other hard material. In the case where rocks, stones or other hard materials are encountered, the 6-inch covering over the pipe may be placed by hand, or other procedures, if first approved by the SPE.

4.5 UNDERGROUND PIPE PROTECTION

Contractor will furnish all material and labor and equipment to apply pipe wrapping. The material will be Tran-Tex VID-20, 6-inch wide applied half-lapped over tapebond adhesive primer; machine applied immediately after application of primer.

Prior to application of any primer or materials on the pipe, the contractor shall remove all moisture, oil, grease, rust, scale, dirt and other foreign material, preferably by sand blasting, or by solvent cleaning and/or wire brushing where necessary. Do not use solvents containing oily constituents for cleaning the pipe. Remove or clean smooth all metal burrs, projections or sharp points. As soon as practical after cleaning the pipe, contractor shall apply tapebond adhesive primer at the rate of approximately 300 square feet per gallon, allowing no bare spots. If any are required, use only non-oily thinners, such as Naptha, Exylene, Toulene, or equivalent. Apply the tape by machine wrapping. Maintain a firm tension, minimum of 5 pounds per inch of width, on the tape during application. Tape overlap shall be 3-inches or half-lap.

Field joints shall be primed and handwrapped to provide complete coverage of the tape over the metal surface. In the case of field joints, the tape wrap shall extend at least 6 inches over the adjacent pipe wrapping.

Contractor is to take all necessary precaution to protect wrapped pipe from damage. Damaged areas, where they do occur, shall be repaired with minimum of two turns of tape, which shall be wrapped as specified above. Damaged areas may be repaired by handwrapping. As many complete turns shall be used as is necessary to completely cover the damaged areas. Overlap onto joining undamaged areas by at least 2 inches.

In the event the contractor incurs an unnecessary large number of damages to the coating, the SPE, at his discretion, shall require coated pipe to be protected by wrapping with L.O.F. rock shield or equivalent. The shield shall be cigarette wrapped around the pipe and bound securely with 3/4-inch J-M Dutch Brand Number 400 Strapping Tape, ends to be butted.

Material and workmanship covered by this specification shall be subject to the inspection of the SPE and shall conform to all the requirements of this specification and/or Manufacturer's recommendations.

Contractor shall test all coated and wrapped pipe with an approved "Holiday Detector" of 7,000 to 8,000 volts, after all pipe, field joints, fittings and patches have been primed and wrapped. Any "Holidays" found shall be repaired immediately in a manner approved by the SPE.

Apparatus for detecting "Holidays" shall be supplied by contractor. Contractor must notify the SPE at least 72 hours prior to testing coated pipe to permit him to witness test.

4.6 CODES

Wherever State, Provincial or Municipal Codes have special regulations concerning material used or connections made, such regulations will apply to that specific area.

Federal codes or regulations covering water lines will also apply to specific areas.

4.7 PIPE AND NIPPLES

Size 3-1/2-inch, 5-inch, 7-inch, or 9-inch pipe shall not be used.

The use of 2-1/2-inch pipe shall be avoided where possible.

For both hot and cold water, pipe and nipples shall be Schedule 40, galvanized, ASTM-A-53 GR B.

For 3-inch pipe and larger, where local codes permit, use ASTM-A-53 GR B with welding fittings.

All pipe shall have the maker's name rolled on, and all nipples shall bear maker's distinguishing mark.

Sprinkler lines may be of steel and are covered by Factory Mutual Specifications.

For filtered hot and cold water use galvanized ASTM-A-53 GR B uncovered, and black or galvanized pipe.

Hot water pipe lines shall be installed with sufficient flexibility to provide for expansion and contraction due to temperature fluctuation.

Pipe for 4-inch headers and smaller, distributing branches to swing joints, etc., which cannot be covered, shall be galvanized ASTM-A-53 GR B pipe for appearance and cleanliness.

Pipe for welding shall be furnished with plain ends.

Pipe 2-inch and smaller may be hard streamline copper, type "K" for factory installations, type "L" for all general plumbing purposes.

Copper pipe and copper fittings are to be used only after obtaining approval of the SPE. The minimum weight per linear foot for this copper pipe shall be as follows:

Size	Weight	Size	Weight
3/8"	0.269	1-1/4"	1.04
1/2"	0.344	1-1/2"	1.36
3/4"	0.641	2"	2.06
1"	0.839		

4.8 BENDS

Bends shall be on a radius equal to five (5) times the diameter of the pipe. Tube turns, of radius equal to one and a half (1-1/2) times the diameter of tube, are to be used only where absolutely necessary, due to limited space, etc.

Bends 2-1/2-inch radius and smaller, with copper pipe, shall be Mueller extra heavy hard, streamline copper, type "K" for factory installations and type "L" for all general plumbing purposes.

4.9 JOINTS

In 2-inch piping and under, joints shall be welded or screwed. In piping over 2-inch, joints shall be flanged, using lap joint or slip-on welding flanges. Screwed flanges may be used with the approval of Acurex.

All threads on screwed piping shall be made with uniform taper, properly cut with sharp, clean dies.

Where streamline copper pipe is used, joints shall be sweated, using 50/50 wire solder and non-corrosive flux for this type of installation. Joints between iron pipe, screw fittings or valves shall be made only with streamline couplings or adapters.

4.10 GASKETS

Gaskets shall be ring type and fit neatly inside the bolt holes. Gasket material shall be Anchorite oil-proof sheet (rubber) packing, 1/16-inch thick, style 410, as manufactured by the Anchor Packing Company, Philadelphia, Pennsylvania and Elkhart, Indiana.

4.11 HANGERS AND GRADING, ETC.

Hangers shall be Grinnell adjustable wrought iron clevis hanger, Figure 260 or crane adjustable clevis hanger, Figure 239F, with pipe spacer on horizontal bolt added for all sized of pipe or approved equal.

In all production areas galvanized or stainless steel hangers shall be used. Pipe shall be graded 1/8-inch per 10 feet to low points for purpose of draining. Provide brass valve with nipple and cap at low points for draining and cleaning.

Hot water lines are to be graded upstream so that air in risers, mains and branches will be carried to a point of discharge.

4.12 COMPOUND

Compound used on pipe threads shall be "Seal Rite" as manufactured Mackson & Company, 125 Cedar Street, New York 6, New York, or "Pipetite Stick Compound" as manufactured by Lack Chemical Company, 3070 W. Carroll Avenue, Chicago, Illinois, or "Key Graphite Paste," as manufactured by the W.K.M. Division of American Car and Foundary, P.O. Box 2117, Houston, Texas. Only threads on pipe shall be coated. "Permacel" ribbon pipe dope is also acceptable.

4.13 FITTINGS (ASTM-A-53 GR B)

Fittings 2-inch and smaller shall be 125 pound American standard cast iron screwed, and over 2-inch shall be "yoloy" welding fittings. One hundred and twenty-five pounds American standard cast iron flanged, faced and drilled may be used if approved by SPE. Screwed fittings shall be black or galvanized to match adjacent pipe.

Fittings 2 inches smaller, used with copper pipe, shall be Mueller streamline copper, or approved equal.

4.14 UNIONS

Unions 2-inch and under shall be malleable iron 250 pounds railroad type, with brass to iron seats, hexagon ring and female screwed ends, Crane Figure 519 or approved equal. Unions shall be black or galvanized to match adjacent pipe.

4.15 FLANGES

In place of unions for pipe sizes over 2 inches, the 150 pound forged steel flanges, faced and drilled regular.

Unions with copper pipe shall be Mueller streamline copper.

4.16 SWING JOINTS

Swing joints shall be bronze "Chiksan" or bronze "Flexo" (90° elbow type) and will be used exclusively where there is regular need for a swing joint.

4.17 VALVES, CHECK

Check valves 2-1/2-inch and smaller shall be Jenkins, standard pattern, bronze, screwed swing, Figure 353. On cold water use a medium soft rubber disc 294-S, and on hot water use a semi-hard disc 110.

Valves 3 inches and over shall be Jenkins standard pattern iron body flanged swing check valves, Figure 295. On cold water use a medium soft rubber disc 294-S, and hot water use a semi-hard disc 110.

4.18 VALVES (GENERAL)

Valves 2-1/2-inch and smaller for cut-off purposes shall be Jenkins standard pattern bronze screwed gate valves. Stationary spindle and inside screw, Figure 370.

Valves 2-1/2-inch and smaller, for frequent use where tightness is essential, as on swing joints, etc., shall be Jenkins standard pattern bronze screwed globe valves, rising stem and inside screw, Figure 106-A. On cold water use a medium-soft rubber disc 294-S, and on hot water use a semi-hard disc 110.

Valves 3-inch and over for cut-off purposes shall be Jenkins standard pattern iron body flanged gate valves, bronze mounted, stationary spindle and inside screw, Figure 326 or OS&Y, Figure 651-A, as called for on Drawings.

Valves 2-inch and smaller with copper pipe, for cut-off purposes, shall be Jenkins bronze solder end gate valves, Figure 1240.

Valves 2-inch and smaller, with copper pipe, for frequent use where tightness is essential, as on swing joints, etc., shall be Jenkins bronze solder end globe valves, Figure 1200. On cold water use a medium-soft rubber disc, 294-S, and on hot water use a semi-hard disc 110.

Each main branch shall be provided with a cut-off gate valve of proper type.

Where more than one fixture is installed on a branch, each fixture will have its own cut-off valve, preferably a rising stem valve.

For hot and cold water supply to kettles use Crane "Accesso" ball valves, Catalog No. 2330-TF.

For fire protection lines, and where specified by the engineer in charge, outside stem and yoke valves are to be used. For 2-inch and 3-inch sizes, use Jenkins Figure 368, screwed, Figure 369, flanged; over 3 inches use Jenkins Figure 651-A, flanged.

4.19 VALVE CHAIN WHEELS

When called for, chain guides shall be provided for valves inaccessible from floor or platform, and shall be similar to those shown in Crane catalog 60, page 280. Babbitt wheels are not satisfactory and are not to be used.

4.20 INSULATION GENERAL

For pipe covering on water lines, see Specification attached.

All permanent cold water piping shall be covered to prevent sweating and the resultant corrosions of the outside of the pipe as well as drip on products and workers beneath pipe hung from ceiling. All permanent hot water piping shall be covered to prevent loss of heat by radiation. Covering on either hot or cold water piping beneath platforms that are washed down frequently must also be waterproofed.

All pipe to be insulated shall be run with sufficient clearance between adjacent pipe lines to permit application of insulation.

4.21 INSERTS.

Seven eights-inch inserts, usually on 4 feet centers are provided in the concrete ceilings of most of the buildings. They may be used by contractors only for piping 6-inch or larger in size unless permission is obtained in writing from Acurex. Contractors are expected to keep smaller pipe lines, conduits, etc., at least 8 inches clear, horizontally, of inserts so as not to interfere with structural supports for other equipment.

4.22 EXPANSION SHIELD ANCHORS (FOR ALL PIPE HANGERS)

Masonry anchors shall be self-drilling tubular expansion shell bolt anchors, with an externally slit expansion shell and a single-cone expander, conforming to Federal Specification FF-S-325, Group 3, Type 1, Para. 3.2.3.1.1, of an approved type, or equal, as listed below:

"Red Head', Phillips Drill Co., Michigan City, Indiana

Pipe Size	Bolt Diameter
2"*	3/8"
3"*	1/2"
4"*	5/8"
6"*	3/4"
8"*	7/8"**

* Intermediate sizes take next larger size
** If inserts are not available

No gunshot inserts are to be used.

4.23 SLEEVES

Sleeves shall ordinarily be made of standard black steel pipe. Wall and floor sleeves shall always have an inside diameter 2-1/2-inch (or more) greater than the outside diameter of the pipe passing through to allow for insulation.

Floor sleeves shall project 3 inches minimum above top of finished floor. If cut through waterproof floor, care must be taken that waterproofing is brought up around sleeve to maintain tightness of membrane. In manufacturing areas, 6-inch and 8-inch diameter pipe sleeves are suggested, regardless of the size of pipe being installed, to allow for future changes.

4.24 CLEANING

The inside of all pipes, valves and fittings shall be left smooth, clean and free from blisters, loose mill scale, sand and dirt. To assist in assuring this, no pipe is to be stored on the ground and, prior to erection, each piece of pipe shall be held in an incline position and hammered to loosen scale and foreign matter.

Open ends of mains shall be plugged or capped during all shut-down periods. Pipe lines shall not be left open at any place where foreign matter might accidentally enter pipe.

All pipe lines shall be blown or flushed out prior to placement in service, and all valves checked to be free of foreign material prior to closing of valve.

4.25 TESTING

All piping is to be tested for tightness before insulation is applied. Hydrostatic test pressure shall be at least 1-1/2 times normal operating pressure. All work shall be satisfactorily tested under normal plant operating conditions for a period of six (6) days before acceptance by Acurex. Contractor shall correct any leaks or other defects in his work which may develop during the testing or during the period of his guarantee.

4.26 DEVIATIONS

Deviations from this specification will be permitted only when approved in writing by the SPE, Acurex Corporation.

4.27 NOTICE TO CONTRACTORS

Contractors must never open or close valves in old piping in order to make new connections. This is necessary to prevent interruptions to production, accidents, etc.

4.28 GUARANTEE

Contractor is to guarantee the above against defects in workmanship and material for a period of 1 year from date of receipt and accpetance, and should any defects develop within that period, contractor must make a replacement satisfactory to Acurex without charge.

SECTION 5

STEAM & CONDENSATE PIPING

5.1 SCOPE

This Specification covers the conditions and requirements for fabricating and erecting standard equipment for steam and condensate piping systems of materials as hereinafter stated.

5.2 GENERAL DESCRIPTION

Under this heading the Specification covers piping for vessels operating up to 250 pounds per square inch. This includes high and low pressure piping, boilers 110-250 psi, blending kettles 90-100 psi, steam hoses 90 psi, retorts operating at various pressures from 30 psi to 90 psi, digesters 75 psi, broth kettles 42 psi, and header systems 1-1/2 to 25 psi.

5.3 CODES

All piping installations shall follow the latest revision of the American Standard Code for Pressure Piping, ASA B31.1, in so far as practicable, with due regard for general requirements for anchorage, sway bracing and guides.

5.4 PIPE AND NIPPLES (for SLEEVES, see Section 5.17 of this Specification)

Sizes 3-1/2", 5" 7", or 9" pipe shall not be used. Where 5" pipe is called for, as on certain centrifugal pumps, "reducer" pieces, 5" to 6", shall be used to make pipe connections.

The use of 2-1/2" pipe is to be avoided wherever possible.

For Steam, pipe sizes through 1-1/2" shall be (extra heavy) Schedule 80, pipe sizes 2" and above shall be (full weight) Schedule 40, black steel pipe, "National", or approved equal, to latest revision of ASTM Specification A-53, Grade B, Type E or S. "Yoloy" may be used as an alternate for black steel pipe.

For Condensate, pipe sizes through 1-1/2" shall be (extra heavy) Schedule 80, pipe sizes 2" and above shall be (full weight) Schedule 40, "Yoloy" pipe.

Pipe for welding shall be furnished with plain ends.

5.5 BENDS

Wherever possible, bends shall be on a radius equal to five (5) times the diameter of the pipe, unless otherwise specified. Tube Turns may be used when specific limitations prohibit the use of bends.

5.6 JOINTS

For 2" and under, joints in piping shall be welded or screwed. Over 2", joints shall be welded or flanged, using lap joint or slip-on welding flanges.

5.7 GASKETS

Gaskets shall be ring type and fit neatly inside the bolt holes, cut from Anchorite graphited fibre sheet (asbestos) packing, 1/16" thick Style 424, as manufactured by the Anchor Packing Company, Philadelphia, Pennsylvania and Elkhart, Indiana.

5.8 HANGERS

For 6" pipe and smaller, pipe hangers shall be Grinnell adjustable wrought steel clevis type Fig. 260, or Fee and Mason Fig. 239 with pipe spacer on horizontal bolt added for all sizes of pipe.

For 8" pipe and larger, use two (2) adjustable rod hangers with pipe rolls, Grinnell Fig. 171 or adjustable pipe roll stands.

Pipe near floor may be supported on pipe standards with base flange and adjustable top yoke.

All horizontal pipe shall have hangers or supports having a maximum spacing in accordance with American Standard Association Code (Maximum 5 feet for 1/2" pipe, up to 22 feet for 10" pipe), Section 6 ASA B 31.1, latest revision.

All hangers and hanger rods to be of galvanized material. All nuts on hangers to be fiber lock nuts.

5.9 COMPOUND

"Pipetite" manufactured by Lake Chemical Company
3052 West Carroll Avenue
Chicago, Illinois 60612

Contains no lead, non-toxic, contains no injurious ingredients.

Provides positive seal for gasoline, oil, ammonia, propane, butane, refrigerants, air, gas, acid, brine, water, and steam.

Withstands pressure to 10,000 psi., temperature to 750°F.

Key Graphite Paste manufactured by W-K-M Division
ARF Industries
P.O. Box 2117
Houston 1, Texas

For sealing screw-thread, flange and gasket joints on steam, gasoline, kerosene, vapor, creosote, tar, gas, hot oil, hot vaseline, air, and acid lines.

5.10 FITTINGS

Fittings 2" and smaller up to 125 pounds pressure shall be 125# American Standard, black, cast iron, screwed, for pressure 126# to 250# American Standard black cast iron screwed. Over 2", fittings shall be standard Yoloy welding fittings.*

5.11 UNIONS

Unions 2" and smaller shall be black malleable iron, 250 pound railroad type, with brass to iron seats, hexagon ring and female screwed ends, Crane Fig. 519, or approved equal.

5.11.1 <u>Flanges</u>

In place of unions for pipe sizes over 2" use 150 pound forged steel flanges, faced and drilled regular. For operating pressures below 150 PSIG and 300# forged steel flanges, faced and drilled regular for operating pressures from 151 PSIG to 300 PSIG.

5.12 TRAPS

Traps for steam headers and bleeders are to be Illinois Eclipse No. 30 or Series 61, and for process equipment Illinois Eclipse, Series 61, or Nicholson Industrial Type with bronze bellows, solid filled.

The pipe from the kettle, coil or header to the trap should be one size larger than the tapped outlet of the trap, if possible. Use a reducing fitting just ahead of the trap.

Traps for hot water heaters, air heating coils and unit heaters on 70 pound steam or less shall be Illinois bucket type traps, No. 30 or Series 61, as required, with separate external Illinois thermostatic air by-pass (No. 1 MG for 1/2" service, No. 3 MG for 3/4" service, No. 5 MG for 1" service).

5.13 VALVES

Gate valves shall be used only where indicated; for 4" and over they shall be O.S. & Y. type, when clearance permits.

* ASTM-A-53 Grade B acceptable substitute

Glove or angle valves shall be used for other services, especially where throttling is necessary. All valves 8" and over shall be provided with by-pass.

5.13.1 Header Service

Each main branch shall be provided with a cut-off valve.

Sizes 3" and over, globe, up to 125 psi - Jenkins Fig. 142 iron body, flanged, bronze mounted with yoke, rising stem, No. 269 bronze disc.

Sizes 2-1/2" and smaller - globe - to 125 psi - Jenkins Fig. 106A with No. 1120 hard rubber fibre disc.

Sizes over 3" - globe - 125 to 250 psi - Jenkins Fig. 923 with extra heavy flanges - No. 269 bronze disc.

5.13.2 Low Pressure and Condensate

Under 30 psi use gate valves, except for throttling, tight shut-off, drains and trap by-passes. Check valves shall be installed between traps and return headers, gate valves shall be used between check valves and return header, valve stem to be drilled and wired open with 0.0475" copper wire and sealed with sprinkler valve seal.

Sizes 2-1/2" and smaller, gate, Jenkins Fig. 370 - screwed with No. 1120 hard rubber fibre disc.

Sizes over 3" - Jenkins Fig. 651-A - flanged with No. 269 bronze disc
Jenkins Fig. 326 - flanged with No. 269 bronze disc

NOTE: Use OS and Y types when clearance permits, for sizes over 3".

5.13.3 Safety Valves

Safety valves shall be installed at all pressure reducing stations, for back pressure on main lines, retort headers, etc.

Safety valves are to be selected to relieve the maximum quantity that can be generated or supplied to the attached equipment without permitting a rise in pressure within the vessel of more than 10 percent above the maximum allowable working pressure when the safety valve is blowing.

Select the safety valve for the quantity to be relieved and the valve to be set for the maximum allowable working pressure stamped on the vessel.

Comply with the ASME Code and the equipment manufacturer's requirements.

The following valves are recommended:

A. Sizes (1" x 2") to (6" x 8") iron body, bronze trim, angle pattern Series 72, Page 24, Marine and Industrial Products Co., North Wales, Pa.

B. Sizes (1-1/2" x 2") to (6" x 10") iron body, stainless steel trim, angle pattern, Figure 1902, Dresser Industries, Inc., 1967 Catalog, Page 37.

5.13.4 <u>Check Valves</u>

Sizes 2-1/2" and smaller - Jenkins Fig. 92A - bronze screwed.

Sizes 3" and over - Jenkins Fig. 624 - iron body, flanged. These check valves to have proper disc or plug, according to service.

5.13.5 <u>Reducing and Pressure Control Valves</u>

For dead-end service and constant load - Leslie L-3, or Leslie GPK-1, as called for on the Drawing. Valves are stainless steel fitted with stellited seat rings.

For variable load and more exact control - Leslie D-3 with air operated pilot valve Type PRA.

5.13.6 <u>Temperature Control</u>

For hot water heaters use a temperature controller, Taylor Catalog No. P-7RR114 with an air filter, Taylor Catalog No. R39S17, reducing valve, Taylor Catalog No. R41S323, and a cast iron body, reverse acting single seated, V-port motosteel control valve with stainless steel trim (example for 4" size - Taylor Catalog No. 20VD237).

5.13.7 <u>Heating System</u>

Radiator valves - 2" and smaller, manual - Jenkins Fi.g 167, globe - Fig. 168, angle.

Controls in production areas shall be pneumatic type, Minneapolis-Honeywell, Johnson Service, or approved equal.

Automatic radiator valves are to be Fulton Sylphon No. 885 or Minneapolis-Honeywell VO 501A.

5.14 VALVE CHAIN WHEELS

Valve chain wheels with chain guides shall be provided for valves inaccessible from floor or platform, and shall be similar to those shown in Crane Catalog 60, page 280. Babbitt wheels are not satisfactory and shall not be used.

5.15 STANDARD HOSE CONNECTIONS

The standard Strahman hot and cold water mixing and hose station shall have the hot water supply on left when facing the station with control valves installed 4'-9" above floor.

The standard steam and cold water hose station using the Sellers Type "B" high pressure jet for cleaning requirements shall have the jet set at 4'-0" above floor with steam connection on top and cold water connection on bottom and with solvent control, overflow and discharge connections adjacent in jet.

5.16 ERECTION

Piping shall be properly aligned and free of dirt and scale when installed, and shall be kept clear during progress of work, closing open ends temporarily as necessary. For changes in size, reducers or reducing fittings shall be used. Bushings will not be permitted.

5.17 SLEEVES

Sleeves shall ordinarily be made of standard black pipe. Wall and floor sleeves shall always have an inside diameter 2-1/2", (or more) greater than the outside diameter of the pipe passing through to allow for insulation.

Floor sleeves shall project 3" above top of finished floor. If cut through waterproof floor, care must be taken that waterproofing is brought up around sleeve to maintain tightness of membrane. In manufacturing areas 6" and 8" sleeves are to be used, regardless of the size of pipe being installed, to allow for future changes.

5.18 INSERTS

Standard 7/8" inserts, usually on 4'-0" centers, are provided in the concrete ceilings of most of the buildings. They may be used by contractors only for piping 8" or larger in size unless permission is obtained in writing. Contractors are expected to keep smaller pipe lines, conduit, etc. at least 8" clear horizontally of inserts so as not to interfere with structural supports for other equipment.

5.19 EXPANSION SHIELD ANCHORS (for all Pipe Hangers)

Masonry anchors shall be self-drilling tubular expansion shell bolt anchors, with an externally slit expansion shell and a single-cone expander, conforming to Federal Specification FF-S-325, Group 3, Type 1, Para. 3.2.3.1.1, of an approved type, or equal, as listed below:

"Red Head", Phillips Drill Co., Michigan City, Indiana

Pipe Size	Bolt Diameter
2"*	3/8"
3"*	1/2"
4"*	5/8"
6"*	3/4"
8"*	7/8"**

* Intermediate sizes take next larger size
** If inserts are not available.

No gun shot inserts are to be used.

5.20 CLEANING

The inside of all pipes, valves, and fittings shall be left smooth, clean, and free from blisters, loose mill scale, sand, and dirt, and blown out with air before being placed in service.

5.21 CONTRACTORS

Contractors shall never open or close valves in old piping. This is necessary to prevent interruptions to production, accidents, etc., and must be strictly observed.

5.22 TESTING

All piping shall be tested for tightness before insulation is applied. Hydrostatic test pressures shall be at least 1-1/2 times the normal operating pressure. Steam and return lines shall also be tested under normal steam pressure for 25 hours before insulation is applied. All work shall be satisfactorily tested under normal plant operation conditions for a period of six (6) days before acceptance by Acurex. Contractor shall correct any leaks or other defects in his work which may develop during the testing or during the period of his guarantee.

5.23 GENERAL

Deviations from this Specification are permitted only when approved in writing by the SPE, Acurex Corporation.

5.24 GUARANTEE

Vendor is to guarantee the above against defects in workmanship amd material for a period of 1 year from date of receipt and acceptance at the plant and should any defects develop within that period, contractor must make a replacement satisfactory to Acurex without charge.

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SECTION 6

SPECIFICATION FOR PIPE COVERING AND PIPE LINE IDENTIFICATION

6.1 SCOPE

This Specification covers the conditions and requirements for all pipe coverings, in the following sections:

- Steam Piping
- Condensate Piping
- Hot and Cold Water and Drain Piping
- Cold Pipe Lines, -50° to +75°F
- Pipe Line Identification
- Alternates

6.2 STEAM PIPING

Covering for steam piping shall be Armstrong sectional "LK-12" calcium silicate, or approved equal, held in place with pasted muslin jacket and finished with an 8-ounce pasted canvas jacket.

For inside waterproof covering, omit the pasted canvas cover and apply a tight spiral wrapping of Scotch Brand 471, or approved equal, white plastic pressure sensitive tape, with a minimum 50 percent overlap.

All flanges, unions and valve bonnets, etc., indoors, shall be left uncovered up to and including 6 inches. Flanges 8 inches and over, indoors, shall have substantial removable molded insulated covers, when specially ordered.

For outside waterproof covering, wire "LK-12" insulation, or approved equal, in place with 0.047 SST wire, using three wires per insulation section (3 ft). Finish with double-coated Flextone roofing paper wired on with 0.047 inches SST wire on 4-inch centers and, in addition, cover flanges, unions and valve bonnets separately and then seal all joints.

Size Pipe	To 50 psi	50 to 175 psi to 400°F	175 psi and over 500°F	600°F
1/2 in to 1-1/2 in	1 in	1 in	2 in	1-1/2 & 1-1/2
2 to 3-1/2	1	1-1/2	2	1-1/2 & 1-1/2
4	1	1-1/2	2	1-1/2 & 1-1/2
6	1	2	1 & 1-1/2	1-1/2 & 2
8 to 10	1-1/2	2	1 & 1-1/2	1-1/2 & 2
12 and over	1-1/2	2	1-1/2 & 1-1/2	1-1/2 & 2

*Superex molded sections or approved equal

6.3 CONDENSATE PIPING

Covering for condensate (or trap return) piping shall be omitted except where workers might get burned by taking hold of it or rubbing against it. Under these conditions the exposed section will be covered. Vertical condensate pipe is to be covered from the floor to 7 feet above the floor or operating platform.

Covering shall consist of 1-inch thickness Armstrong section "LK-12" calcium silicate, or approved equal, held in place with pasted muslin jacket and finished with an 8-ounce pasted canvas cover.

For inside waterproof covering omit the pasted canvas cover and apply a tight spiral wrapping of Scoth Brand 471, or approved equal, white plastic pressure sensitive tape, with a minimum of 50 percent overlap.

For outside waterproof covering wire "LK-12" insulation, (Johns-Manville, etc.) or approved equal, in place with 0.047-inch SST wire, using three wires per insulation section (3 ft). Finish with double coated Flextone roofing paper wired with No. 14 B&S solid copper wire on 4-inch centers and, in addition, seal all joints.

All flanges, unions and valve bonnets shall be left uncovered if waterproof covering is not used.

6.4 HOT AND COLD WATER AND DRAIN PIPING

Hot and cold water and drain piping are covered to prevent sweating or to prevent freezing. Insulate with 1/2-inch wall thickness, flexible, foamed plastic, closed cell, pipe insulation, Armstrong "Armaflex 22", or approved equal. (Temperature limit for this material is 200°F.)

6.4.1 Application

"Armaflex 22" insulation shall be slipped on the pipe prior to erection wherever possible and butt joints sealed with Armstrong 520 adhesive. Where the slip-on technique is not possible, the "Armaflex 22" insulation shall be slit and applied to the pipe with longitudinal seams and butt joints sealed with 520 Adhesive.

Fitting cover insulation shall be fabricated and installed according to the manufacturer's recommended procedures. Sweat fittings shall be insulated with miter-cut pieces of "Armaflex 22" pipe insulation, the same size as on adjacent piping. Screwed fittings shall be insulated with sleeved fitting covers fabricated from miter-cut pieces of "Armaflex 22" pipe insulation according to the manufacturer's sleeving size recommendations, overlapped and sealed to the adjacent pipe insulation. All valves shall be insulated with "Armaflex 22" pipe and sheet insulations. All joints and miter-cut pieces shall be sealed with 520 Adhesive, or approved equal.

At outside carrying hanger locations, nominal 1/2-inch wall thickness Armstrong rigid "Armaflex" pipe insulation shall be installed and protected with 28-gauge galvanized sheet metal shields for pipe sizes smaller than 1-1/2-inch IPS and 26-gauge for pipe sizes 1-1/2-inch IPS and larger. All joints and seams shall be sealed with two coats of 520 Adhesive, or approved equal.

6.4.2 Finish

All exposed pipe insulation shall be finished with two coats of Armstrong "Armaflex Finish" or approved equal, color to be as specified in Pipe Line Identification, Section 6.

6.5 COLD PIPE LINES -50°F TO +75°F (Includes Chilled Water, Brine and Refrigerant Pipe Lines)

Lines above 30°F shall be insulated with "Armaflex 22", or approved equal, applied and finished according to the procedures specified in Section 4 of this Specification. Insulation thickness shall be as shown in following table. Other materials shown in table may be substituted if there is economic justification.

Lines below 30°F shall be insulated with either polystyrene or polyurethane in accordance with insulation manufacturer's recommendations and following table. Minimum density of insulation should be 1.7 lbs per cubic foot in either case. Insulation shall be provided with Kraft backed aluminum foil vapor barrier. All insulation joints shall be sealed with joint sealer such as Foster "Foamseal" 30-45 or 81-33, or approved equal. Seal aluminum foil jacket with Foster 82-07, or approved equal, adhesive using 4-inch wide strips at circumferential joints. Secure with bands of aluminum, stainless steel or pressure sensitive tape not less than 4 bands every 3 feet.

Finish indoor lines with vinyl-type covering. Finish outdoor lines with Childers 0.006-inch aluminum jacketing banded every foot.

Valve and fitting insulation shall be factory or field fabricated from same material and thickness as pipe insulation. If field fabricated, they shall be carefully and neatly made in accordance with manufacturer's instructions. Particular care must be taken to positively vapor seal all joints at valves and fittings. Valve stems, strainer caps, etc. must be left exposed for service. The vapor seal at these exposed surfaces shall be protected against normal service damage.

Finish for fittings and valves shall be the same as pipe insulation using strips of vapor barrier set with Foster 82-07 adhesive and canvas "Insulcolor" finish for inside work. Outside work shall be finished with two coats of Foster 30-70 "Lagtone" using "Lag-fab" cloth.

INSULATION THICKNESS CHART

Pipe Fluid Temp., °F	Armaflex	Polyurethane*	Polystyrene*
+50 to 75	1/2"	1/2"	1"
+30 to +49	3/4"	1"	1-1/2"
-10 to +29	-	1-1/2"	1-1/2" up to 3/4" IPS 2 for 1" to 4" IPS 2-1/2 for 6" IPS and up
-50 to -11	-	2" up to 1-1/4" IPS 2-1/2" for 1-1/2" to 4" IPS 3" for 6" IPS and up	2" up to 3/4" IPS 2-1/2" for 1" to 2-1/2" IPS 3" for 3" to 6" IPS 3-1/2" for 8" IPS and up

*Minimum density 1.7 lbs per cubic foot, based on 90°F, ambient, 85 percent relative humidity.

6.6 PIPE LINE IDENTIFICATION

a. Pipe line identification shall conform to the United States of America Institute's Standard 13.1-1956 "Scheme for the Identification of Piping Systems." This scheme is limited to to the identificaiton of piping systems in industrial plants, not including pipes buried in the ground, and electrical conduits. Fittings, valves and pipe coverings are included, but not supports, brackets or other accessories. Piping systems under this Standard are classified by the nature of the material carried. Each system is placed, by the nature of its content, in one of the following classifications:

Class	Color
F = Fire Protection, Materials and Equipment	Red
D = Dangerous Materials	Yellow

Class	Color
S = Safe Materials	Green
P = Protective Materials	Bright Blue
V = Extra Valuable Materials	Deep Purple

By way of explanation, the "P" and "V" symbols as used in the Standard are defined as follows:

1. "P" (Protective Materials) are those piped through plants for the express purpose of being available to prevent or minimize the hazard of the dangerous materials (which are flammables, toxic, corrosive at high temperatures and pressures, productive of poisonous gases or in themselves poisonous).
2. "V" (Extra Valuable Materials) are those piped through the plant to various processing stations which, in themselves, are extremely valuable as or toward end products. (These would include such pipelines as broth, sauce and juice lines, soup, gravies, emulsions, milk, etc.)

b. All main piping, concealed (but not underground) or exposed, except branch lines from mains to points of service outlet, are to be identified by means of self-sticking pipe markers and banding tape. Pipe markers are to be the self-adhering Type B-500+, Perma-Code Pipe Markers with Color-Code Pipe Banding Tape, as manufactured by the W.H. Brady Co., 727 W. Glendale Ave., Milwaukee, Wisconsin. Markers to be placed on the pipelines so they can be readily identified from the floor, banded with corresponding color tape at each end of marker.

c. Pipe markers and banding tape shall be applied in the following locations:

1. At each valve
2. At every tee connection
3. At each point of exit and entry where pipe passes through wall, floor, partition or ceiling
4. On long continuous runs of pipe, every 50 feet (max), except "non-potable water" and "cooling water" which must be every 20 feet.
5. An arrow marker adjacent to each pipe marker with the arrow showing direction of flow and pointing away from the pipe marker. Use double-headed arrow if flow in pipeline can be in both directions.

d. All pipe markers and banding tape are to be applied where view is unobstructed and the legend can be easily read and identified. All markers and tape are to be applied in strict accordance with the manufacturer's instructions.

6.7 GUARANTEE

Contractor is to guarantee the above against defects in workmanship and material for the period of 1 year from date of receipt and acceptance at the plant and should any defects develop within that period, contractor must make a replacement satisfactory to Acurex without charge.

SECTION 7

ELECTRICAL SPECIFICATION

7.1 SCOPE OF WORK

The work of this section comprises the furnishing and installing of all electrical work as shown or called for on the drawings and as herein specified, complete and ready for operation to the satisfaction of Acurex, including the furnishing of all materials, equipment, labor, tools, and services necessary therefor and incidental thereto, except as otherwise provided.

All schedules included in the specifications or shown on the plans are approximate as to the number of circuits, outlets, fixtures, and the like, and the contractor shall check these against the layout and the details on the plans. Where a discrepancy occurs, the contractor shall furnish such items necessary to make a complete, operable installation as intended by the layout and details on the plans. All of the various components such as disconnects, starters, combination starters, relays, panel boards, etc. shall be complete with all appurtenant accessories.

All electrical work shall be properly coordinated and timed with the work of others, and, in particular, with mechanical, piping and installation of new and relocation of existing machines and equipment to avoid delays and mistakes. The contractor shall bear the burden of any expense involved due to his failure to comply with these requirements or due to his failure to acquaint himself with the work of others as it affects the electrical work.

7.2 DRAWINGS

The electrical drawings are diagrammatic and the circuits are schematic and are not to be scaled for dimensional purposes. Where dimensions are shown on electrical drawings, the work is to be located accordingly. All other dimensions are to be obtained at the job site.

7.3 GUARANTEE

The contractor will guarantee all work against defects in workmanship and material for a period of ONE (1) YEAR from date of receipt and acceptance of completed project, and should any defects develop within that period will make a replacement satisfactory to Acurex without charge.

7.4 CODES, RULES, SAFETY ORDERS AND PERMITS

All work installed or material used must comply with the latest rules of the following agencies:

A. Public Utilities Commission, State of California. Rules for overhead line construction.

B. California Administrative Code, Title 24, Part 3 Basic Electrical Regulations

C. National Board of Fire Underwriters, The National Electrical Code (NEC)

The rules of the National Electrical Code (NEC) shall govern where the California Administrative Code is not specific, but in all other cases the latter code shall be followed.

The electrical contractor shall obtain all permits and pay all fees required by any governmental agency having jurisdiction over this work. Inspections required by local ordinances during construction shall be arranged by the electrical contractor. Upon completion of the work, satisfactory written evidence shall be furnished to Acurex to show that all work has been installed in accordance with these codes.

7.5 INSPECTION AND TESTS

During its progress, the work shall be subject to inspection by representatives of Acurex at which times the contractor shall assist the inspector in ascertaining any information that may be required.

The electrical contractor shall test all wiring and connections for continuity and grounds before any equipment is connnected, and where such tests indicate faulty insulation or other defects, they shall be located, repaired and retested at the contractor's expense.

Rotation of all motors shall be checked and corrected, if necessary, after final connections are made.

7.6 SUPERVISION

The contractor shall personally, or through an authorized and competent representative, constantly supervise the work from its beginning to its completion and acceptance. He shall, so far as is possible, keep the same foreman and workmen on the work from its commencement to its completion.

7.7 MATERIALS

Materials shall be furnished in ample quantities and at such times as to insure uninterrupted progress of the work. They shall be stored properly and protected as required. The contractor shall be entirely responsible for damage and loss by weather or other causes. All materials shall be new, of merchantable grade, of the quality called for on the drawings or specified herein, free from defects, and approved by the Underwriter's Laboratories for the purpose for which they are used. Materials shall be of uniform type and make throughout the installation.

7.8 WIRING METHODS

7.8.1 General

No wire shall be drawn into conduit until all work of any nature that may cause injury is completed. No blocks, tackle or other mechanical means shall be used in pulling-in wires, Number 8 or smaller, and care shall be taken in pulling-in the wires to prevent damage to the insulation or wire. No wire smaller than Number 12 shall be used for light and power circuits unless specifically requested. Control wiring may be Number 16 AWG.

No joints will be permitted except in outlet boxes, pull boxes, panel board gutters and other spaces approved by governing codes. Joints and splices made in wires Number 8 and larger shall be by cast fittings using screw thread device to tighten on the wire such as Thomas and Betts "Lock-Tite" and "Tite-Bind" or other make using similar principles. All joints and splices shall be taped with not less than two double lapped layers of "Scotch 33", tightly applied over rubber tape. All standard wires connecting to screws, bolts or studs shall be lugged. Lugs shall be of similar construction to the connectors specified above. All motor lead connections shall be lugged, bolted and insulated as described above.

7.8.2 Lubricants

Graphite, talc or an approved compound may be used as a lubricant for pulling conductors through raceways. Cleaning agents or lubricants that have a deleterious effect on conductor coverings shall not be used.

7.8.3 Tagging

All branch circuits must be left securely tagged showing distinctly the purpose of each. All feeders, branch circuits, and control circuits shall be tagged in all pull boxes and in the gutters of all panels to which they connect. Premarked, self-adhesive, wraparound type markers equal to Brady Quick Label or E-Z Code wire markers shall be used.

7.8.4 Color Coding

Color coding of conductors of branch circuits shall be in accordance with NEC.

7.9 WIRE 600 VOLTS OR LESS

All wires shall be type THHN-THWN stranded copper of not less than 98 percent conductivity unless otherwise specified. All wire installed in this contract shall be of a standard manufacture approved by the Underwriter's Laboratories, Inc., and shall bear their label. All wire shall be brought to the job in unbroken packages.

7.10 CONDUIT MATERIALS

An accessible, exposed iron pipe system shall be installed for the connection of all outlet boxes, junction boxes, panel board cabinets, etc. as indicated on the drawings.

A. Rigid Conduit – shall be standard weight, mild steel pipe, of the white galvanized type only. The inside and outside of the conduit except the threads shall be finished with enamel or lacquer over the zinc coating. The interior surface shall be thoroughly cleaned of all scale, burrs, or rough spots. The conduit shall be manufactured under the supervision of the Underwriter's Laboratories' factory inspection and label service. Each length of conduit shall bear the Underwriters' label and the name of the manufacturer. Fittings such as couplings, elbows, bends, etc. shall be subject to the same requirements as for rigid conduit.

B. EMT – The use of Electric Metallic Tubing is absolutely prohibited.

C. Flexible Conduit – For connections to motors and devices shall be of the liquid-tight variety and shall have a continuous zinc coating on the steel strips employed therein. The interior surfaces shall be free of all scale, burrs, and sharp edges. Conduit shall bear the Underwriters' label. Terminating fittings shall be Thomas and Betts Series 5300 or an equal approved by the Resident Engineer.

7.11 CONDUIT INSTALLATION

7.11.1 General

All conduit shall be rigid. Conduits shall be run continuous between outlets with a minimum number of bends. All conduit subject to rough usage while on the job before installation and not acceptable to Acurex shall be removed from the premises upon notice. All screwed conduit connections shall be tight to preserve ground continuity and other connections to boxes, etc. shall be installed with care in order that moisture may be excluded from the conduit system. All conduits must be kept dry and free from water or debris with approved pipe plugs or caps.

7.11.2 Bending

Where conduit run is exposed, it shall be neatly installed parallel or at right angles to the structural members. Conduits shall be used to achieve all changes in direction of conduit runs except where bends are expressly permitted. All field bends for rigid conduit shall be of the proper radius required by E.S.O. They shall be made with standard tools and equipment manufactured especially for this purpose. Care shall be taken not to reduce the internal diameter of the conduit. The bends shall be free of kinks, indentations or flattened surfaces. The heating of any conduits for the purpose of bending is prohibited.

7.11.3 Flexible Connection

Flexible conduit will be permitted to connect the bottom of motor junction boxes to conduit. Flexible connections shall be flexible liquid-tight metal conduit.

7.11.4 Locknuts and Bushings

All conduits where they enter panel boxes, pull boxes or outlet boxes shall be secured in place by galvanized locknuts and bushings — one locknut inside and one locknut outside of box with bushing on end of the conduit, drawn tight to insure perfect electrical and mechanical contact. The locknuts shall be tightened against the box without deforming the box. Insulating bushings shall be installed as required by Paragraph 2359 (f) of the E.S.O. In wet areas where conduits are terminating in boxes or pushbutton enclosures without hubs, Meyers Scrutite zinc series hubs shall be used.

7.11.5 Runs, Single or Multiple

Where conduits are run exposed, whether single or in multiple runs, they shall be installed straight and true with respect to each other and the adjacent construction.

7.11.6 Running Threads

The use of running threads is absolutely prohibited and where some such device is necessary, Erickson or equal couplings shall be used.

7.11.7 Separation

A minimum separation of 6 inches shall be maintained between conduits and steam or hot water lines whenever possible.

7.11.8 Roof Flashing

All conduits projecting through roofing shall be made watertight by proper flashing. A sheet metal cap and tightening band or storm collar shall be securely fastened to conduits. Flashing shall extend a minimum of 6 inches in all directions from conduit.

7.12 CLEARANCES FOR SANITATION

In addition to the requirements of the electrical codes relating to working clearances, electrical conduit and devices installed in the production areas of the Plant shall have the following clearances from columns, walls, and ceilings in order to meet the Plant sanitation requirements.

Clearances from Ceiling

Item	Minimum Clearance
Junction Boxes	
Maximum dimension of junction boxes	
6 inches or less	2 inches
12 inches	4 inches
18 inches	6 inches
24 inches	8 inches
30 inches	10 inches
36 inches or more	12 inches
Lighting Outlets	1 inch

Conduit — 1 inch minimum for single conduit plus 1" for each additional conduit in the same run up to a maximum of 12 inches. For example: (1) 1/2 inch, (3) 3/4 inch and (1) 1 inch conduit are in the same run; minimum clearance 5 inches.

Clearances from Walls and Columns

Item	Minimum Clearance
Junction Box, Starter Circuit Breaker or Switch	
Minimum dimension of item	
6 inches or less	2 inches
12 inches	4 inches
18 inches	6 inches
24 inches	8 inches
30 inches	10 inches
36 inches or more	12 inches

Where starters and switches are mounted on a single rack with a wiring trough, the minimum clearance for the entire assembly shall be the minimum clearance for the entire assembly shall be the minimum clearance which is required for the largest component in the assembly, but in no case less than 6 inches.

Where boxes are mounted, within 4 inches of each other, the minimum dimension above shall be that of the entire group of boxes. For example, with a 12-inch box mounted 3 inches away from a 6-inch box, use overall dimension of an 18-inch box and mount 6 inches from wall or ceiling.

Item	Minimum Clearance
Motor Control Centers	
End to Wall	12 inches
Back to Wall	
Up to 3 sections long	15 inches
4 and 5 sections long	18 inches
6 sections long	21 inches

Patented hangers such as Unistrut, Kindorf, etc. are not to be used for mounting brackets below a 10-foot height above the floor. Easy to clean, flat or round brackets are to be used when mounting electrical devices on the production equipment.

7.13 INSERTS, HANGERS

7.13.1 General

Conduits shall be supported at intervals not greater than 5 feet, and within 3 feet of every outlet or junction box. This shall apply on vertical runs as well as horizontal runs. Light fixtures shall be supported as follows: All surface and stem suspension fixtures shall be securely anchored to the ceiling by calking anchors with machine threads using two 10-24 screws where double supports are required. The following methods are not approved:

a. Wood or fiber plugs

b. Powder actuated inserts

Where a number of conduits are to be run exposed and parallel with another, they shall be grouped and supported by patented inserts and hangers of the proper size, such as Unistrut, or equal, matching the existing work. Powder actuated tools for installing anchors will not be approved. Wood or fiber plugs or concrete nails also will not be acceptable.

7.14 MOTOR STARTER

Unless otherwise designated on the drawings, the contractor is to furnish and install three overload relays and renewable type fuses in all mangetic starters including those starters furnished by Acurex.

SECTION 8

SITE PREPARATION AND CONCRETE

8.1 GUARANTEE

Any defects which develop within a period of 1 year after final acceptance by Acurex, which are due to faulty workmanship, or the use of inferior materials shall be corrected by the Contractor at his expense.

8.2 LOCATION OF FACILITIES AND GRADES

Before any work is begun, Acurex's SPE shall meet with the Contractor on the site for the purpose of staking out with the Contractor the location of individual facilities. All finish grades where shown on the Drawings shall be established by Contractor and verified by Acurex's SPE.

8.3 CLEARING AND GRADING

Contractor shall clear site, remove all obstructions interfering with the construction and operation of the Plant, and do all excavating, grading and filling required for the construction as necessary to bring grades and levels to required elevations.

8.4 EARTHWORK — GENERAL

Contractor shall perform all necessary excavation, filling, hauling, compacting and grading as required for the completion of the facilities

General filling shall be made using soils and materials included in Groups A-1a, A-1b, A-2 — 4, A-2 — 5, and A-3, as classified by the United States Public Roads Administration. Before any fill is placed, all grass, bushes, vegetation and debris shall be removed from the area. Fill shall be spread in not over 12-inch layers and compacted with a sheeps-foot roller or vibratory tamper approved by Acurex's SPE. Each successive layer of fill material shall be compacted in layers, after which the final layer in areas to be paved shall be compacted with a rubber-tired roller which shall have a weight of not less than 225 pounds per inch of tread.

All soils shall be sprinkled during the compaction process to insure obtaining the optimum moisture content. In areas which are too small for, or inaccessible to rollers, tamping equipment, consisting of pneumatic tampers or vibratory compacting equipment shall be used to obtain the desired degree of compaction.

When backfilling ditches for pipework, the pipelines shall be carefully laid on firm bearing and the ditches filled with material and by procedures stated above for general filling.

All backfill for building slabs and footings shall start at natural grade and shall be of material approved by SPE compacted to 95 percent density but in no case shall have a bearing capacity of less than 2500 pounds per square foot. All backfill for underground tanks shall be bank-run sand or other approved materials designated by SPE free from large stone, vegetable or other foreign matter.

All foundations and footings shall be carried a minimum of 18 inches below finished grade to bottom of loading.

8.5 CONCRETE

The owner reserves the right to select the brand of cement used throughout the entire job and the Contractor shall secure written approval from the owner of the brand selected.

All sand, crushed stone or gravel shall be first quality, clean, sharp and free of loam, salt, clay, vegetable or any other foreign matter. Coarse aggregate shall be crushed hard stone or gravel, or other material approved by the SPE, of a size passed by a 1-1/4-inch screen and retained on a 1/2-inch screen, uniformly graded and must be clear and uncoated.

Water shall be clean and free from deleterious amounts of acid, salts, alkalis, or organic materials.

All concrete shall be transit (ready) mixed proportioned to produce an ultimate strength of 2,500 psi, at 28 days, except that concrete slab for the accumulator tank shall be 5,000 psi concrete, 28 days. Test cylinders shall be taken and tested at 48 hours. Contractor to include cost of testing in his bid. Testing to be done by qualified personnel licensed by the State of California to do so. At least 3 minutes of mixing time shall be at the job site.

8.6 FORMS

Earth bank forms may be used for below-grade foundation work, provided banks are firm, neatly trimmed, and will retain the concrete in precise size and shapes. Wood forms shall be carefully formed to required sizes and securely braced, cleated and shored in a manner to prevent spreading, warping and undue settlement. Forms must be thoroughly wetted before concrete is poured. Form lumber may be reused, if cleaned and reconditioned.

8.7 PLACING CONCRETE

After the subgrade, forms and reinforcing steel (where required) have been properly prepared, concrete shall be deposited in even horizontal layers so that lateral flow is kept to a minimum, so as to prevent segregation of materials. It shall be tamped or vibrated into all corners and recesses of forms and around all reinforcement. Pouring operations shall be a continuous sequence between predetermined joints.

8.8 FINISHING CONCRETE

Tank slab shall be installed as shown on plans with dusted on monolithic surface and shall be finished with a hard steel trowel finish leaving a rotary steel trowel finish.

8.9 CURING

All concrete shall be cured with an approved colorless curing compound or other methods approved by SPE. No concrete shall receive traffic or heavy loads until curing is completed, and shall be protected from damage during the entire construction period.

8.10 REINFORCING

Wire mesh or deformed bars shall conform to ASTM A-15, intermediate grade. Standard hooks and bends shall be used where called for on the Drawings or where necessary to develop bond. Lap of bars must be at least 40 diameters. Reinforcing must be securely wired in place.

8.11 EXPANSION JOINTS

All concrete expansion joints, if called for on the drawings, in the yard paving shall have 5/8 x 24-inch dowels spaced 2 feet on centers, one end greased or wrapped with felt to prevent bonding with the concrete. Slabs shall be tooled at all edges. Expansion joints shall have 3/4-inch expansion board set 1/2 inch below finished surface. Joints above the premoulded expansion board shall be filled with Aero Sealz, as manufactured by U.S. Rubber Company, or an approved equal.

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SECTION 9

ROOFING

It shall be the responsibility of the general contractor to maintain the bonded integrity of the roof to the satisfaction of the SPE.

Roofing is to be repaired in a workmanlike manner by skilled roofers to insure waterproofing.

All pitch pockets, as shown on the drawings are to be the complete responsibility of the general contractor. Drawings included in this package are typical and dimensions must be adjusted to suit actual field conditions.

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APPENDIX B

ENERGY REDUCTION AND ECONOMIC ANALYSIS REPORT

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DECEMBER 1976

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Aerotherm Report TR-76-220 Rev A

December 1976

Contract E043-1218

CDRL/PA 5

APPLICATION OF SOLAR ENERGY TO THE SUPPLY OF INDUSTRIAL PROCESS HOT WATER

ENERGY REDUCTION AND ECONOMIC ANALYSIS REPORT

Prepared for

Energy Research and Development Administration
1333 Broadway
Oakland California 94612

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SECTION 1

INTRODUCTION

The purpose of this report is to provide a discussion of the following aspects of the ERDA-Acurex solar process hot water program:

- Criteria and rationale used in process selection
- Expected fuel savings to be provided by widespread use of the solar energy system in the industry
- Economic evaluation of the system

This program involves the design, construction, operation and evaluation of a solar water heating system for application to the can washing process at the Campbell Soup Company's plant located in Sacramento, California. The information presented in this report was provided in part by the National Canners Association (NCA), consultants to Acurex on the program.

The three sections which follow are direct responses to the three items listed above. The general conclusions which can be made in regard to these items are:

- The selection of the can washing process at the Sacramento plant is an excellent choice for this experimental program, since it fully meets all criteria set down by ERDA and Acurex to realize maximum benefits from the program
- The flexibility of the Acurex solar energy system design will allow widespread usage of the system concept in industry, with an estimated potential fuel savings of 18×10^{15} joules per year (17×10^{12} Btu/year) for canning industry process hot water
- The solar water heating system appears to have the potential for achieving economic viability in the future, although the present experimental system will provide energy at a cost about four times as great as the cost of conventional energy

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SECTION 2

INDUSTRIAL PROCESS SELECTION

A rational approach to the widespread implementation of solar energy systems for generation of industrial process hot water requires careful selection of the points of introduction. The processes and industries selected for demonstration programs must be well suited to the use of solar heated water, offer good potential for future substitution of solar energy for current energy sources, and allow good transferability of solar water heating technology to other processes and industries. Considering these factors, a logical and ordered selection procedure was applied to determine which processes and industries are the most practical candidates and to identify the single process most suitable for this program. A set of selection criteria was established and applied to a number of industries and processes which consume significant quantities of hot water. Can washing was finally selected as the process having the best potential for providing a successful demonstration program.

Section 2.1 describes the details of the selection criteria. Section 2.2 gives the rationale for selecting the canning industry, and the can washing process in particular, for a demonstration program. In Section 2.3 details of the selected process are given, and in Section 2.4 the energy consumption levels involved are shown.

2.1 SELECTION CRITERIA

The primary objective of this program is to implement solar energy for heating industrial process hot water in a manner which will maximize the future benefits resulting from the program. To meet this objective, two criteria were defined for an initial screening of the candidate industries and processes, namely:

1. Total annual energy consumed nationally by the industry or process for generating process hot water
2. General "solar suitability" for industry or process: location and seasonal characteristics

Once these criteria had been applied and the number of candidate industries and processes reduced, more specific criteria could then be applied to specific processes identified within an industry. These criteria are:

1. Present and future hot water requirements for the process

   - Total annual consumption
   - General usage of process within industry
   - Current sources of energy
   - Potential for reduction of hot water requirements through conservation, process improvments, waste-heat recovery, etc.

2. Transferability potential

   - Similarity to other processes in same industry
   - Similarity to processes in other industries

3. Solar suitability

   - Geographic location of process (nationally)
   - Seasonal and daily characteristics of process hot water requirements
   - Temperature level and energy usage rate
   - Typical physical configuration of process, plants containing process line, and immediate vicinities (e.g., availability of areas for solar collector siting)
   - Availability of parallel process lines to allow comparison of solar to conventional system
   - Potential for integration of solar energy system into existing process system; ease of interfacing with existing equipment

In addition to the above, some less quantifiable criteria were necessarily considered, such as the availability of necessary information from the plant, company and industry selected, and the general willingness of industry personnel to cooperate in the program. The latter consideration was felt to be extremely important to ensure the smooth operation and success of the program and to aid in future widespread implementation of solar energy hot water systems in industry.

2.2 SELECTION RATIONALE

The selection criteria discussed in the section above were employed to identify the primary candidate industries, and from these the industry most suitable for a solar hot-water demonstration program was selected. After a specific industry was chosen, the various processes using hot water within that industry were studied and a decision was made on which process was most compatible with the demonstration's objectives. The details of the selection procedures are given in the following subsections.

Before discussing the detailed selection procedure, it is important to consider the total energy consumed in process hot water. The data from various sources (References 2-4 and 2-5) indicate that process hot water is a significant consumer of energy on a national basis, requiring about 3×10^{18} joules (3×10^{15} Btu) in 1975. Table 1 summarizes the energy consumed by industry and the relative importance of process hot water. It also is relevant to note the energy sources for industry. As shown in Table 2, natural gas is the primary constituent of industrial fuel usage; in fact, it is also the primary fuel used in hot water generation. It can thus be anticipated that the current problems with domestic gas cost and supply will be quickly reflected in industries using large amounts of process hot water, and this was found to be true in conversations with manufacturers.

2.2.1 Industry Selection

Prior to engaging in energy usage surveys of individual industries, an initial screening was performed to identify the most likely candidates. The industries which appeared to have the most promise were those consuming the largest amounts of energy. The six major industrial energy users, classified by the Standard Industrial Classification (SIC) categories, are given in Table 3. Together they consume three-quarters of all U.S. industry energy, with a total demand of over 26×10^{18} joules (25×10^{15} Btu) annually. These six industries were examined in detail to isolate processes which consume significant quantities of energy for water heating. In addition, the following industries and processes (most of which are included in the six SIC categories of Table 3) were considered individually, either because of previous indications of suitability or because of easy access to critical information regarding their energy consumption:

- Automobile manufacturing
- Cement
- Dairy
- Service industries
- Electronics
- Lumber
- Textiles
- Canning

TABLE 1. INDUSTRIAL ENERGY CONSUMPTION AND THE ROLE OF PROCESS HOT WATER (1975 ESTIMATES)

Item	% of U.S. Total	10^{18} joules (10^{15} Btu) Consumed	
• Total U.S. Consumption	100	86	(82)
• Total Industrial Consumption	41	36	(34)
-- Process hot water	4	3	(3)
– Process steam	12	12	(11)
– Direct combustion heating	11	10	(9)
– Electrical	10	8	(8)
-- Miscellaneous	4	3	(3)

NOTES:

1. 1975 consumption estimated using data provided by Lawrence Livermore Laboratories (Reference 2-4) and Federal Energy Administration (Reference 2-5).

2. Process hot water consumption estimated.

TABLE 2. ENERGY SOURCES FOR INDUSTRY (ESTIMATED FOR 1975)

Source	% of Industry Total	10^{18} joules	(10^{15} Btu)
Natural gas	43	16	(15)
Coal	26	10	(9)
Petroleum	21	7	(7)
Electricity	10	3	(3)
TOTAL	100%	36	(34)

Source: References 2-1 and 2-4.

TABLE 3. MAJOR ENERGY-CONSUMING INDUSTRIES BY SIC CATEGORY

SIC	Industry	% of Industrial Energy Consumed	% of National Energy Consumed	10^{18} joules	(10^{15} Btu)
20	Food & Kindred Products	8	3.3	2.9	(2.7)
26	Paper & Allied Products	9	3.7	3.2	(3.0)
28	Chemicals & Allied Products	20	8.2	7.1	(6.7)
29	Petroleum & Coal Products	11	4.5	3.9	(3.7)
32	Stone, Clay & Glass Products	9	3.7	3.2	(3.0)
33	Primary Metal Industries	19	7.8	6.7	(6.4)
	TOTALS	76%	31%	26.9	(25.5)

Source: References 2-1 and 2-4.

- Glass
- Pharmaceuticals
- Paints
- Plastics
- Rubber
- Aluminum
- Steel and iron
- Copper
- Coal
- Ceramics
- Mining
- Bottle washing

To eliminate industries having relatively low hot water consumption rates and to provide a ranking of the remaining condidates, information was sought concurrently from published summary reports (e.g., References 2-1 to 2-8), trade journals, trade associations, government agencies, and direct contact with individuals in industry. In the course of this investigation it was found that many of the industries listed above did not use significant quantities of process hot water. Other industries, while consuming large amounts of hot water, were eliminated because the energy they used for heating water came primarily from waste heat sources rather than burning fuel. A few industries were deleted from further consideration because of their being predominantly located in urban and high population areas, thus adversely affecting their "solar suitability." The final selection narrowed to the following four industries:

- Paper and pulp products
- Dairy products
- Textile dyeing and finishing
- Canning

Of the four industries listed above, the paper and pulp industry (SIC 26) has the largest total energy consumption, amounting to 10 percent of the nation's total industrial consumption. However, statements by plant engineers indicated that most of the energy consumption for hot water could be met by waste-heat recovery from the numerous high temperature processes encountered in paper and pulp mills. The industry was therefore not considered further for a solar hot water demonstration program.

Both the dairy and textile industries consume large amounts of energy, a sizable portion of which goes into the production of hot water. In 1974, the dairy industry (SIC 202) used a total of over 105 x 10^{15} j/year (100 x 10^{12} Btu/year) and the textile industry (SIC 22) consumed a total of 338 x 10^{15} j/year (320 x 10^{12} Btu/year). The dairy industry is concentrated most heavily in the north central region of the United States, whereas the textile industry is located mainly in the south. Moreover, the industries tend to be situated in rural and suburban areas where ample land area is available for solar collectors. Hence both the dairy and textile industries may be well suited for using solar energy for supplying their hot water energy requirements.

The canning industry was found to use large quantities of hot water almost universally, at temperatures ranging from about 60°C to 100°C (140°F to 212°F), for can washing, plant and equipment cleanup, blanching, pasteurizing, cooking, sterilizing, and various other processes. The industry as a whole (SIC 203 — Canned, Cured and Frozen Foods) consumed nearly 137 x 10^{15} joules (130 x 10^{12} Btu) of purchased fuels and electricity in 1974; nearly two-thirds of this was by the portions of the industry directly involved in canning (i.e., excluding frozen and dehydrated foods). The canning industry is estimated to use approximately 25 percent of its total energy consumption in hot water.

The industry is distributed all over the U.S., but California accounts for a large fraction of the total production — about 35 percent of the canned fruits and vegetables produced in the States are from California. The plants are generally located near agricultural areas and thus tend to be in rural, low-population regions. These areas also tend to have high annual insolation, and the peak canning period occurs during a period of high insolation (May to October). Also the canning industry, represented by the National Canners Association (NCA), had already been very active in energy problems and when contacted during the study showed a strong interest in cooperation on the program.

In light of the above information, canning was selected for the current program. The canning industry has a clear-cut, large demand for hot water, and its general "solar suitability" is excellent. Also, as California is a large producer of canned goods, communications with industry representatives and data acquisition is facilitated. Finally, the interest and aid of NCA is considered to be an immensely important positive factor in assuring the general success of the demonstration program.

NCA's communication channels with the industry were used for the final selection of a plant. After consideration of canning plants in the local area (Northern California), the Campbell Soup Company plant in Sacramento was identified as being appropriate for this program. Subsequently corporate approval was received from Campbell to work with that plant. The plant is an ideal choice for several reasons:

1. It operates nearly all year, which will allow testing of the solar system over varying seasonal conditions
2. It is near the Acurex corporate headquarters in Mountain View, thus facilitating communications and construction
3. It is a large plant, with numerous process lines for comparison
4. It is a modern plant, using state-of-the-art technology and equipment, and thus being representative of the canning industry for the near future

Once the selection of an industry and a particular plant was finalized, it still remained to select a specific process for the demonstration program. Details of the selection are given in the subsection below.

2.2.2 Process Selection

The hot water uses as the Campbell Soup plant in Sacramento were investigated and are reviewed here. The total hot water demand at the plant varies between 1900 and 3000 l/min (500 and 800 gpm) during regular production shifts, and hits a peak of over 3800 l/min (1000 gpm) for an hour or so during the cleanup shift. Most of the hot water is heated in the boiler room by a combination of waste heat recovery and low pressure (3.5 kg/cm^2 (5 psi)) steam heat exchangers. The hot water emerges from the boiler room at a temperature of approximately 71°C (160°F) and is transported to the various process areas. Booster heaters at the process areas, using low pressure or medium pressure (14 kg/cm^2 (20 psi)) steam, then raise the temperature of the water to the desired level required for the particular process. A detailed diagram of the water heating system is shown in Figure 1.

The major uses of hot water are in the following processes:

1. Vegetable Blanching. Rice and beans are blanched with water at 96°C (205°F). There are three blanchers in the plant with a total demand of 230 l/min (60 gpm) of hot water. This process is also seasonal and slacks off during summer months to make room for tomato processing.

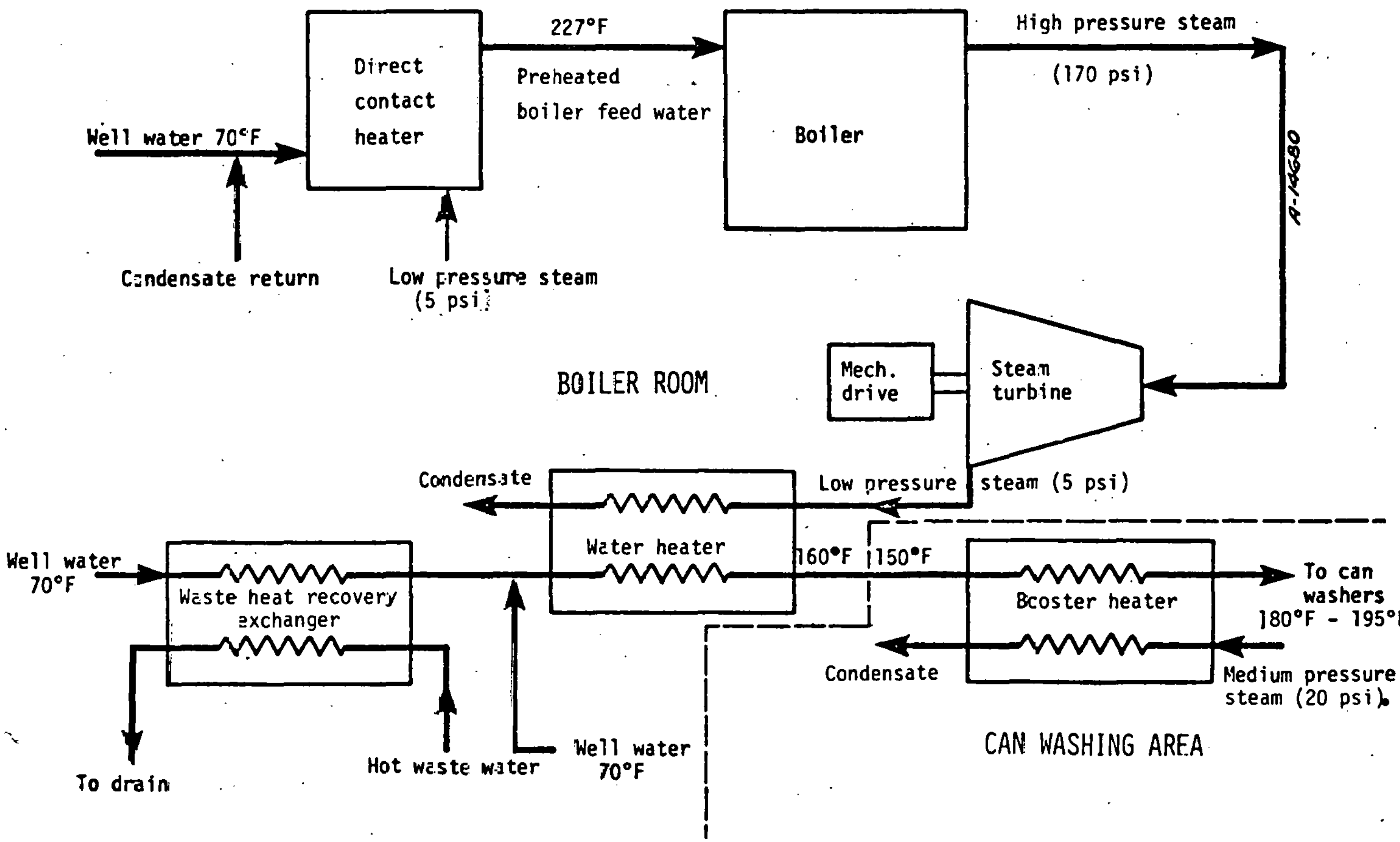

Figure 1. Water heating system at Campbell Sacramento plant.

2. Meat Preparation. Water at a temperature of 96°C to 99°C (205°F to 210°F) is used for the defrosting of meat. The operation is a batch-type and requires about 1100 liters (300 gallons) per hour (average 19 l/min (5 gpm)).

3. As a Product Ingredient. Many products require hot water in their preparation. Again, these are batch-type operations, so that the water demand varies greatly. It is estimated that between 380 and 760 l/min (100 and 200 gpm) of water is required on the average.

4. Can Washing. This is a year round operation with a hot water supply at temperatures of 82°C to 88°C (180°F to 190°F). There are 20 parallel can washing lines, with the converted lines requiring 38 to 57 l/min (10 to 15 gpm) and unconverted lines about double that amount. In converted lines, the hot water used for washing the empty can is reused for washing the filled cans. In the unconverted lines, fresh hot water is used for both processes. The total demand for the can washing operation is approximately 1100 l/min (300 gpm).

5. Hydrostatic Cookers. The hydrostatic cooker consists of two open columns of hot water that balance the steam pressure in an enclosed steam dome. The average temperature of water in the cooker is around 93°C (200°F) and the total volume about 30,000 liters (8000 gallons). The unit is drained and refilled only once a week. It is refilled with cold water and then heated by contact with the steam in the dome.

6. Cleanup Operation. This operation demands the largest volume of hot water usage in the plant. Cleanup usually takes place during the third shift, and for about an hour the hot water demand may be as high as 4900 l/min (1300 gpm). The temperature of water drops to 66°C (150°F) or lower during these periods. In addition to the major cleanup, there is a 4 to 5 minute cleanup period per machine every hour during the regular shifts.

Of all the hot water uses at the Campbell plant, can washing offers the best choice for a demonstration of the feasibility of solar hot water application. The U and V lines are particularly suited for this purpose. Some of the reasons for choosing can washing, and lines U and V in particular, are given below.

- The main advantage of the can washing process is the availability of numerous parallel lines for comparison purposes. The performance of two similar lines, one of which has been converted to solar, can be monitored and evaluated. U line will be used for the solar demonstration and the adjacent line will be used as the comparison line.

- Can washing has the single largest demand for hot water in the plant during the regular shifts. However, the demand for each line is only around 57 l/min (15 gpm), which is not excessive for an experimental solar system. Following a successful experiment, other lines can be converted easily without any need for major design reevaluation of the basic solar collector system.
- Can washing is one of the few processes which requires a continuous supply of hot water. Batch-type processes where the demand is discontinuous would require a larger storage system for the hot water. In addition, monitoring of flow rates, temperatures, etc. would require more sophisticated equipment to account for and record the variations. Evaluation of results and comparisons would also be more difficult if the variations were irregular.
- The location of the U and V lines within the plant is ideal for the solar experiment, since ample rooftop area is easily accessible. The control system and data acquisition system can be installed in a stairwell directly outside the washdown area. The storage tank can be placed either in the courtyard or parking lot in the immediate vicinity.
- The temperature level required for can washing is fairly typical of that required for many other processes. Thus, the system design for this experiment should be easily transferrable to other applications.

2.3 PROCESS DESCRIPTION

The process selected for this demonstration program is the can washing process which occurs as a part of a soup manufacturing production line. Can washing occurs at two points along the line. First, the empty cans are thoroughly washed with hot water and sterilized. Then the cans, after being filled and sealed, are washed to remove any spilled food residue from the exterior. All of the production lines at the Campbell Sacramento plant start out with fresh hot water from the mains for empty can washing. The converted lines then reuse this water to accomplish filled can washing. The unconverted lines use separate supplies for both empty can and filled can washing.

Line U, which will be supplied hot water by the solar collector system, is used for the manufacture of chicken noodle soup during the regular season. Line V, which will be monitored for comparison purposes, is used for beef noodle soup. The processing rates and the can sizes for both lines are similar. The cans are 8.73 cm (3-7/16 inches) in diameter and 11.59 cm (4-9/16 inches) in height. In August and September, during the tomato harvesting season, both lines U and V change over to processing tomato soup. The two lines are then exactly identical both in product and process during that time period.

The can washing devices are quite simple in operation. The empty cans are conveyed through the washers on six metal rails which form a cage. The empty washer itself is a sheet metal enclosure approximately 2.4 m (8 ft) long and has a water supply tube with a series of eight nozzles located along one lower corner. During the transit through the washer the rail cage is twisted through an angle so that all surfaces of the can are exposed to the fixed streams of hot water. For the converted lines, the hot water draining off from the empty can washer flows into a sump below the filled can washer. Part of this water is fed with detergent and sprayed into the first section of the washer through a bank of 18 nozzles. The remaining hot water from the sump is then used to rinse off the filled cans in the second section of the washer, which is equipped with 19 nozzles. A schematic diagram of the can washing process is shown in Figure 2.

The hot water supplied to the can washing line must meet the following requirements:

- Flowrate. A continuous supply of hot water is required at the rate of 47.3 l/min (12.5 gpm).
- Pressure. The supply pressure must be at least 42 kg/cm^2 (60 psi).
- Temperature. The temperature of the hot water must be within the range of 82°C to 91°C (180°F to 195°F).
- Duty Cycle. The can washer must be supplied with hot water during the first two shifts (and partly during the cleanup shift). There is a 4 to 5 minute cleanup period every hour. The plant normally operates 5 days a week. For 4 to 6 weeks during harvest season, the plant operates 6 days a week. The plant is shut down for 2 weeks beginning June 18th and 1 week at Christmas.

2.4 ENERGY CONSUMPTION

Process hot water consumes more energy than any other hot water process at the Campbell plant at Sacramento. A breakdown of the energy usage for can washing is shown in Table 4. The annual

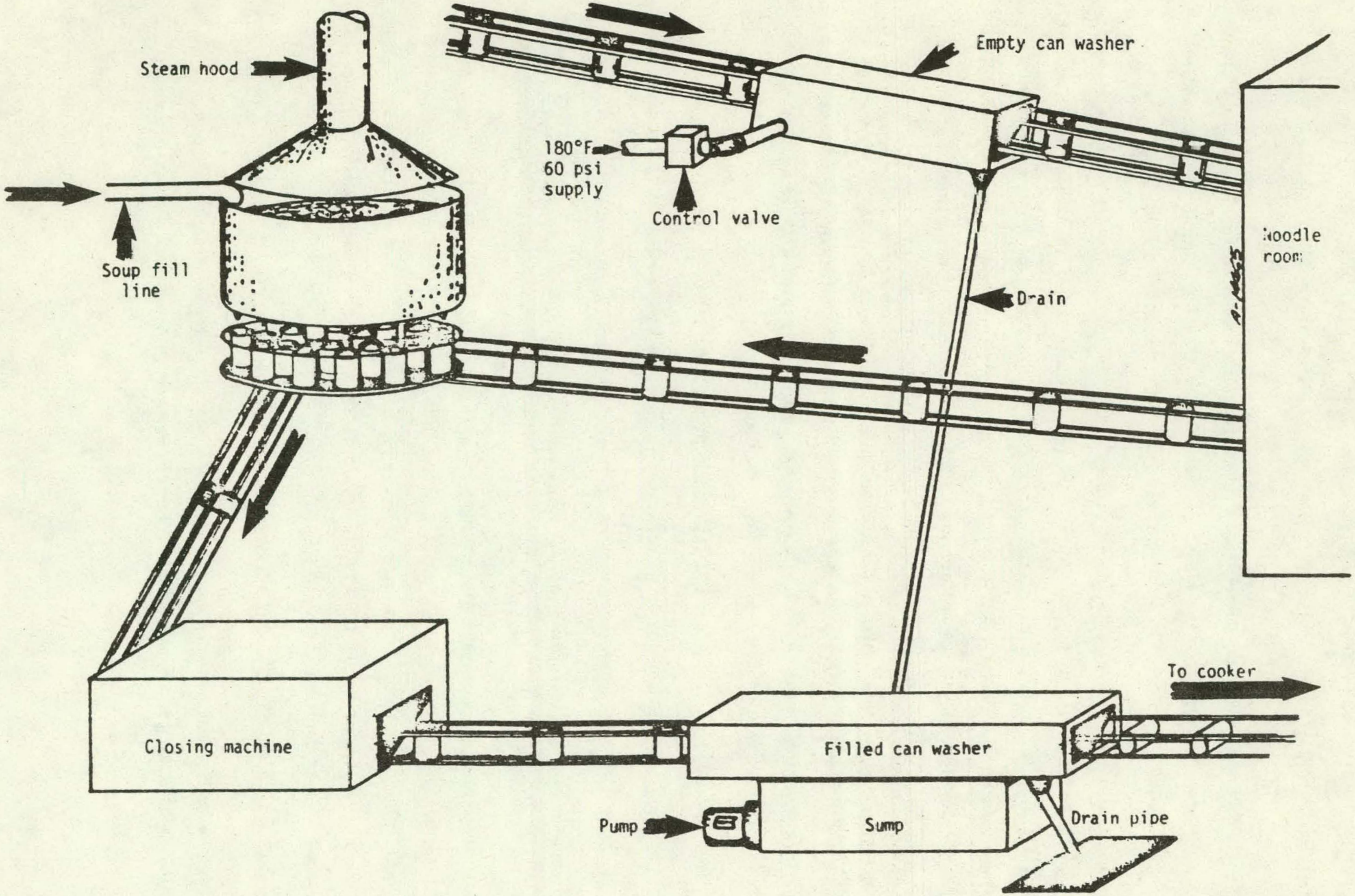

Figure 2. Can washer configuration.

TABLE 4. ENERGY CONSUMPTION FOR CAN WASHING PROCESS AT CAMPBELL SACRAMENTO PLANT

Item	Basic Energy Demand joules (Btu)	Actual Fuel Energy Required joules (Btu)	bbl Oil Equivalent
Hourly consumption rate per converted line	790×10^6 (750×10^3)	1.3×10^9 (1.2×10^6)	0.22
Daily consumption per converted line	12×10^9 (11×10^6)	18×10^9 (17×10^6)	3.1
Annual consumption per converted line	3.0×10^{12} (2.8×10^9)	4.4×10^{12} (4.2×10^9)	760
Annual consumption, all can washers	88×10^{12} (83×10^9)	134×10^{12} (127×10^9)	22,990

demand per converted line is 3.0 trillion joules (2.8 billion Btu). Since the converted lines reuse hot water for filled can washing, they have half the energy demand of the unconverted lines. The plant has approximately an equal number of converted and unconverted lines. The annual demand for energy for the whole can washing process is thus estimated to be 88 trillion joules (83 billion Btu).

The actual energy consumed by the can washers exceeds this amount due to inefficiencies and losses at various points in the production and delivery of hot water. Industrial boilers of the type used at the Campbell plant generally have an efficiency of 80 percent. There is, therefore, a 20 percent energy loss in the generation of steam for heating water. Another 10 percent of the energy supplied is assumed to be lost in the steam-water heat exchangers. Finally, losses due to dissipation of heat from steam and hot water piping are estimated to be around 10 percent for the plant. The overall efficiency for the production of process hot water then amounts to 65 percent. On this basis, the actual fuel energy required for can washing has been calculated to be 134 trillion joules (127 billion Btu) per year. This amount of energy translates to burning about 23,000 barrels of oil a year for the can washing process alone.

A tabulation of the energy consumption, in terms of actual fuel energy required, is given in Table 5 for the various processes using hot water at the Campbell plant. Most of the hot water required is in the 82°C to 99°C (180°F to 210°F) temperature range. The total energy consumption amounts to about 326 trillion joules (310 billion Btu) per year. It would require approximately 56,000 barrels of oil per year to satisfy this energy requirement.

The energy consumption can be reduced substantially by a program of stringent energy conservation techniques. The rising cost of energy, and the scarcity of fuel (such as the natural gas currently used by the plant) will result in a more concerted effort to conserve energy in the near future. A study of the hot water system at the plant in Sacramento indicated that there are three major areas for energy conservation. These are waste heat recovery, condensate return, and reduction of heat losses (insulation). An estimate of the energy conservation potential is shown in Table 6. The total possible energy savings amount to 87 trillion joules (82 billion Btu) per year. This is a substantial fraction (approximately 25 percent) of the total energy consumption for process hot water. It should be noted, however, that this figure represents a limit. As mentioned above, the plant already employs standard conservation techniques. Further energy savings can be realized but the cost of equipment rises sharply as the limit as approached. A detailed economic analysis, taking into account projected fuel costs, would establish the optimal level of conservation at the plant.

TABLE 5. ENERGY CONSUMPTION FOR PROCESS HOT WATER AT CAMPBELL SACRAMENTO PLANT

Process	Temperature Level °C (°F)	Energy Consumption 10^{12} joules/year (10^9 Btu/yr)
Blanching	96 (205)	26 (25)
Product Ingredient	99 (210)	69 (65)
Meat Preparation	99 (210)	2 (2)
Can Washing	82-91 (180-195)	134 (127)
Cleanup	60-71 (140-160)	48 (46)
Others	82-99 (180-210)	47 (45)
Total		326 (310)

TABLE 6. ENERGY CONSERVATION POTENTIAL AT CAMPBELL SACRAMENTO PLANT

Conservation Method	Energy Savings 10^{12} j/yr (10^9 Btu/year)	
	Temperatures Below 66°C (150°F)	Temperatures Above 66°C (150°F)
Waste Heat Recovery	34.1 (32.3)	
Condensate Recovery		22.8 (21.6)
Insulation	6.1 (5.8)	23.1 (21.9)
Total	40.2 (38.1)	45.8 (43.5)

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SECTION 3

ENERGY IMPACT

A major objective of this experimental program is to provide information which will aid in assessing the potential impact of solar energy technology on industrial process hot water energy consumption in the future. In this section, information gathered during the Phase I design effort is used to make a preliminary assessment of that potential impact. The performance of the solar water heating system at the Sacramento plant is compared to the can washer energy requirements in Section 3.1. Utilizing this performance data in conjunction with an assessment of significant characteristics of the canning industry, an estimated energy impact is determined in Section 3.2. A further extrapolation is made in Section 3.3 to estimate the potential impact on other industries.

3.1 ENERGY PROVIDED BY SOLAR WATER HEATING SYSTEM

A detailed evaluation of system performance is presented in the Design and Performance Report (submitted concurrently with this report). The results of that analysis are given in Table 7 for Sacramento, Albuquerque and Omaha, for a 365-day year. Allowing for the time periods when the can washing lines are inoperative (and thus collected solar energy is not usable) these numbers are reduced by a factor of 0.96 (see Section 2). The energy demand for the U line can washing hot water is shown in Section 2 to be 3.0×10^{12} joules/year (2.8×10^{9} Btu/year). Based on these figures, the net solar contribution was calculated and is shown in Table 8 for the three locations. The information in this table should be interpreted carefully, since the system design is optimum for Sacramento and probably not optimum for Albuquerque or Omaha. In fact, a significant attribute of the "mixed field" concept (i.e., flat plates and concentrators) developed by Acurex is the inherent ease of optimizing for various locations by adjusting the field mix (fraction of flat plates versus fraction of concentrators). The cost-optimization procedure employed to arrive at the field mix for the baseline (Sacramento) system design is presented in Section 2 of the Design and Performance Report. This field mix — 41 percent concentrators, 59 percent flat plates on the basis of effective collector area — could vary significantly if the cost-optimization were performed for Albuquerque or Omaha, because of differences in direct/diffuse radiation, ambient temperatures, etc.

TABLE 7. SYSTEM USEFUL ENERGY
Flat Plate Collector Field = 4134 ft^2 (384.1 m^2)
Concentrator Field = 2880 ft^2 (267.6 m^2)

Day	Location					
	Sacramento		Omaha		Albuquerque	
	q_u		q_u		q_u	
	MBtu/Day	MJ/Day	MBtu/Day	MJ/Day	MBtu/Day	MJ/Day
Feb 21	3.57	3765	2.63	2773	5.59	5895
Apr 21	6.57	6928	4.54	4787	6.44	6791
Jun 21	9.17	9670	6.49	6844	8.55	9016
Aug 21	8.79	9269	6.29	6633	7.63	8046
Oct 21	6.29	6633	4.86	5125	6.93	7308
Dec 21	2.59	2731	3.20	3374	5.83	6148
Annual Average Daily	6.16	6496	4.67	4925	6.83	7201
Average Total Yearly (Average Daily x 365)	2.25 x 10^9 Btu	2.37 x 10^6 MJ	1.70 x 10^9 Btu	1.79 x 10^6 MJ	2.49 x 10^9 Btu	2.63 x 10^6 MJ

TABLE 8. ANNUAL ENERGY CONTRIBUTION BY SOLAR WATER HEATING SYSTEM

Location	Total Collected Energy 10^{12} joule/yr (10^9 Btu/yr)	Fraction of Load Provided by Solar
Sacramento	2.28 (2.16)	.77
Albuquerque	2.52 (2.39)	.85
Omaha	1.72 (1.63)	.58

As indicated in Table 8, the fraction of the can washer energy load carried by the solar energy system is about 77 percent. This is believed to be near the cost optimum for future large-scale systems, based on general experience in solar energy systems of various types and on the design procedures used in this program.

3.2 ENERGY IMPACT ON CANNING INDUSTRY

It is necessary to extrapolate from the experience gained on this experimental program to determine the potential impact of solar process hot water systems on the entire canning industry. Such an extrapolation is possible because of general similarities between the operation of the Campbell Sacramento plant and that of other canning plants. It should be noted first of all that the can washing operation is only one of many process hot water usages at the Sacramento plant and most other canning plants. In a full-scale solar water heating system, it would be economically optimum to supply hot water for a multiplicity of processes to provide a greater diversity in the net load, and thus a better utilization of the collector field output. The can washing process was singled out for this program largely because the characteristics of the process (uniform daily load, existence of comparison lines, etc.) are extremely advantageous for the purposes of the experiment. Based on an excellent knowledge of the plant operations, Acurex strongly believes that our basic solar energy system design developed for the can washing application would be applicable to the full-scale system, providing process hot water to the entire plant. This system concept has tremendous flexibility for different applications by varying such items as field mix, total collector area, flat plate tilt angle, concentrator alignment (e.g., north-south, east-west, etc.) and storage volume. Thus there is good reason to believe that a future scaled up system could provide process hot water at a level proportionate to the current system; e.g., in the range of 70 to 80 percent of the load. Order-of-magnitude calculations show that there is adequate roof and land area at the plant to do so.

The discussion in this section is directed at the remainder of the canning industry. The approach taken is to:

1. Consider seasonal and geographic variations in hot water demand and solar radiation levels (Section 3.2.1)
2. Consider the hot water energy usage in canning plants compared to incident solar radiation on the plant area (Section 3.2.2)
3. Estimate the optimum level of solar substitution (fraction of load carried by solar) in the industry, based on geographic variation of key parameters (Section 3.2.3)

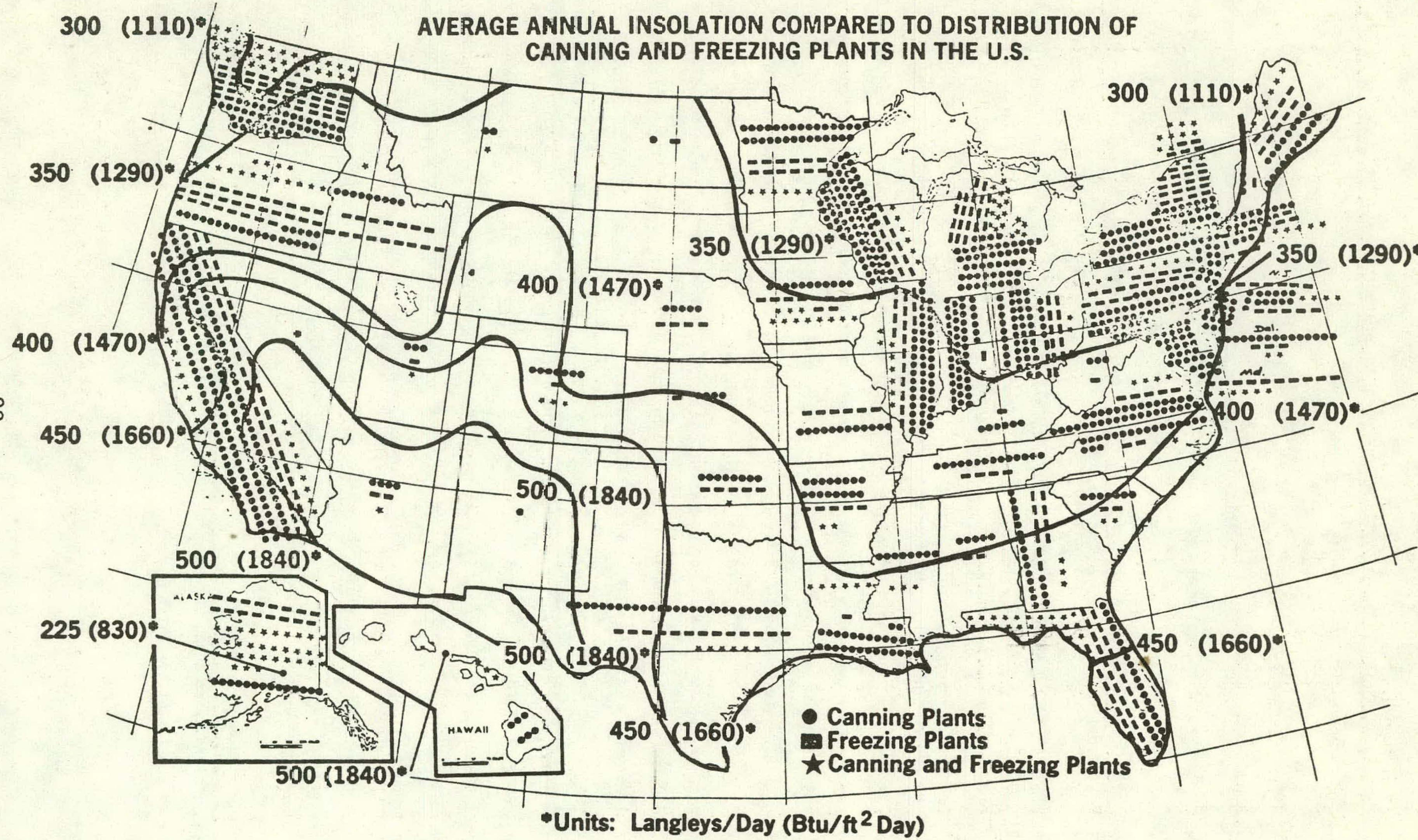
4. Factor in the industry's estimated process hot water consumption to determine the net potential for energy substitution with solar

3.2.1 Seasonal and Geographic Variation

The distribution of canning plants in the United States is shown in Figure 3. Lines of constant average solar radiation are superimposed on the figure for the contiguous states. There is a heavy concentration of canning plants in the northeast, where the level of average insolation is lower than in most other parts of the country. However, fuel costs are higher in the northeast. The region, therefore, does have a strong potential for solar application. It should also be noted that the number of canning plants in a certain area does not directly reflect upon the energy usage in that area. As is demonstrated in the next section, the West generally tends to have larger plants, and they consume more energy than their counterparts in the rest of the nation.

The energy consumption pattern in the canning industry varies markedly with the time of the year. The highly seasonal character of fruit and vegetable harvesting causes the industry-wide production to increase sharply during the summer months. Peak use usually occurs in September when production is highest. During the other months, some plants switch to processing foodstuffs other than fruits and vegetables while others shut down altogether in winter. Figure 4 shows the variation in total energy consumption with season (Reference 3-1). The ratio of peak to average energy consumption for the year 1974 was calculated to be 2.1. For comparison purposes, the variation of solar irradiation on a flat horizontal surface with the months of the year, for four different national geographic regions, is shown in Figure 5 (Reference 3-2). Peak solar radiation usually occurs in June. By September, when energy demand is highest, the levels of insolation are only about 1.1 times the average values. Insolation level alone, however, is not the only factor which governs the output from a solar collector. Other important parameters which influence solar energy conversion are ambient temperature, wind velocity, cloudiness, etc. When these factors are taken into consideration, the energy delivered by a solar collector becomes a maximum around September in many locations. The supply of energy by solar means hence tends to follow the pattern of demand in the canning industry.

The daily duty cycle varies from plant to plant. Some large plants, such as the Campbell plant in Sacramento, which process a wide variety of food products, operate on two regular work shifts a day throughout the year. The Sacramento plant closes down during the weekends except during the harvest period when it may run 6 or more days a week. The energy requirements for hot water are more or less constant throughout the two regular shifts, but hit a peak shortly after midnight due to the increased demand for hot water during cleanup. There is very little variation in energy consumption


AVERAGE ANNUAL INSOLATION COMPARED TO DISTRIBUTION OF
CANNING AND FREEZING PLANTS IN THE U.S.
300 (1110)*
350 (1290)*
400 (1470)*
450 (1660)*
500 (1840)*
300 (1110)*
350 (1290)*
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225 (830)*
500 (1840)*
ALASKA
HAWAII
N.J.
Del.
Md.
● Canning Plants
▬ Freezing Plants
★ Canning and Freezing Plants
*Units: Langleys/Day (Btu/ft² Day)

Figure 3.

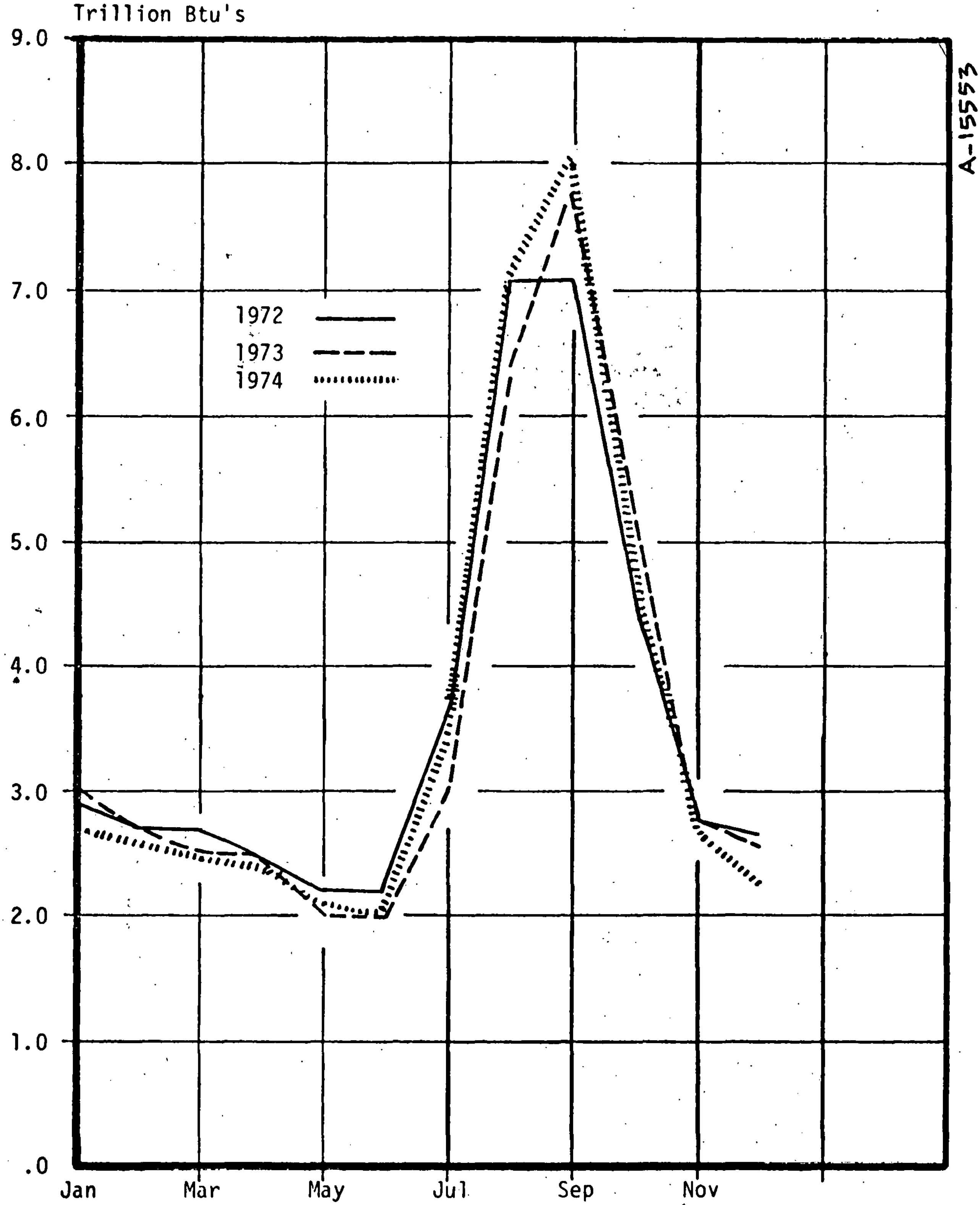

Figure 4. Seasonality of energy use in representative cross section of canning industry (Reference 3-1).

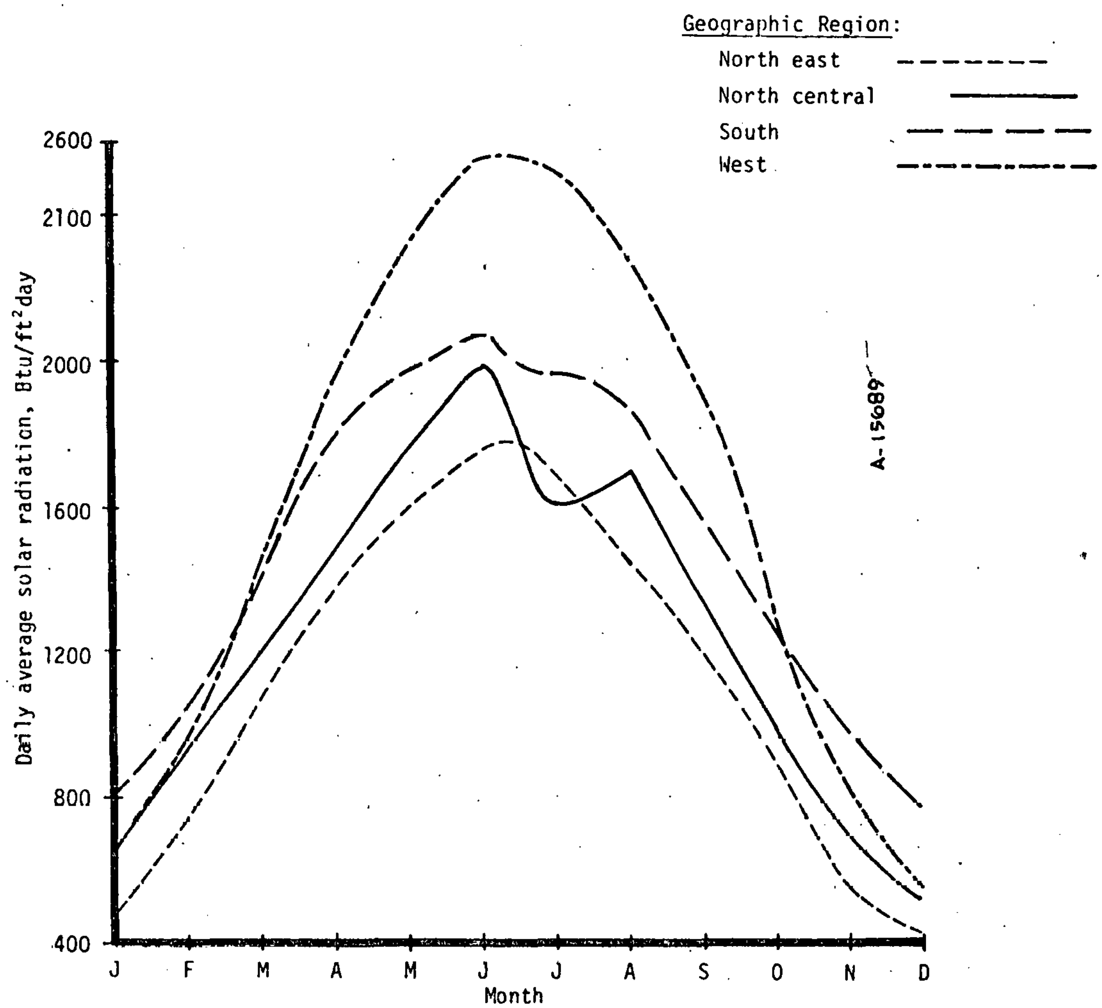

Figure 5. Variation of solar radiation on flat horizontal surfaces with season.

with season. On the other hand, smaller canning plants usually operate on two shifts during the harvest season and change to a single shift for the test of the year, or in some cases shut down completely for part of the year.

3.2.2 Plant Size and Incident Energy Levels

The breakdown of the number of plants and the total production by geographical unit and SIC category is shown in Table 9 for 1972 (Reference 3-3). The average production per plant in terms of dollar value totaled for all three SIC categories is also shown in the table for each of the four geographic areas. It is seen that the West (with California accounting for 75 percent of the production therein) has the largest number of plants, the largest total value of production, and the largest average production per plant. Hence, the West, and California in particular, not only manufactures the greatest amount of canned goods but also has larger manufacturing facilities in general.

A survey was conducted by a representative of the National Canners Association to determine the roof area available for solar collectors at typical canning plants throughout the country (Reference 3-4). It was found that the roof area was approximately proportional to the plant production capacity and averaged about 1000 m^2 (0.25 acres) per million dollars production per year. Uncovered land area around the plant building averaged an additional 70 percent of the roof area to bring the total plant area to approximately 1720 m^2 (18,500 ft^2) per million dollars production per year. The average plant areas in the four geographic regions are shown in Table 10, based on the above estimates.

The energy consumed in heating process water throughout the canning industry is estimated to be around 18.3×10^{15} joules (17.4 trillion Btu) per year (Reference 3-5). The hot water energy consumption in the four geographic units under consideration is assumed to be proportional to the total energy consumption. The consumption levels in the different regions can then be calculated on the basis of this assumption, and are shown in Table 11. The distribution of the total energy consumption was derived from a study of energy usage in the food industries (Reference 3-6). Table 3 indicates that the canning industry in the Western region of the U.S. uses more than half of the total energy consumption in the industry. The energy consumption per plant is also more intensive in the West. This is reasonable in light of the larger production levels and plant sizes encountered in that geographic unit.

The daily solar radiation on a flat horizontal surface is given in Table 12 for the four geographic regions of interest. Both average and September levels, when the energy demand is at a peak, are tabulated. The solar radiation is largest in the Western region which is fortunate as the energy

TABLE 9. NUMBER OF PLANTS AND PRODUCTION FIGURES OF THE CANNING INDUSTRY

Geographic Region	SIC 2033 Canned Fruits and Vegetables		SIC 2032 Canned Specialties		SIC 2091 Canned and Cured Seafoods		Total		Production per Plant 10^6 \$
	No. of Plants	Production 10^6 \$	No. of Plants	Production 10^6 \$	No. of Plants	Production 10^6 \$	No. of Plants	Production 10^6 \$	
Northeast	211	689	47	644	68	106	326	1439	4.4
Northcentral	299	968	41	602	15	17	355	1587	4.5
South	259	686	52	366	96	93	407	1145	2.8
West	269	1701	63	265	129	504	461	2470	5.4
Total	1308	4044	203	1877	308	720	1549	6641	4.3 (average)

TABLE 10. AVERAGE CANNING PLANT AREA

Region	Average Plant Area $10^3 m^2$ (10^3 ft^2)
Northeast	7.5 (81)
Northcentral	7.7 (83)
South	4.8 (52)
West	9.3 (100)
Average	7.4 (80)

TABLE 11. ENERGY CONSUMPTION FOR HOT WATER IN CANNING INDUSTRY*

Region	Percent Total Energy Consumption	Hot Water Energy Consumption 10^{15} joule (10^{12} Btu)	Hot Water Energy Consumption per Plant 10^{12} joule (10^{9} Btu)
Northeast	10.1	1.9 (1.8)	5.7 (5.4)
Northcentral	21.7	4.0 (3.8)	11.2 (10.6)
South	12.4	3.3 (2.2)	5.6 (5.3)
West	55.8	10.2 (9.7)	22.3 (21.1)
Total	100	18.4 (17.4)	11.8 (11.2) (Average)

*Actual fuel energy consumed

TABLE 12. INSOLATION ON FLAT HORIZONTAL SURFACE

Region	Average Daily Solar Radiation 10^6 joules/m^2 day (Btu/ft^2 Day)	Daily Solar Radiation in September 10^6 joules/m^2 day (Btu/ft^2 Day)
Northeast	12.5 (1100)	13.9 (1220)
Northcentral	14.4 (1270)	15.3 (1350)
South	16.6 (1460)	17.5 (1540)
West	18.1 (1590)	20.7 (1820)

consumption is also greatest in that area. As the average plant sizes are known for various regions, one can now calculate the solar energy incident upon a plant and compare it with the energy requirements for process hot water used at the plant. This comparison is shown in Table 13 and is discussed below.

Table 13 lists the ratio of solar radiation incident upon the total plant area to the energy consumption to meet hot water requirements per plant. Both annual average and values during September are listed for the four regions. It is seen that there is ample plant area to supply the energy requirements for hot water, even during the period of peak demand. In the West, where energy demand per plant is highest, 67 percent coverage of the plant area with solar collectors is sufficient to meet peak requirements. The above figures are all for flat horizontal collectors. In practice, in order to reduce the collector surface area, the flat plate collectors will be inclined at an optimal tilt angle and the concentrators will track the sun. The area of collectors required will be smaller, but the total area required may increase due to mutual shading problems. Nevertheless, these calculations show that in an average sized plant, the area required for solar collectors will not be a limiting factor in supplying the hot water requirements for the plant.

3.2.3 Solar Substitution Levels

If solar energy is used as an alternate energy source for process heat, it is usually not economically feasible to supply all the energy requirements by solar means. For the Campbell plant at Sacramento, a detailed analysis indicated that 77 percent solar substitution was the optimal level. Such an analysis for other parts of the country and industrial plants with different duty cycles and energy requirements is not available. Löf and Tybout (Reference 3-7) have calculated the optimal solar substitution levels for various locations as apply to home heating. Lacking data for industrial process heating, the results of Löf and Tybout are assumed to apply to process hot water as well. Their analysis indicates that for a location with less than 300 Langleys/day (1100 Btu/ft^{2}day) of average annual solar radiation, the optimal substitution for hot water is 50 to 55 percent, and this percentage rises to 75 to 80 percent for a solar incidence of greater than 500 Langleys/day (1800 Btu/ft^{2}day). Using these numbers as guidelines, the optimal solar substitution values for the four regions were estimated and are given in Table 14. Weighing these solar substitution values with the fraction of energy consumed in each region, the average value of solar substitution in the contiguous United States amounts to 68 percent.

The amount of energy for process hot water that can be replaced by solar heating can now be estimated as is shown in Table 15. Solar energy has the potential of replacing about 12.6 x 10^{15}

TABLE 13. RELATIVE RATIO OF SOLAR RADIATION ON TOTAL PLANT AREA TO HOT WATER ENERGY CONSUMPTION

Region	Average	Value in September
Northeast	6.0	3.2
Northcentral	3.6	1.8
South	5.2	2.6
West	2.8	1.5

TABLE 14. ESTIMATED OPTIMUM SOLAR SUBSTITUTION

Region	Average Daily Insolation Langleys (Btu/ft^2)	Optimum Solar Substitution (Percent)
Northeast	300 (1105)	58
Northcentral	350 (1290)	63
South	400 (1473)	68
West	430 (1584)	72

TABLE 15. POTENTIAL SOLAR ENERGY REPLACEMENT IN CANNING INDUSTRY

	Present Consumption 10^{15} joules/year (10^{12} Btu/year)	Potential Solar Substitution 10^{15} joules/year (10^{12} Btu/year)
Process Hot Water	18.4 (17.4)	12.4 (11.8)
Low-Temperature Steam	6.0 (5.7)	2.7 (2.6)
Total	24.4 (23.1)	15.2 (14.40)

joules/yr (12 trillion Btu/yr) of fuel energy presently used for heating water in the canning industry. As many of the collectors available for generating high temperature hot water are also capable of producing low temperature steam, it is of interest to calculate the amount of energy used to produce low temperature steam in the canning industry. This amount of energy is estimated to be 5.7 trillion Btu/yr throughout the nation.

3.3 IMPACT ON OTHER INDUSTRIES

The solar collector design for providing process hot water for can washing can be applied to other industrial processes with very few modifications. The combination of flat plate and concentrating collectors can also be employed to generate low temperature steam. The impact of solar energy on industry is, therefore, potentially quite significant as hot water and low temperature steam are used extensively in many diverse industrial processes and the total energy consumed in these processes is very large. To judge the impact quantitatively, however, has been difficult up to now due to lack of specific data on energy consumption for process hot water or steam and the corresponding temperature levels involved. Recently, Battelle Laboratories and Inter Technology Corporation have compiled data for the application of solar energy to industrial process heat (References 3-8 and 3-9). The following discussion is based mainly on the preliminary results from the Battelle study.

The energy consumption for various industries using substantial quantities of hot water and low temperature steam is summarized in Table 16. Most of the hot water used in industry is between 60°C and 99°C (140°F and 210°F). The Frasch sulfur extraction process is the only one that uses large amounts of pressurized hot water in the industries shown in (about 140 trillion Btu/yr). The optimal solar substitution level for each of these industries can be calculated by a process similar to that described in the section above for the canning industry, although the data available regarding geographic distribution, seasonal variation, etc., are not as accurate or extensive as those for the canning industry. The potential for replacing the energy used for hot water in various industries was estimated and is shown in Table 16. It is seen that for the partial list of industries tabulated, the solar substitution potential is over 85 x 10^{15} joules (80 trillion Btu/yr).

As was mentioned above, concentrating solar collectors can be used to produce low temperature steam with little change in the basic design. The energy consumed in producing steam below 177°C (350°F) for various industries is shown in Table 16. For the industries listed, the total energy consumption exceeds 610 x 10^{15} joules (580 trillion Btu/year). To estimate the solar impact of these processes, data on optimal solar substitution levels for these processes must be known. Lacking this data, it was assumed that for steam below 150°C (300°F), the optimal substitution percentage

TABLE 16. INDUSTRIAL HOT WATER AND STEAM ENERGY CONSUMPTION AND SOLAR SUBSTITUTION POTENTIAL

Industry (SIC Number)	Hot Water			Low Temperature Steam			Geographic Location
	Temp Level °C (°F)	Energy Consumption 10^{15} j/yr (10^{12} Btu/yr)	Potential Solar Substitution 10^{15} j/yr (10^{12} Btu/yr)	Temp Level °C (°F)	Energy Consumption 10^{15} j/yr (10^{12} Btu/yr)	Potential Solar Substitution 10^{15} j/yr (10^{12} Btu/yr)	
Canning (2032, 2033, 2091)	60-89 (140-210)	18 (17)	12.6 (12)	121-149 (250-300)	6.3	3 (3.2)	West, Northcentral
Dairy Products (202, Excluding 2023)	60-100 (140-212)	8.4 (8)	5.3 (5)	121 (250)	47.4 (45)	21 (20)	West, Northcentral
Sulfur (1477)	163 (325)	46.4 (44)	18 (17)				Gulf Coast, Texas, Louisana
Pulp & Paper (261, 262)				160-177 (320-350)	145 (137)	50.6 (48)	South, Northcentral
Automobiles & Trucks (371)	49-82 (120-180)	13.7 (13)	7.4 (7)	<177 (<350)	1 (1)	0.5 (0.5)	
Chlorine/Caustic (2812)	71 (160)	21 (20)	14.8 (14)	<177 (<350)	95 (90)	34 (32)	West, near salt deposits
Potassium Chloride	<100 (<212)	4.2 (4)	3.2 (3)	<177 (<350)	2.1 (2)	1 (1)	California, New Mexico
Glass (321, 2322)	60-82 (140-180)	8.4 (8)	5.3 (5)	<177 (<350)	3.2 (3)	1 (1)	
Copper (3331)	57-66 (135-150)	14.8 (14)	11 (11)				West
Sugar (206)				124-143 (255-290)	77 (73)	36 (34)	West, Midwest
Textiles (22)	38-100 (100-212)	9.4 (9)	7.3 (7)	121-149 (250-300)	208 (199)	106 (100)	Southeast
Concrete Block & Brick (3271)				<177 (<350	14.7 (14)	5.3 (5)	
Lumber	<100 (<212)	4.2 (4)	2.1 (2)	<177 (<350)	13.6 (13)	4.2 (4)	
Total		148 (141)	87 (83)		610 (583)	260 (248)	

was two-thirds of the values estimated earlier for hot water, and for steam between 140°C and 177°C (300°F and 350°F), the optimal level was half that for hot water. These assumptions were based on the fact that solar collector efficiencies tend to drop with higher fluid temperatures, and hence tend to be less competitive with conventional fuel burning equipment at high temperatures. The energy that can be replaced by solar means for low temperature steam generation is about 260 x 10^{15} joules (250 trillion Btu) per year for the industries under consideration. Hence, the total energy replacement potential for process hot water and low temperature steam is over 343 x 10^{15} joules (325 trillion Btu) per year.

As the cost of fuel increases, a program of stringent energy conservation will in all likelihood be instituted simultaneously with a shift towards alternate energy systems. It is estimated that about 20 percent of energy now consumed could be saved by an intensive energy conservation program throughout industry. The potential solar substitution levels will therefore change downwards by that amount. For hot water, solar energy could then contribute as much as 69 x 10^{15} joules (65 trillion Btu)/year, conservation would account for 30 x 10^{15} joules (28 trillion Btu)/year, and the other 48 x 10^{15} joules (45 trillion Btu)/year required for the industries shown on Table 16 would come from conventional fuel burning. For low temperature steam, solar energy could supply an estimated 210 x 10^{15} joules (200 trillion Btu)/year, with the conservation measures saving about 130 x 10^{15} joules (120 trillion Btu)/year and the remaining 270 x 10^{15} joules (260 trillion Btu)/year would be generated by regular fuels. The total solar substitution potential for both hot water and low temperature steam still exceeds 260 x 10^{15} joules (250 trillion Btu)/year.

REFERENCES FOR SECTION 3

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SECTION 4

ECONOMIC ANALYSIS

This section of the report presents the results of the economic analysis for the Acurex solar water heating system design versus a conventional fossil fuel system. The section is subdivided into three parts. In the first, the economics for the Albuquerque and Omaha locations are presented for a no-fuel-cost-escalation assumption, and for a five-percent (compounded annually) assumption. This is the analysis requested by ERDA and was performed using the Acurex FPS computer code (see Appendices A, B, and C).

Section 4.2 presents the economics for the Sacramento location. The analysis was performed using cost inputs based on the initial ERDA assumptions and industry practices. It is of interest to compare these costs with those computed for the Albuquerque and Omaha locations, since Sacramento will be the actual location of the proposed solar system.

Finally, in Section 4.3, the economics of the Sacramento location are examined further, taking into account anticipated reductions in system costs, estimated California fuel cost escalations, an increased Federal investment tax credit, and an accelerated depreciation method. These cost inputs are assumed to apply in 1980 and represent a realistic estimate of the economics of this proposed system in the near future.

4.1 ECONOMIC ANALYSIS: ERDA GUIDELINES

This section presents the results of the economic analysis for the Campbell hot water solar system for both the Albuquerque and Omaha locations. The calculation performed here uses the same input parameters that were suggested in ERDA's guidelines (see Appendix B) with the exception of the boiler end-use efficiency. A value of 0.65 rather than 0.7 was used and accounts for the losses in the boiler and transmission to the can washer. The analysis was also performed for a five-percent annual fuel cost escalation. The installed system costs are summarized in Table 17. The total system cost was lowered by $38,782 to agree with the labor rate of $15/hr suggested by ERDA.

Table 18 presents the results of the analysis. These results indicate that the required investment in the solar system is too high for the fuel savings realized to be economical over a 20 year life. The investment of $260,951 represents an installed cost of $370.71/m^2 ($34.44/ft^2)

TABLE 17. ESTIMATED INSTALLED SOLAR SYSTEM COST: SACRAMENTO

Item	Material $	Labor $	Total Cost $	Cost per Unit Area[a]	
				$/m^2	($/ft^2)
Site Preparation (Remove, replace fence prepare for drain, cranes, etc.		2,100	2,100	2.98	(0.28)
Collectors					
Flat plates	44,493	17,766	62,259	88.45	(8.22)
Flat plate support structure	8,316	12,002	20,318	28.86	(2.68)
Concentrators	38,246	20,446	58,692	83.36	(7.75)
Concentrators support structure	4,700	7,520	12,220	17.36	(1.61)
Storage Tank System	15,901	8,181	24,082	34.21	(3.18)
Interface with Existing Plumbing	612	154	766	1.09	(0.10)
Piping, Valves, Ducting	12,818	20,989	33,807	48.02	(4.46)
Insulation — Pipes and Tank	4,200	8,400	12,600	17.90	(1.66)
Electrical Work	2,600	8,676	11,276	16.02	(1.49)
Controls	13,875	15,526	29,401	41.76	(3.88)
Roof Repair and Water Proofing	2,600	6,115	8,715	12.38	(1.15)
System Checkout	0	9,662	9,662	13.72	(1.27)
Concentrator Interface		11,238	11,238	15.96	(1.48)
Others (taxes, overtime, etc.)	1,037	1,560	2,597	3.69	(0.34)
TOTAL	149,398	150,335	299,733	425.76	(39.55)

[a]Area used here is total gross collector area (704.3 m^2 or 7578 ft^2)

TABLE 18. ECONOMICS OF CAMPBELL SOLAR HOT WATER SYSTEM: ERDA ANALYSIS

Location	Total Investment, $	% Total Energy[a] Supplied by Solar	Before Tax Costs[b] $/1000 MJ ($/MBtu)			Payback,[c] Years	ROR[d] %
			Conventional	Solar	Solar Only		
No fuel cost escalation:							
Albuquerque	260,951	85	3.97 (4.18)	15.54 (16.38)	17.23 (18.16)	>20	-1.0
Omaha	260,951	58	3.97 (4.18)	16.56 (17.45)	25.25 (26.61	>20	-2.4
With 5% fuel cost escalation compounded annually:							
Albuquerque	260,951	85	5.57 (5.87)	15.97 (16.83)	17.23 (18.16)	17.9	1.3
Omaha	260,951	58	5.57 (5.87)	17.23 (18.16)	25.25 (26.61)	>20	-0.5

[a] Total annual energy requirement at the can washer = 2.7×10^{12} MJ (2.8×10^{9} Btu)

[b] 1054 MJ = 10^{6} Btu

[c] Payback is based on net cash flow after taxes.

[d] ROR — minimum rate of return on the net cash flow after taxes for 20 years

for the solar system (704.3 m^2 or 7578 ft^2 of collectors). The five percent fuel cost escalation increases the annual cost, but makes the comparison more favorable for the solar system. With this fuel cost escalation the Albuquerque location has a payback period of about 18 years and a slight rate-of-return (1.3 percent) on the investment after taxes. Nevertheless, the Omaha location, which receives much less solar insolation (and thus less fuel savings), is still unable to offset its investment with its discounted annual savings. Therefore the rate-of-return for both calculations is negative. The computer output for the cases presented in Table 4-1 are included in Appendix D for reference. These printouts detail by year the solar system operating costs.

4.2 ECONOMIC ANALYSIS: SACRAMENTO

The results of two economic analyses for the Sacramento location are presented here for comparison with the Albuquerque and Omaha locations. The first analysis differs from the previous analysis only in the amount of insolation (less than Albuquerque, but more than Omaha) and the installed costs (based on general contractors labor rates).

The second analysis was made to duplicate canning industry methods used in an economic analysis as well as fuel costs that are relevant to the Sacramento location. The inputs to the analysis that differ from the ERDA guidelines are as follows:

- Diminishing balance (accelerated) depreciation
- Fuel cost escalation of 3.4 percent compounded annually
- Combined Federal (48 percent) and State (6 percent) income tax rate of 51 percent.

The fuel cost projection is based on numerous estimates of fuel costs and availability in the Sacramento area. This information was compiled as a part of an Acurex/Aerotherm contract to the State of California to evaluate alternate energy sources for the heating and cooling plant that supplies a complex of buildings in the State Capitol Mall.

Table 19 presents the results of the two analyses. Again, for the ERDA guidelines, the solar system investment cost more than offsets its operating cost savings. With the five percent fuel cost escalation, the payback period is just less than 20 years and there is a slight positive rate-of-return. This system cost translates into \$425.71/m^2 (\$39.55/ft^2).

The results of the analysis using industry assumptions do not differ significantly from the results using the ERDA guidelines. The accelerated depreciation and higher tax rate offset each other more or less; therefore the lower fuel cost escalation assumption causes the result to fall between the no-fuel-cost-increase and the five-percent-fuel-cost-increase cases. The computer printouts of these calculations are included in Appendix E for reference.

TABLE 19. ECONOMICS OF CAMPBELL SOLAR HOT WATER SYSTEM: SACRAMENTO

	Total Investment, $	% Total Energy[a] Supplied by Solar	Before Tax Costs[b] $/1000 MJ ($/MBtu)			Payback,[c] Years	ROR[d] %
			Conventional	Solar	Solar Only		
ERDA guidelires:							
Sacramentc	299,733	77	3.97 (4.18	17.96 (18.93)	21.77 (22.95)	>20	-1.8
Sacramentc with 5% Fuel Escalatior	299,733	77	5.57 (5.87)	18.33 (19.32)	21.77 (22.95	19.6	0.2
Industry Assumptions:							
Sacramentc with 0.51 tax rate, accelerated depreciation, and California fuel cost escalation of 3.4%	299,733	77	4.87 (5.13)	17.26 (18.19)	20.76 (21.88)	>20	-1.3

[a]Total annual energy requirement at the can washer = 2.7×10^{12} MJ (2.8×10^{9} Btu)

[b]1054 MJ = 10^{6} Btu

[c]Payback is based on net cash flow after taxes.

[d]ROR — minimum rate of return on the net cash flow after taxes for 20 years

4.3 ECONOMIC ANALYSIS: POTENTIAL COST REDUCTION

The preceding sections have demonstrated the relatively high cost of a solar energy system based on a prototype development. It is reasonable to assume, however, that installed costs for solar energy systems can be reduced and that conventional sources of fuel will continue to increase in cost. This section examines the sensitivity of the economic analysis to the earlier cost assumptions in an effort to illustrate the potential economic advantages that can be realized in the future by a solar energy system.

Specifically this section investigates the effect in Sacramento of reducing the Campbell hot water solar system costs in addition to:

- Assuming fuel costs escalate 3.4 percent (compounded annually) with the base year in 1980 ($2.61/1000 MJ or $2.75/MBtu)
- Using an investment tax credit of 20 percent in place of 10 percent
- Using diminishing balance (accelerated) depreciation in place of straight-line

All of these assumptions will shift the analysis in favor to the solar energy system. The fuel cost scenario is based on several sources concerning fuel cost and availability in the Sacramento area (see Section 4.3). The increased investment tax credit is also a likely possibility assuming Congress will continue to provide additional incentives for the investment in solar technology. Accelerated depreciation is substituted for the straight-line method since it is the more common practice by industry for large investments.

System costs can be assumed to be reduced in the future with justification. The installed costs incurred by Acurex in this initial design consists of:

- Nonrecurring labor charges and higher (than production or installation) labor rates associated with a prototype development
- Collector costs of $\$124.87/m^2$ ($\$11.60/ft^2$). These can reasonably be expected to drop to $\$80.73/m^2$ ($\$7.50/ft^2$) because of high volume production and less expensive materials

Based on these considerations, the economic analysis was performed for two lower system costs and is summarized in Table 20. (Computer printouts are included in Appendix F.) The time frame is assumed to begin in 1980 using the above assumptions. This analysis illustrates the significance of installed costs on the outcome of the cost comparison. Reducing system costs by 40 percent (to $188,200) accomplishes a 15 year payback and a small (2.8 percent) rate-of-return compared to paybacks exceeding 20 years and negative rates-of-return for the high cost case. The lowest installed

TABLE 20. ECONOMIC ANALYSIS: SACRAMENTO, BASED ON ANTICIPATED COST REDUCTIONS

Location	Total Investment, $	% Total Energy[a] Supplied by Solar	Before Tax Costs[b] $/1000 MJ ($/MBtu)			Payback,[c] Years	ROR[d] %
			Conventional	Solar	Solar Only		
Sacramento	188,220[e]	77	5.27 (5.55)	10.17 (10.72)	11.27 (11.88)	15.1	2.8
Sacramento	112,920[f]	77	5.27 (5.55)	6.85 (7.22)	6.95 (7.33)	11.2	6.5

[a]Total annual energy requirement at the can washer = 2.7×10^{12} MJ (2.8×10^{9} Btu)

[b]1054 MJ = 10^{6} Btu

[c]Payback is based on net cash flow after taxes.

[d]ROR — minimum rate of return on the net cash flow after taxes for 20 years

[e]An installed cost of $\$270/m^2$ ($\$25/ft^2$) based on 704 m^2 (7578 ft^2)

[f]An installed cost of $\$160/m^2$ ($\$15/ft^2$) based on 704 m^2 (7578 ft^2)

system cost, \$161.46/m² (\$14.90/ft²) gives encouraging results. The payback period is reduced to 11 years with a 6.5 percent rate-of-return after taxes — a respectable return for an investment in an alternate energy system.

APPENDIX A

ECONOMIC ANALYSIS APPROACH

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This appendix describes Acurex's approach to the economic analysis and a computer simulation used to perform the analysis. Acurex's economic approach is identical to that outlined in the 10 August 1976 Lawrence Livermore Laboratory memorandum (Appendix B). A computer simulation, however, was developed early in the design phase of the program, primarily to facilitate calculations involving nonuniform cash flows that are characteristic of industry methods. This computer program was also used in various subsystem cost optimizations.

The following sections briefly describe our economic approach (Section A.1) and summarize the computer simulation program (Section A.2). A computer output of the ERDA cost comparison example is attached as Appendix C to demonstrate the equivalence of Acurex's code to the approach described in the ERDA memo.

A.1 ECONOMICS APPROACH

An economic analysis is an essential step in the design of a solar system which will replace or supplement a conventional energy system. This analysis serves to answer the question "Are the benefits in fuel savings that will be realized over the lifetime of a solar energy system worth the investment in that system?" To answer this question an economic analysis must be made based on life-cycle costing, i.e., the ultimate viability of a solar energy system must be determined by comparing its costs over its lifetime with those of a conventional energy system.

Some form of a "present value" technique (e.g., annualized cost or minimum rate-of-return) should be utilized for this analysis. These techniques are termed "present value" because they recognize that a dollar earned today is worth more at the "present" than a dollar earned a year from now, since today's dollar accrues value over the years at some interest (or rate-of-return of an alternate investment). These present value techniques are favored over average rate-of-return or payback methods which ignore the "cost" (interest or potential rate-of-return) of the invested money over the anticipated project lifetime.

The economics of a solar/conventional cost comparison may be expressed in several ways. The more commonly accepted present value methods are:

- Annualized costs — all costs of a system over its lifetime are converted to equivalent annual disbursements. These costs are expressed in terms of dollars per total useful energy (in Btu's) supplied to the system.
- Minimum rate-of-return — this is the interest rate at which the present value of all costs over the system lifetime are equal to the present value of all benefits. This rate-of-return is compared to some criterion; if it is higher than the criterion, then the project is said to be economical.
- Breakeven point — this is a variation of the rate-of-return calculation. Here the interest rate is specified and the year in which the present value of costs equals the present value of all benefits is computed. Of course, the project is more economical for smaller breakeven points.

The annualized cost method is generally preferred over the latter two methods, especially the rate-of-return, which can be difficult to compute due to large negative cash flows occurring late in the project life, or very nonuniform cash flows. Nevertheless, any of these techniques are preferable to average rate-of-return and simple payback methods which ignore the "time value" of money. Therefore, the annualized cost approach was chosen for this analysis. Much of industry, however, still utilizes these simplified methods. Consequently, a code was developed which could evaluate solar energy systems in terms of annualized costs, rate-of-return, breakeven point, and simple payback (the time in years in which accumulated solar benefits after taxes just offset the solar investment). This code is described in more detail in the following section.

A.2 COMPUTER SIMULATION PROGRAM

The computer simulation described in this section can be especially useful in performing a cost calculation for this application, where many nonuniform costs (costs varying from year-to-year; for example, accelerated depreciation, escalating fuel costs, and "lumpy" maintenance charges) cause a "hand" calculation to be time consuming, or where it is desired to compute several cost comparisons for different assumptions in a quick and consistent manner. Considerations such as inflation, or a combination of debt and equity financing may also be taken into account by the code. Ultimately, this cost analysis code could be coupled with a solar system performance code to determine system optimums.

The basic computer code used to perform the financial analysis was obtained through Acurex's computer time-sharing service, Information Systems Design (ISD) of Santa Clara, California. This program, named Financial Planning Simulator (FPS), allows the user to write a FORTRAN program for his particular analysis utilizing a library of subroutines and functions for common financial calculations (loans, depreciation, rate-of-return, compounding and escalations, for example), and then to present the results of the analysis in his predetermined format. The program provides much flexibility in performing a variety of calculations and presenting the results in a consistent manner. The program utilizes the same analysis method outlined by ERDA in computing annualized costs. This program was used to evaluate the optimum design of various system components (piping and storage tank) and evaluate the system costs for the two solar locations based on input data specified by ERDA. In addition to these, a computation was performed for the Sacramento site (for several sets of assumptions) to be compared with the above cases.

Acurex recognizes ERDA's desire to evaluate various solar designs on a common basis as a necessary step in determining the economic and technical viability of different proposed systems. Thus, Appendix C includes a sample output of the Acurex FPS program which demonstrates its equivalency with the ERDA method of economic analysis for the example problem given in the ERDA memorandum. This memorandum is attached as Appendix B for easy reference.

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APPENDIX B

LAWRENCE LIVERMORE LABORATORY MEMORANDUM

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LAWRENCE LIVERMORE LABORATORY

August 10, 1976

Dear Contractor:

Enclosed is a revised version of the Method of Economic Analysis which is to replace the initial version distributed to all of you at the University of Maryland workshop. There are a number of changes made in this new version which we feel makes it more accurate as well as more useful to the contractors and to ERDA. Therefore we ask that you read it through carefully.

The principal changes have been suggested by members of the contractor's groups, both at the workshop and subsequently. This applies to the inclusion of Omaha as well as Albuquerque as "fiducial" locations for the economic analysis of your solar process heat system. This will provide an instructive comparison of system performance in a southwest location and in a more cloudy region with more severe winter weather. It also will bring out differences between focussing systems and flat-plate systems as a function of climatic region.

It will be noted that our worked-out example of Plan A versus a Plan B system now follows a different format and results in different values for the Plan B cost of energy as well as for the cost of solar energy alone. Our initial method was incorrect in that we did not properly differentiate between before-tax and after-tax items in the cost analysis. We are indebted to Bob McCarthy of General Electric for bringing this error to our attention.

Also please note that we are now requesting a calculation of the Plan B payback period. It became obvious at the workshop that industry places a great deal of importance on short payback periods. Therefore we felt that this information should be included in the analysis.

In the initial version we presented a method for taking into account a projected differential escalation in the price of fossil fuel. However it was not required that you include this calculation. A much simpler method of making this calculation has been brought to our attention by Bob McCarthy which gives equivalent results to the incremental present worth calculation we were using.* Therefore we now request that you include this calculation, using a 5% projected escalation factor for fuel oil. This of course will make the comparative costs of solar energy more favorable.

We wish also to express our thanks to John Rupert of Honeywell for providing us with useful information and for bringing to our attention the excellent report of R. T. Ruegg.

Please feel free to phone or write us if you run into any problems in completing the requested economic analysis.

Yours truly,

William C. Dickinson
Solar Projects Leader

WCD:dmb
Attach.

* The numerical values for annual cost worked out in the example are in fact different than our previous ones. This is because we were escalating the first year's fuel bill (assumed paid at end of year) by the escalation factor whereas, using the multiplying factor approach suggested by McCarthy, the initial cost of fuel applies to the first year and escalation begins in the second year.

Method of Economic Analysis for Comparison of Solar Process Heat Systems

Prepared by

W. C. Dickinson

J. N. Shearer

(Revised August 1, 1976)

Lawrence Livermore Laboratory
Livermore, California 94550
(415)-447-1100, Ext. 8693

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THE PURPOSE

"The main objective of (the Industrial Process Heat) program is to apply solar technology and develop solar systems which could supply a significant amount of the process heat requirements of industry, and to make solar systems for industrial applications commercially available in as short a time as possible. These systems must show economic viability, maintainability, reliability, and be capable of integration into existing industrial processes." This quote comes from p.5 of ERDA 76-88, May 1976, titled "Solar Energy for Agriculture and Industrial Process Heat".

The purpose of the economic analysis being requested here is to assist ERDA in evaluating the economic viability of the system you propose to install and operate during Phases II and III. The standard conditions defined in the following pages will allow this to be done in a way that is both meaningful to ERDA and equitable for all contractors.

In many ways this analysis may impose conditions that are quite different from your particular industrial process and solar system. For example, to avoid the influence of different amounts of insolation in different parts of the country, you are asked to do the economic analysis for two "fiducial" locations, Albuquerque, N.M. and Omaha, Neb. Likewise, fuel oil at $15 per bbl. has been chosen as the standard fossil fuel energy source. Please use this for the purposes of this economic analysis even though your particular plant may use natural gas or coal rather than oil. Likewise, it is necessary to standardize assumed lifetimes, income tax, rate of return on investment, and other factors which in reality will vary from one location to another or from one industry to another.

LIFE-CYCLE COSTING FOR A COMBINED SOLAR/FOSSIL FUEL INDUSTRIAL PROCESS HEAT SYSTEM

- To simplify the cost analysis it is recommended that the method of "equivalent uniform annual net disbursements", usually referred to as the "annual cost method", be used. A year by year incremental present worth calculation is generally not necessary and provides essentially the same result as the calculation of annual energy cost.

- Assume that "Plan A" represents a conventional process heat system using fuel oil and "Plan B" represents a combined solar/fuel oil facility. It is necessary to calculate the equivalent annual cost of energy under Plan A and Plan B. The results can be expressed in $/MBtu for each plan. The cost of solar energy alone in $/MBtu should also be presented. This is equal to the total incremental annual cost incurred by installation of the solar system divided by the average annual solar heat delivered to the process.

- So that different solar systems can be directly compared, Albuquerque, New Mexico, and Omaha, Nebraska have been chosen as "fiducial" locations for each system calculation. (See attached solar insolation data and average daytime ambient temperature data for these two locations.) It should also be assumed that fuel oil at the delivered price of $15/bbl. is the conventional fuel.

- Do not include in the economic analysis any proposed improvements to the present process heat system such as energy conservation or energy recovery systems which could equally well be added to a facility using fossil fuel alone. Also, include only costs of instrumentation and controls necessary for on-line operation of the solar system.

- The economic analysis is to be performed on the system which is being proposed for Phases II and III. All costs should be those appropriate for Phases II and III, not projected costs for future systems where savings due to mass production might be anticipated. For purposes of intercomparison, quote all costs in 1976 dollars, even though purchase of hardware and construction might not commence until a later time.

Suggested References:

1. Principles of Engineering Economy, E. L. Grant and W. G. Ireson. Fifth edition, Ronald Press, New York. 1970.

2. Solar Heating and Cooling in Buildings: Methods of Economic Evaluation, R. T. Ruegg, NBSIR 75-712, July, 1975. Available from the Institute for Applied Technology, National Bureau of Standards, Washington, D. C., 20234.

REQUIRED INPUT PARAMETERS FOR ANNUAL COST CALCULATION

1. Estimated total annual requirement for energy and percentage contribution of solar energy. (p.4)

2. Estimated installed solar system cost. (p.4)

3. Assume a 20 year lifetime for solar system and for boilers or process heaters of conventional system. (p.5)

4. Assume straight line depreciation on solar system. (p.5)

5. Estimated operation, maintenance, component replacement, and insurance premium costs for solar system. (p.5)

6. Assume federal + state income tax = 50%. (p.6)

7. Assume 10% initial investment tax credit. (p.6)

8. Assume a zero inflation rate. (p.6)

9. Assume a real after tax rate of return of 10% (p.7)

10. Assume the conventional fuel is fuel oil at a delivered price of $15/bbl. (1 bbl. = 5.8 MBtu)

11. Assume overall annual costs of boiler or process heater, including amortization of capital cost, operation and maintenance, to be $0.20/MBtu, based on total process heat required by plant. (p.7)

12. Assume fuel oil conversion efficiency = 70%. (p.8)

13. Assume zero salvage value at end of 20 years for solar system and for boilers or heaters. (p.8)

1. Estimated annual percentage contribution of solar energy.

Use attached solar insolation data for the appropriate collector configurat If, for example, the collectors will be tilted at an angle L(=latitude) at the actual location, you should use the values of L(latitude) for Albuquerque and Omaha in these calculations. Use direct or total insolation values as appropriate. Data are given as seasonal means for each of the four seasons. Several smoothed graphical curves of this data are also attached. Be guided by the shapes of these curves if you find it necessary to construct additional curves for other data. If it is desired to use hourly data with a computer simulation program, you should also present a comparison of daily sums of hourly insolation with Sandia average daily values.

The average annual energy contribution of the solar system is required. Experimental collection efficiency and performance data on your collectors should be presented and used in these calculations. If experimental data is limited to only certain times of the year, computer simulation data may be used. However the extent of agreement between experimental and computer data should be presented.

Use attached values of monthly average daytime ambient temperatures (obtained from Liu and Jordan tables.†) Assume an average wind speed of 10 mph. in calculating collector heat loss coefficients.

2. Estimated installed solar system cost. (To be expressed as a total amount and also in terms of $\$/ft^2$ of collector area.)

The following items should be included:

a) Site preparation
b) Collectors
   1. Materials and construction
   2. Installation
c) Storage system
d) Hook-up to and any required modification of conventional system
e) Piping and ducting
f) Pumps, valves, etc.
g) Electrical wiring
h) Instrumentation and controls necessary for on-line operation of solar system.

Assume that the average labor rate is $15/hour at each location.

†B.Y.H. Liu and R.C. Jordan, Solar Energy 7 (2), 53 (1963).

3. <u>Assume a 20 year lifetime for solar system and for boilers or heaters of conventional system.</u>

The average expected lifetime for boilers and process heaters is about 20 years. Therefore, if a new plant is installing a solar/fossil fuel system, it is convenient to assume the same lifetime for all parts of the system. If an existing plant is installing a supplementary solar system, it will be assumed in order to simplify the economic calculation that the plant is installing new boilers or heaters at the same time.

Generally the annual cost of process heat is quite insensitive to the assumed lifetime of the system in a life-cycle cost analysis. For example, the assumption of a 25 year rather than a 20 year lifetime would in most cases only decrease the annual cost of energy by 1% or 2%.

4. <u>Assume straight line depreciation on solar system over 20 years.</u>

The assumption of straight line depreciation simplifies the economic calculation. For a solar system where there is little or no experience in terms of its performance, reliability, or lifetime, the I.R.S. might indeed allow an accelerated depreciation which would have the effect of reducing equivalent annual energy costs. However, the allowed period and type of accelerated depreciation will vary from one system to another so it is preferred here to assume the simpler straight line write-off of the solar system.

5. <u>Estimated operation, maintenance, component replacement, and insurance premium costs of solar system.</u>

Assume a constant annual cost for operation and maintenance of the solar system even though maintenance costs might be expected to increase toward the end of the 20 year system life. Also, assume an equivalent annual cost for component replacement even though such replacements may only occur every few years. Estimate annual insurance premium on solar system. Assume cost of electrical energy at each location is 3¢/kWh.

6. Assume federal + state income tax = 50%.

See page 9 for a discussion of before-tax vs. after-tax energy costs. Also the worked-out examples show how the income tax is to be handled in the calculation of energy cost. Do not include any property tax or other taxes in these calculations.

7. Assume 10% initial investment tax credit.

To convert this to an equivalent annual cost (a negative cost in this case), multiply the tax credit by the appropriate capital recovery factor. CRF (10%, 20 years) = 0.11746. The tax credit does not reduce the depreciation base.

8. Assume a zero inflation rate.

The economic calculation is simplified by assuming that all costs, prices, and wages will escalate at the same rate over future years. Hence, inflation can be ignored and dollars of constant value (here taken as 1976 dollars) can be used in calculating annual cost of energy. If it is then desired to escalate the annual energy cost on the basis of a projected inflation rate, this can easily be done. The same escalation rate would apply to both Plan A and Plan B annual energy costs. However, it is not necessary for present purposes.

The assumption of a zero inflation rate gives valid results only if the solar system is purchased with equity funds and not with debt financing. (See Ruegg, op, cit.) Also, an error is introduced in using a constant annual depreciation since inflation causes the annual depreciation expense to fall in terms of dollars of uniform value. However, the future rate of inflation is quite speculative and in any event the effect on annual energy costs of neglecting this factor will generally be small.

It may well be that the price of fossil fuels will escalate over the next few years at a higher rate than the general inflation rate. For example, a reasonable assumption, also to be used in the economic analysis, is that there will be a 5% differential increase in oil prices, compounded yearly. This will result in a yearly increase in energy costs under both Plan A and Plan B, but will make Plan B more attractive relative to Plan A. In order to calculate the equivalent uniform annual cost, the basic approach is to first calculate the present worth of Plan A over the 20 year lifetime and then the incremental present worth of Plan B relative to Plan A. The present worth of each plan may then be converted to equivalent annual energy costs by multiplying by the appropriate capital recovery factor.

However a much simpler method is presented on page 14 which gives identical results. In this method a multiplying factor is calculated and then applied to the initial cost of fossil fuel to obtain a "levelized" cost of fuel over the 20 year lifetime of the system. This levelized fuel cost can then be used in the conventional annual cost calculation.

9. Assume a real after tax rate of return = 10%.

The real rate of return excludes the inflation factor and is related to the market rate of return which includes an inflation factor by the expression:

$$\left(1 + \frac{\text{market rate}}{100}\right) = \left(1 + \frac{\text{inflation}}{100}\right)\left(1 + \frac{\text{real rate}}{100}\right)$$

Thus, for an assumed inflation factor of 6%, a real rate of return of 10% corresponds to a market rate of 16.6%.

10. No Comments.

11. Assume overall annual costs of boiler or process heater = \$0.20/MBtu.

It should be assumed that the boiler provides 100% backup to the solar facility. Therefore, the same boiler capacity is required under Plans A and B. Current catalog prices for boilers run about \$30,000 for an annual output capacity of 10^5 MBtu/yr. It is assumed for simplicity that there is linear scaling between boiler cost and output capacity. For a boiler with rated output of 10^5 MBtu/yr ($\approx$ 10,000 lb/hr of wet steam), the operation and maintenance costs are assumed to be about \$15,000 per year. For a 20 year boiler lifetime, 10% rate of return on investment and straight line depreciation, the overall boiler cost per MBtu of output is:

Capital amortization	= $0.07/MBtu	(before tax)
Depreciation deduction	= -0.015	(before tax)
Approximate O & M cost	≈ 0.15	" "
Total	≈ $0.20/MBtu	(before tax, see p.9)

12. Assume fuel oil conversion efficiency = 70%.

This is a reasonable average value for conversion of fuel oil energy to process heat delivered at point of use. For example, a typical boiler conversion efficiency is 80% and a typical heat loss in delivering hot water or steam to the point of use might be 10%.

If you have data showing the actual overall conversion efficiency at your process plant is substantially different from 70% you may use the actual value. Clearly indicate what value you are using.

13. Assume zero salvage value at end of 20 years for solar system and for boilers or heaters.

The present worth of salvage value is generally quite small. Since assuming a salvage value changes the annual depreciation allowance and hence affects income tax, it is simpler to assume zero salvage value. This will generally have only a small effect on annual energy costs.

ENERGY COSTS EXPRESSED IN BEFORE-TAX VS. AFTER-TAX DOLLARS

When a company spends \$1.00 for fuel, its cash flow after taxes is only reduced by \$0.50 (assuming a 50% income tax). Hence the after-tax cost of energy is only one half the before-tax cost. This is illustrated in the following example:

No fuel oil purchased

Gross receipts	=	\$1000
Cash flow before taxes	=	1000
Income tax	=	500
Cash flow after taxes	=	\$ 500

Fuel oil purchased

Gross receipts	=	\$1000
Cost of fuel oil	=	200
Cash flow before taxes	=	800
Income tax	=	400
Cash flow after taxes	=	\$ 400

Note that although the purchase price for the fuel oil is \$200, the effect of the purchase is to reduce cash flow after taxes by only \$100. Although it might seem logical to calculate the cost of energy based on the after-tax cost of fuel oil, we follow the general practice to calculate before-tax energy cost.

It follows that for the Plan B case of a combined fuel oil/solar process heat system, the before-tax energy cost must be calculated to compare with the before-tax energy cost for the Plan A case of fuel oil alone. Similarly, the before-tax cost of solar energy alone is to be calculated.

If an annual cost calculation or an incremental present worth calculation provides an amount for the increase in after-tax energy cost, the corresponding amount for the increase in before-tax energy cost is obtained by dividing by 0.5. This is illustrated by returning to the above example and increasing the price of fuel oil to \$300:

Gross receipts	=	\$1000
Cost of fuel oil	=	300
Cash flow before taxes	=	700
Income tax	=	350
Cash flow after taxes	=	\$ 350

Hence a before-tax increase in cost of fuel of \$100 results in an after-tax decrease in cash flow (or equivalently an after-tax increase in cost of fuel) of \$50.

EXAMPLE OF AN ANNUAL ENERGY COST CALCULATION

Assumed conditions:

1. Annual requirement for process hot water = 2×10^5 MBtu.
2. Annual contribution from solar facility = 10^5 MBtu (50%).
3. Area of solar collectors = 8 acres.
4. Installed solar system cost = \$10.00/ft^2 (\$10.00/ft^2 x 348,480 ft^2 = \$3,484,800)
5. Annual O & M, replacement and insurance = \$30,000.

PLAN A - ANNUAL ENERGY COST CALCULATION

Cost of fuel oil energy: $\frac{\$15/\text{bbl} \times 2 \times 10^5 \text{ MBtu}}{5.8 \text{ MBtu/bbl} \times 0.7}$ = \$738,920 (before tax)

Boilers: \$0.20/MBtu x 2×10^5 MBtu = 40,000 (before tax)

Deductible expenses:

Fuel oil	=	\$738,920
Boilers	=	40,000
Total	=	\$778,920

Effect of expenditures for Plan A process heat system on reduction of income taxes = -389,460

Plan A after-tax energy cost = \$389,460

Plan A before-tax energy cost = \$778,920

$$\frac{\$778{,}920}{2 \times 10^5 \text{ MBtu}} = \$3.89/\text{MBtu}$$

PLAN B ANNUAL ENERGY COST CALCULATION

Repayment to equity for solar facility [3,484,800 x 0.11746]	= $ 409,320	
10% investment tax credit	= – 40,930	
Cost of fuel oil energy	= 369,460	before tax
Boilers	= 40,000	before tax
Solar O&M, replacement and insurance	= 30,000	before tax

Deductible expenses:

Fuel oil	=	$369,460
Boilers	=	40,000
OMRI	=	30,000
Depreciation	=	174,240
Total	=	$613,700

Effect of expenditures for Plan B process heat system on reduction of income taxes = -306,850*

Plan B after-tax energy cost = $ 501,000

Plan B before-tax energy cost = $1,002,000

$$\frac{\$\ 1{,}002{,}000}{2 \times 10^5\ \text{MBtu}} = \$5.01/\text{MBtu}$$

*Note that the reduction of income tax for Plan B is $82,610 less than for Plan A. Stated differently, the income tax paid under Plan B is $82,610 greater than under Plan A.

ANNUAL COST CALCULATION FOR SOLAR ENERGY ALONE

Repayment to equity for solar facility	=	$409,320
10% investment tax credit	=	-40,930
Solar O&M, replacement and insurance	=	30,000] before tax

Deductible expenses:

OMRI	=	$ 30,000
Depreciation	=	174,240
Total	=	$204,240

Effect of expenditures for solar heat alone on reduction of income taxes	=	-102,120
After-tax cost of solar energy alone	=	$296,270
Before-tax cost of solar energy alone	=	$592,540

$$\frac{\$592,540}{1\times10^{5}\ \text{MBtu}} = \$5.93/\text{MBtu}$$

CALCULATION OF PAYBACK PERIOD FOR PLAN B

Notation:

F_o = Annual Plan A fuel oil bill

K = Fraction of annual process heat supplied by solar in Plan B

N = System lifetime

OMRI = Annual O & M, replacement and insurance costs for solar system

Tax Rate = 0.5

I = Total installed cost of solar system

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1. Annual Plan B cash savings $= KF_o - OMRI$
2. Added income before tax $= KF_o - OMRI - \frac{I}{N}$
3. Added income tax $= 0.5\,[KF_o - OMRI - \frac{I}{N}]$
4. Net annual incremental cash flow $= 0.5\,[KF_o - OMRI + \frac{I}{N}]$

$$\text{Payback Period} = \frac{\text{Net initial investment}}{\text{Net annual incremental cash flow}} = \frac{I - 0.1\,I}{0.5\,[KF_o - OMRI + \frac{I}{N}]}$$

For our example:

$$\text{Payback Period} = \frac{\$3{,}136{,}320}{\$256{,}850/\text{yr}} = 12.2 \text{ years}$$

CALCULATION OF EQUIVALENT ANNUAL PLAN A AND PLAN B ENERGY COSTS FOR CASE OF ESCALATION IN FUEL COSTS

Additional notation:

e = Differential escalation rate on annual price of fuel oil

i = Real rate of return on investment

F_o = Fuel oil bill at end of first year. (At end of second year, bill = $F_o(1+e)$, third year = $F_o\ (1+e)^2$, etc.)

CRF = Capital recovery factor = $\left[\frac{i(1+i)^N}{(1+i)^N-1}\right]$

Multiplying factor to obtain "levelized" cost of fuel oil over N years:

$$M.F. = \frac{CRF}{(i-e)}\left[1 - \left(\frac{1+e}{1+i}\right)^N\right]$$

For our example with e = 0.05, i = 0.10, N = 20, CRF = 0.11746:

M.F. = 1.4227

Multiplying this by the initial price of fuel oil, \$15/bbl, gives \$21.34/bbl for the levelized price over the 20 year system life. Using this new price for fuel oil and repeating the Plan A and Plan B annual cost calculations results in:

Plan A before-tax energy cost = \$5.46/MBtu

Plan B before-tax energy cost = \$5.79/MBtu

[Note that a zero general inflation rate is still assumed. Annual energy costs above can be escalated on the basis of any assumed general inflation rate if desired.]

SUMMARY OF REQUESTED ECONOMIC CALCULATIONS AND DATA FROM CONTRACTORS

1. Make all calculations listed below separately for Albuquerque and Omaha.
2. Use input parameters listed on page 3. List clearly:
    - Estimated total annual requirement for process heat.
    - Estimated percentage contribution of solar energy.
    - Estimated installed solar system cost (with breakdown).
    - Estimated OMRI costs.
    - Overall fuel oil conversion efficiency (if different from 70%).
3. Calculate Plan A before-tax energy cost as on page 10.
4. Calculate Plan B before-tax energy cost as on page 11.
5. Calculate before-tax cost of solar energy alone as on page 12.
6. Calculate Plan B payback period using equation on page 13.
7. For an assumed 5% escalation rate in price of fuel oil, calculate Plan A and Plan B before-tax energy costs. See page 14.

Average day-time ambient temperatures for Albuquerque N.M. and Omaha, Neb.

(from Liu and Jordan)

	F° Albuquerque	F° Omaha	C° Albuquerque	C° Omaha
Jan.	37.3	27.8	2.9	-2.3
Feb.	43.3	32.1	6.3	0.06
Mar.	50.1	42.4	10.1	5.8
Apr.	59.6	55.8	15.3	13.2
May	69.4	65.8	20.8	18.8
Jun.	79.1	76.0	26.2	24.4
July	82.8	82.6	28.2	28.1
Aug.	80.6	80.2	27.0	26.8
Sept.	73.6	71.5	23.1	21.9
Oct.	62.1	59.9	16.7	15.5
Nov.	47.8	43.2	8.8	6.2
Dec.	39.4	31.8	4.1	-0.11

SOLAR RADIATION AVAILABILITIES IN ALBUQUERQUE, N.M.

The attached data are excerpted from a report by Dr. Eldon C. Boes of the Sandia Albuquerque Laboratories: Solar Radiation Availability to Various Collector Geometries: A Preliminary Study, SAND 76-0009, February 1976. The report consists of a compilation of solar radiation availabilities for 3 locations - Albuquerque, N.M., Blue Hill, Mass., and Omaha, Nebraska, using 1962 National Weather Service solar strip chart records of both direct-normal and total-horizontal data.

With these two types of data, taken simultaneously, it is possible to compute values for all of the 14 quantities listed in the attached table. The average availability numbers are seasonal means and the clear day values given in parentheses are for single days near the appropriate solstice and equinox days. To get yearly sums it is sufficiently accurate to add up the four seasonal values and multiply by 365/4. If average hourly values of radiation are needed, these can be obtained from the average daily values using the method presented by Liu and Jordan, Solar Energy 7 (2), 53 (1963).

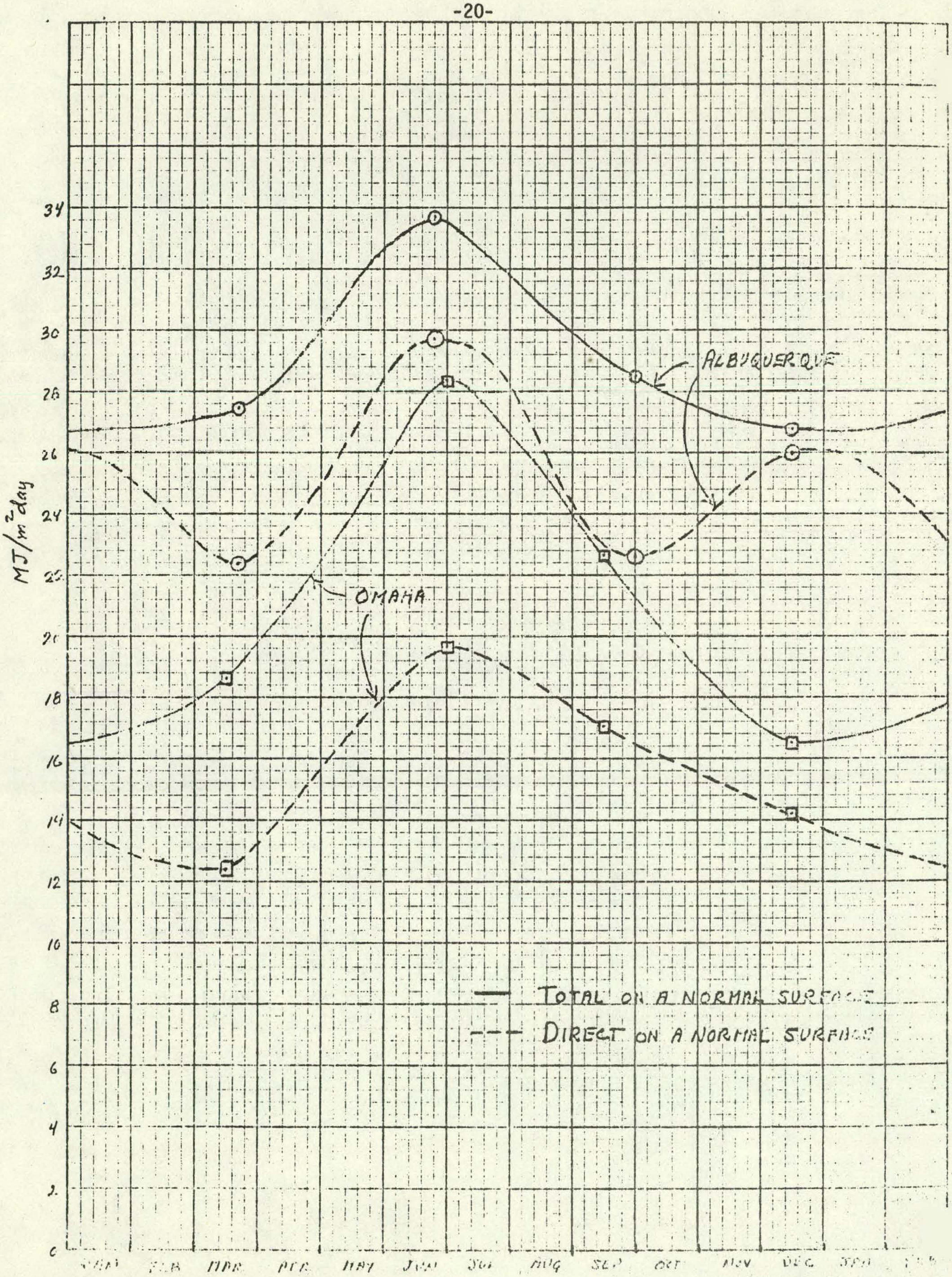
The solar group at LLL has checked the attached values of total radiation on a horizontal surface (#12) against data for other years in Albuquerque and 1962 turns out to have been a pretty average solar year.

Average and Clear Day ( ) Solar Radiation Availabilities for Albuquerque (A) and Omaha (O). (From Eldon Boes, SAND 76-0009).

MJ/m^{2}day [Multiply by 88.1 to obtain Btu/ft^2 day]

RADIATION TYPE		SPRING	SUMMER	FALL	WINTER
1) Direct on a normal surface	A	22.4(32.7)	29.7(35.6)	22.6(32.9)	26.0(28.7
	O	12.4(23.0)	19.7(34.4)	17.1(32.7)	14.2(22.2
2) Direct on surface which rotates about horizontal East-West axis.	A	16.3(25.1)	22.7(26.9)	17.1(24.3)	22.2(24.4
	O	9.7(19.6)	14.7(25.3)	13.1(24.0)	12.4(19.5
3) Direct on surface which rotates about North-South polar axis	A	22.4(32.7)	27.3(32.6)	22.5(32.8)	23.9(26.3
	O	12.2(22.1)	18.1(31.6)	17.1(32.6)	13.1(20.4
4) Direct on surface which rotates about Horizontal North-South axis	A	19.9(28.6)	29.3(35.0)	19.3(28.5)	16.7(18.4
	O	10.3(15.2)	19.2(33.6)	14.7(28.9)	8.1(12.6
5) Direct on a horizontal surface	A	13.2(19.9)	21.8(25.8)	13.0(18.5)	10.2(11.2
	O	7.1(9.8)	14.0(24.0)	10.2(19.4)	4.6(7.2
6) Direct on tilted surface: 10°	A	14.7(22.2)	22.0(25.9)	14.7(21.0)	13.5(14.7
	O	8.1(12.6)	14.3(24.6)	11.5(21.6)	6.5(10.2
20°	A	15.7(23.9)	21.6(25.3)	16.0(22.8)	16.3(17.9
	O	8.8(14.9)	14.2(24.4)	12.4(23.1)	8.2(12.9
30°	A	16.3(24.9)	20.6(23.9)	16.8(23.9)	18.7(20.4
	O	9.2(16.9)	13.7(23.4)	13.0(23.9)	9.8(15.2
40°	A	16.3(25.1)	18.9(21.8)	17.1(24.2)	20.4(22.4
	O	9.4(18.4)	12.7(21.8)	13.1(23.9)	10.9(17.1
50°	A	15.9(24.5)	16.7(19.0)	16.8(23.9)	21.6(23.7
	O	9.3(19.2)	11.4(19.5)	12.9(23.3)	11.8(18.4
60°	A	15.0(23.1)	13.9(15.8)	16.1(22.8)	22.1(24.3
	O	8.8(19.5)	9.8(16.7)	12.2(21.9)	12.3(19.2
70°	A	13.6(21.1)	10.8(12.1)	14.9(21.0)	22.0(24.1
	O	8.2(19.2)	7.8(13.4)	11.2(19.9)	12.4(19.4
80°	A	11.8(18.5)	7.4(8.2)	13.2(18.6)	21.2(23.2
	O	7.2(18.4)	5.7(9.8)	9.8(17.2)	12.2(19.0
7) Direct on south-facing vertical surface.	A	9.7(15.3)	3.8 (4.1)	11.2(15.7)	19.7(21.6
	O	6.1(16.9)	3.4 (6.0)	8.2(14.1)	11.6(18.0

RADIATION TYPE			SPRING	SUMMER	FALL	WINTER
8) Total on a normal surface		A	27.5(34.8)	33.7(38.1)	28.5(36.5)	26.8(29.1)
		O	18.6(26.4)	28.4(39.8)	22.7(36.1)	16.5(23.5)
9) Total on surface which rotates about horizontal East-West axis		A	21.7(27.4)	26.9(29.6)	23.3(28.0)	23.1(24.8)
		O	16.2(23.0)	23.8(31.0)	19.0(27.7)	14.7(20.8)
10) Total on surface which rotates about North-South polar axis		A	27.7(34.9)	31.1(35.1)	28.8(36.6)	24.8(26.8)
		O	18.8(25.9)	26.7(36.9)	22.9(36.2)	15.7(21.9)
11) Total on surface which rotates about horizontal North-South axis		A	25.2(30.8)	33.2(37.5)	25.5(32.2)	17.5(18.9)
		O	16.8(18.9)	27.9(39.0)	20.5(32.5)	10.5(14.0)
12) Total on a horizontal surface		A	18.8(22.3)	26.1(28.5)	19.6(22.5)	11.1(11.7)
		O	14.1(13.7)	23.3(29.8)	16.5(23.3)	7.3(8.7)
13) Total on tilted surface:	10°	A	20.3(24.7)	26.3(28.7)	21.3(24.9)	14.4(15.2)
		O	15.0(16.5)	23.5(30.3)	17.7(25.4)	9.2(11.7)
	20°	A	21.3(26.3)	25.8(28.0)	22.5(26.7)	17.2(18.4)
		O	15.6(18.9)	23.3(30.1)	18.6(26.9)	10.9(14.4)
	30°	A	21.7(27.2)	24.7(26.5)	23.2(27.7)	19.6(20.9)
		O	15.9(20.7)	22.6(29.1)	19.0(27.6)	12.3(16.7)
	40°	A	21.6(27.3)	22.9(24.4)	23.3(28.0)	21.3(22.9)
		O	15.9(22.1)	21.5(27.3)	19.0(27.6)	13.5(18.5)
	50°	A	21.0(26.7)	20.6(21.6)	22.9(27.5)	22.5(24.2)
		O	15.6(22.9)	19.8(24.8)	18.5(26.8)	14.3(19.8)
	60°	A	19.9(25.3)	17.7(18.2)	21.9(26.3)	23.0(24.7)
		O	14.9(23.0)	17.9(21.8)	17.7(25.3)	14.7(20.6)
	70°	A	18.3(23.1)	14.4(14.5)	20.4(24.4)	22.8(24.5)
		O	14.0(22.6)	15.6(18.3)	16.4(23.1)	14.7(20.7)
	80°	A	16.3(20.4)	10.8(10.4)	18.4(21.8)	21.9(23.6)
		O	12.7(21.5)	13.1(14.4)	14.8(20.3)	14.3(20.2)
14) Total on south facing vertical surface		A	13.9(17.1)	7.1(6.2)	16.1(18.6)	20.4(22.0)
		O	11.3(19.9)	10.4(10.4)	12.9(17.0)	13.6(19.2)


34
32
30
28
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24
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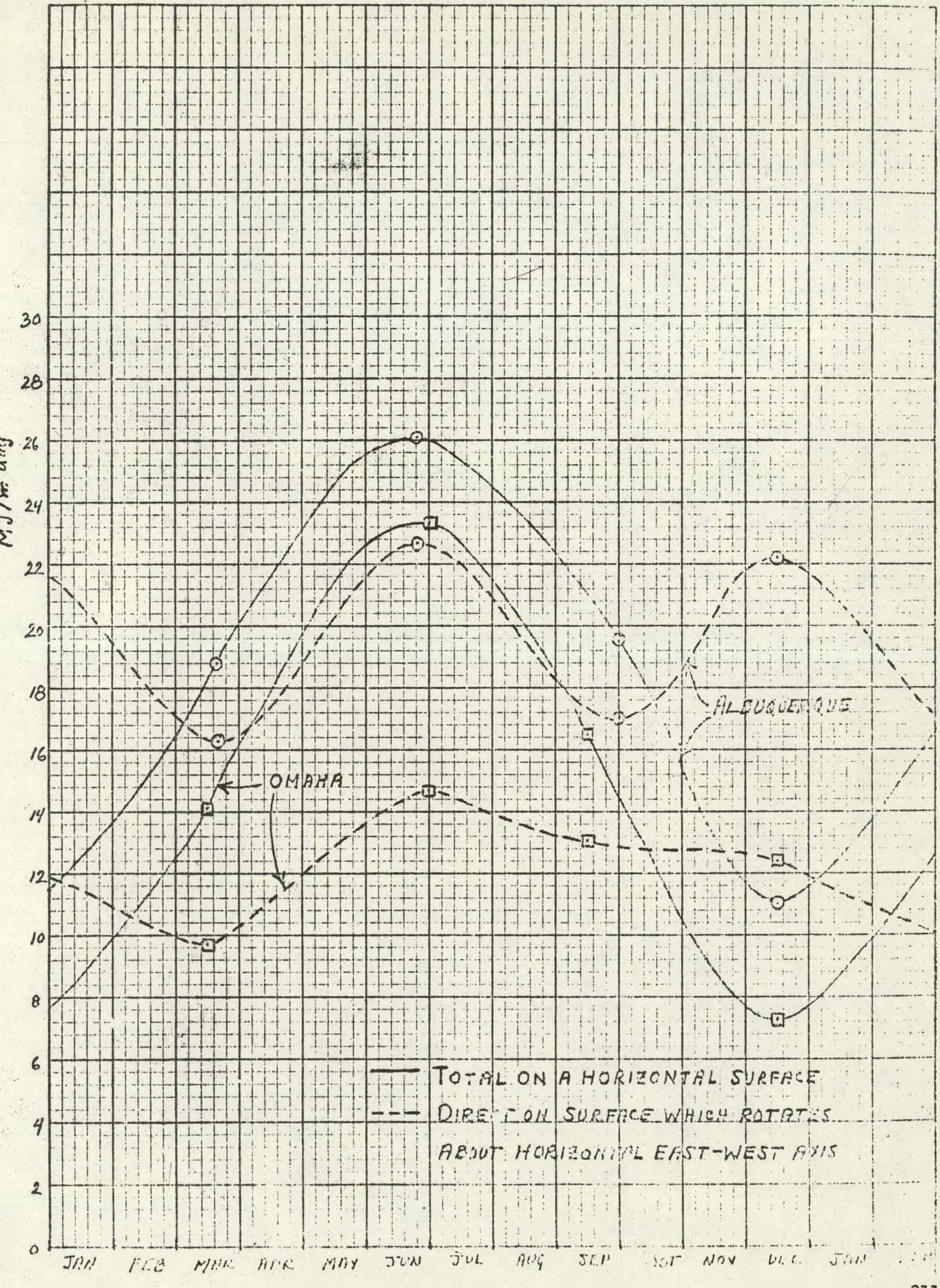
18
16
14
12
10
8
6
4
2
0
MJ/m²day
ALBUQUERQUE
OMAHA
TOTAL ON A NORMAL SURFACE
DIRECT ON A NORMAL SURFACE
MAR
APR
MAY
JUN
AUG
SEP
OCT
NOV
DEC


30
28
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8
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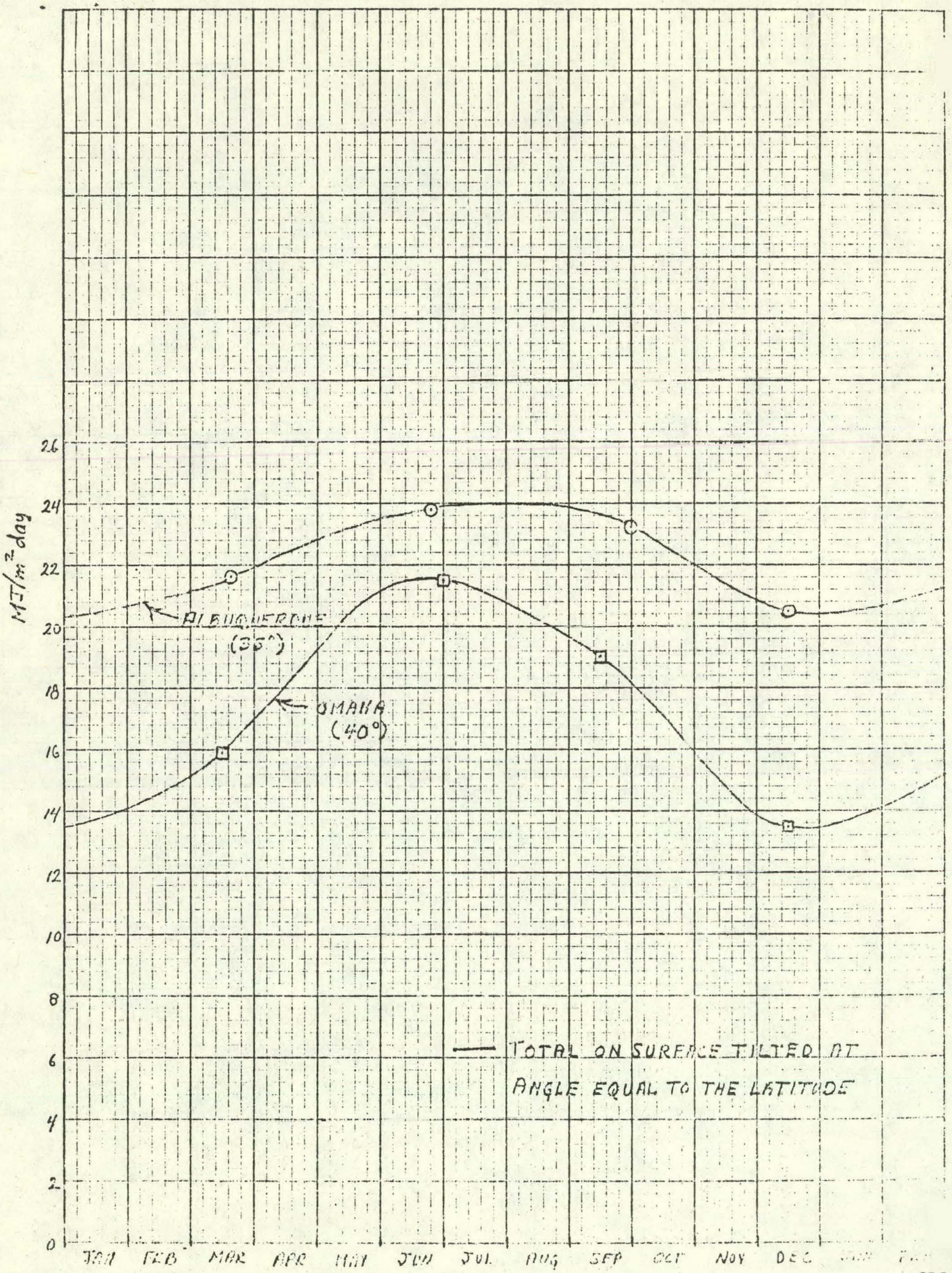
MJ/m²day
OMAHA
ALBUQUERQUE
TOTAL ON A HORIZONTAL SURFACE
DIRECT ON SURFACE WHICH ROTATES
ABOUT HORIZONTAL EAST-WEST AXIS
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
NOV
DEC
JAN


MJ/m²day
26
24
22
20
18
16
14
12
10
8
6
4
2
0
ALBUQUERQUE (35°)
OMAHA (40°)
TOTAL ON SURFACE TILTED AT ANGLE EQUAL TO THE LATITUDE
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

APPENDIX C

SAMPLE OUTPUT OF THE ACUREX FPS PROGRAM

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ERDA Example Problem: No Fuel Cost Increase

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
FUEL	0	-369,460	-369,460	-369,460	-369,460	-369,460	-369,460	-369,460
FIXED CHARGES	0	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000
BOILER	0	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999
1) TOTAL	0	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459
CONVENTIONAL COSTS								
FUEL	0	-738,920	-738,920	-738,920	-738,920	-738,920	-738,920	-738,920
BOILER	0	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999
2) TOTAL	0	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919
TAX CALCULATION								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459
-DEPRECIATION	0	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240
TAXABLE INCOME	0	-613,699	-613,699	-613,699	-613,699	-613,699	-613,699	-613,699
-INCOME TAX	0	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849
-INVEST TAX CREDIT	349,479	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-349,479	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849
CONVENTIONAL:								
TAXABLE INCOME	0	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919
4) TOTAL INCOME TAX	0	-389,459	-389,459	-389,459	-389,459	-389,459	-389,459	-389,459
AFTER TAX CASH FLOWS								
SOLAR, 1)-3)	-3,136,320	-132,610	-132,610	-132,610	-132,610	-132,610	-132,610	-132,610
CONVENTIONAL, 2)-4)	0	-389,460	-389,460	-389,460	-389,460	-389,460	-389,460	-389,460
NET CASH FLOW AFTER TAXES	-3,136,320	256,850	256,850	256,850	256,850	256,850	256,850	256,850
ACCUMULATED AT 0%	-3,136,320	-2,879,470	-2,622,620	-2,365,770	-2,108,920	-1,852,070	-1,595,220	-1,338,370
ACCUMULATED NPV AT 10%	-3,136,320	-2,902,820	-2,690,547	-2,497,572	-2,322,140	-2,162,656	-2,017,671	-1,885,866

RATE-OF-RETURN FOR 20 YEARS = 5.2415833

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -1.9472999
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -2.5050047

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -3.8945999
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -5.0100093

ANNUAL COST BEFORE TAX : SOLAR ONLY $/MBTU = -5.9254200

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-369,460	-369,460	-369,460	-369,460	-369,460	-369,460	-369,460	-369,460
FIXED CHARGES	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000
BOILER	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999
1) TOTAL	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459
CONVENTIONAL COSTS								
******************								
FUEL	-738,920	-738,920	-738,920	-738,920	-738,920	-738,920	-738,920	-738,920
BOILER	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999
2) TOTAL	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459	-439,459
-DEPRECIATION	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240
TAXABLE INCOME	-613,699	-613,699	-613,699	-613,699	-613,699	-613,699	-613,699	-613,699
-INCOME TAX	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849	-306,849
CONVENTIONAL:								
TAXABLE INCOME	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919	-778,919
4) TOTAL INCOME TAX	-389,459	-389,459	-389,459	-389,459	-389,459	-389,459	-389,459	-389,459
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	-132,610	-132,610	-132,610	-132,610	-132,610	-132,610	-132,610	-132,610
CONVENTIONAL, 2)-4)	-389,460	-389,460	-389,460	-389,460	-389,460	-389,460	-389,460	-389,460
NET CASH FLOW AFTER TAXES								
*************************	256,850	256,850	256,850	256,850	256,850	256,850	256,850	256,850
ACCUMULATED AT 0%	-1,081,520	-824,670	-567,820	-310,970	-54,120	202,729	459,579	716,429
ACCUMULATED NPV AT 10%	-1,766,044	-1,657,113	-1,558,088	-1,468,063	-1,386,223	-1,311,823	-1,244,186	-1,182,698

	1992	1993	1994	1995	1996
SOLAR COSTS					
***********					
FUEL	-369,460	-369,460	-369,460	-369,460	-369,460
FIXED CHARGES	-30,000	-30,000	-30,000	-30,000	-30,000
BOILER	-39,999	-39,999	-39,999	-39,999	-39,999
1) TOTAL	-439,459	-439,459	-439,459	-439,459	-439,459
CONVENTIONAL COSTS					
******************					
FUEL	-738,920	-738,920	-738,920	-738,920	-738,920
BOILER	-39,999	-39,999	-39,999	-39,999	-39,999
2) TOTAL	-778,919	-778,919	-778,919	-778,919	-778,919
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-439,459	-439,459	-439,459	-439,459	-439,459
-DEPRECIATION	-174,240	-174,240	-174,240	-174,240	-174,240
TAXABLE INCOME	-613,699	-613,699	-613,699	-613,699	-613,699
-INCOME TAX	-306,849	-306,849	-306,849	-306,849	-306,849
-INVEST TAX CREDIT	0	0	0	0	0
3) TOTAL INCOME TAX	-306,849	-306,849	-306,849	-306,849	-306,849
CONVENTIONAL:					
TAXABLE INCOME	-778,919	-778,919	-778,919	-778,919	-778,919
4) TOTAL INCOME TAX	-389,459	-389,459	-389,459	-389,459	-389,459
AFTER TAX CASH FLOWS					
********************					
SOLAR, 1)-3)	-132,610	-132,610	-132,610	-132,610	-132,610
CONVENTIONAL, 2)-4)	-389,460	-389,460	-389,460	-389,460	-389,460
NET CASH FLOW AFTER TAXES					
*************************	256,850	256,850	256,850	256,850	256,850
ACCUMULATED AT 0%	973,279	1,230,129	1,486,979	1,743,829	2,000,679
ACCUMULATED NPV AT 10%	-1,126,800	-1,075,584	-1,029,787	-987,790	-949,611

ERDA Example Problem: 5% Fuel Cost Increase

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS
****

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
***********								
FUEL	0	-369,460	-387,932	-407,329	-427,696	-449,080	-471,534	-495,111
FIXED CHARGES	0	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000
BOILER	0	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999
1) TOTAL	0	-439,459	-457,932	-477,329	-497,696	-519,080	-541,534	-565,111
CONVENTIONAL COSTS								
******************								
FUEL	0	-738,920	-775,865	-814,659	-855,392	-898,161	-943,069	-990,223
BOILER	0	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999
2) TOTAL	0	-778,919	-815,865	-854,659	-895,392	-938,161	-983,069	-1,030,223
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT.	0	-439,459	-457,932	-477,329	-497,696	-519,080	-541,534	-565,111
-DEPRECIATION	0	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240
TAXABLE INCOME	0	-613,699	-632,172	-651,569	-671,936	-693,320	-715,774	-739,351
-INCOME TAX	0	-306,849	-316,086	-325,784	-335,968	-346,660	-357,887	-369,675
-INVEST TAX CREDIT	348,479	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-348,479	-306,849	-316,086	-325,784	-335,968	-346,660	-357,887	-369,675
CONVENTIONAL:								
TAXABLE INCOME	0	-778,919	-815,865	-854,659	-895,392	-938,161	-983,069	-1,030,223
4) TOTAL INCOME TAX	0	-389,459	-407,932	-427,329	-447,696	-469,080	-491,534	-515,111
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	-3,136,320	-132,610	-141,846	-151,544	-161,728	-172,420	-183,647	-195,435
CONVENTIONAL, 2)-4)	0	-389,459	-407,932	-427,329	-447,696	-469,080	-491,534	-515,111
NET CASH FLOW AFTER TAXES								
************************	-3,136,320	256,850	266,086	275,784	285,968	296,660	307,887	319,675
ACCUMULATED AT 0%	-3,136,320	-2,879,470	-2,613,383	-2,337,598	-2,051,630	-1,754,970	-1,447,082	-1,127,406
ACCUMULATED NPV AT 10%	-3,136,320	-2,902,820	-2,682,913	-2,475,712	-2,280,392	-2,096,189	-1,922,395	-1,758,351

RATE-OF-RETURN FOR 20 YEARS = 8.0212460

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.7281181
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -2.8954137

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -5.4562361
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -5.7908273

ANN COST BEFORE TAX : SOLAR ONLY $/MBTU = -5.9254200

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-519,867	-545,860	-573,153	-601,811	-631,901	-663,497	-696,671	-731,505
FIXED CHARGES	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000	-30,000
BOILER	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999
	----------	----------	----------	----------	----------	----------	----------	----------
1) TOTAL	-589,867	-615,860	-643,153	-671,811	-701,901	-733,497	-766,671	-801,505
CONVENTIONAL COSTS								
*****************								
FUEL	-1,039,734	-1,091,721	-1,146,307	-1,203,622	-1,263,803	-1,326,994	-1,393,343	-1,463,010
BOILER	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999	-39,999
	----------	----------	----------	----------	----------	----------	----------	----------
2) TOTAL	-1,079,734	-1,131,721	-1,186,307	-1,243,622	-1,303,803	-1,366,994	-1,433,343	-1,503,010
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-589,867	-615,860	-643,153	-671,811	-701,901	-733,497	-766,671	-801,505
-DEPRECIATION	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240	-174,240
TAXABLE INCOME	-764,107	-790,100	-817,393	-846,051	-876,141	-907,737	-940,911	-975,745
-INCOME TAX	-382,053	-395,050	-408,696	-423,025	-438,070	-453,868	-470,455	-487,872
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
	----------	----------	----------	----------	----------	----------	----------	----------
3) TOTAL INCOME TAX	-382,053	-395,050	-408,696	-423,025	-438,070	-453,868	-470,455	-487,872
CONVENTIONAL:								
TAXABLE INCOME	-1,079,734	-1,131,721	-1,186,307	-1,243,622	-1,303,803	-1,366,994	-1,433,343	-1,503,010
4) TOTAL INCOME TAX	-539,867	-565,860	-593,153	-621,811	-651,901	-683,497	-716,671	-751,505
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	-207,813	-220,810	-234,456	-248,785	-263,830	-279,628	-296,215	-313,632
CONVENTIONAL, 2)-4)	-539,867	-565,860	-593,153	-621,811	-651,901	-683,497	-716,671	-751,505
NET CASH FLOW AFTER TAXES								
************************	332,053	345,050	358,696	373,025	388,070	403,868	420,455	437,872
ACCUMULATED AT 0%	-795,353	-450,302	-91,606	281,419	669,490	1,073,359	1,493,815	1,931,687
ACCUMULATED NPV AT 10%	-1,603,445	-1,457,110	-1,310,817	-1,188,074	-1,064,422	-947,436	-836,717	-731,894

	1992	1993	1994	1995	1996
SOLAR COSTS					
***********					
FUEL	-768,080	-806,484	-846,808	-889,149	-933,606
FIXED CHARGES	-30,000	-30,000	-30,000	-30,000	-30,000
BOILER	-39,999	-39,999	-39,999	-39,999	-39,999
1) TOTAL	-838,080	-876,484	-916,808	-959,149	-1,003,606
CONVENTIONAL COSTS					
******************					
FUEL	-1,536,161	-1,612,969	-1,693,617	-1,778,298	-1,867,213
BOILER	-39,999	-39,999	-39,999	-39,999	-39,999
2) TOTAL	-1,576,161	-1,652,969	-1,733,617	-1,818,298	-1,907,213
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-838,080	-876,484	-916,808	-959,149	-1,003,606
-DEPRECIATION	-174,240	-174,240	-174,240	-174,240	-174,240
TAXABLE INCOME	-1,012,320	-1,050,724	-1,091,048	-1,133,389	-1,177,846
-INCOME TAX	-506,160	-525,362	-545,524	-566,694	-588,923
-INVEST TAX CREDIT	0	0	0	0	0
3) TOTAL INCOME TAX	-506,160	-525,362	-545,524	-566,694	-588,923
CONVENTIONAL:					
TAXABLE INCOME	-1,576,161	-1,652,969	-1,733,617	-1,818,298	-1,907,213
4) TOTAL INCOME TAX	-768,080	-826,484	-866,808	-909,149	-953,606
AFTER TAX CASH FLOWS					
********************					
SOLAR, 1)-3)	-331,920	-351,122	-371,284	-392,454	-414,683
CONVENTIONAL, 2)-4)	-768,080	-826,484	-866,808	-909,149	-953,606
NET CASH FLOW AFTER TAXES					
*************************	456,160	475,362	495,524	516,694	538,923
ACCUMULATED AT 0%	2,387,648	2,863,210	3,358,734	3,875,429	4,414,353
ACCUMULATED NPV AT 10%	-632,620	-538,572	-449,447	-364,964	-284,856

APPENDIX D

ECONOMIC ANALYSIS:

Albuquerque - No fuel cost increase

Albuquerque - 5% fuel cost increase

Omaha - No fuel cost increase

Omaha - 5% fuel cost increase

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ALBUQUERQUE: NO FUEL COST INCREASE

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS
****

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
***********								
FUEL	0	-1,673	-1,673	-1,673	-1,673	-1,673	-1,673	-1,673
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	0	-3,452	-3,452	-3,452	-3,452	-4,642	-3,452	-3,452
CONVENTIONAL COSTS								
*****************								
FUEL	0	-11,153	-11,153	-11,153	-11,153	-11,153	-11,153	-11,153
BOILER	0	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	0	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-3,452	-3,452	-3,452	-3,452	-4,642	-3,452	-3,452
-DEPRECIATION	0	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	0	-16,500	-16,500	-16,500	-16,500	-17,690	-16,500	-16,500
-INCOME TAX	0	-8,250	-8,250	-8,250	-8,250	-8,845	-8,250	-8,250
-INVEST TAX CREDIT	26,095	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-26,095	-8,250	-8,250	-8,250	-8,250	-8,845	-8,250	-8,250
CONVENTIONAL:								
TAXABLE INCOME	0	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713
4) TOTAL INCOME TAX	0	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856
AFTER TAX CASH FLOWS								
*******************								
SOLAR, 1)-3)	-234,855	4,797	4,797	4,797	4,797	4,202	4,797	4,797
CONVENTIONAL, 2)-4)	0	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856
NET CASH FLOW AFTER TAXES								
************************	-234,855	10,653	10,653	10,653	10,653	10,058	10,653	10,653
ACCUMULATED AT 0%	-234,855	-224,201	-213,548	-202,894	-192,240	-182,181	-171,527	-160,873
ACCUMULATED NPV AT 10%	-234,855	-225,170	-216,365	-208,361	-201,084	-194,838	-188,824	-183,357

RATE-OF-RETURN FOR 20 YEARS = -1.0088354

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.0916666
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -8.1878225

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -4.1833332
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -14.375645
ANNUAL_COST BEFORE TAX : SOLAR ONLY $/MBTU = -10.159162

ALBUQUERQUE: NO FUEL COST INCREASE

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-1,673	-1,673	-1,673	-1,673	-1,673	-1,673	-1,673	-1,673
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-960
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-700
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	-3,452	-3,452	-7,692	-3,452	-3,452	-3,452	-3,452	-4,642
CONVENTIONAL COSTS								
*****************								
FUEL	-11,153	-11,153	-11,153	-11,153	-11,153	-11,153	-11,153	-11,153
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-3,452	-3,452	-7,692	-3,452	-3,452	-3,452	-3,452	-4,642
-DEPRECIATION	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	-16,500	-16,500	-20,740	-16,500	-16,500	-16,500	-16,500	-17,690
-INCOME TAX	-8,250	-8,250	-10,370	-8,250	-8,250	-8,250	-8,250	-8,845
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-8,250	-8,250	-10,370	-8,250	-8,250	-8,250	-8,250	-8,845
CONVENTIONAL:								
TAXABLE INCOME	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713	-11,713
4) TOTAL INCOME TAX	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	4,797	4,797	2,677	4,797	4,797	4,797	4,797	4,202
CONVENTIONAL, 2)-4)	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856	-5,856
NET CASH FLOW AFTER TAXES								
************************	10,653	10,653	8,533	10,653	10,653	10,653	10,653	10,058
ACCUMULATED AT 0%	-150,219	-139,565	-131,031	-120,377	-109,723	-99,069	-88,415	-76,356
ACCUMULATED NPV AT 10%	-178,387	-173,869	-170,578	-166,944	-163,450	-160,363	-157,558	-155,150

ALBUQUERQUE: NO FUEL COST INCREASE

	1992	1993	1994	1995	1996
SOLAR COSTS					
***********					
FUEL	-1,673	-1,673	-1,673	-1,673	-1,673
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
	----------	----------	----------	----------	----------
1) TOTAL	-3,452	-2,982	-2,982	-2,982	-2,982
CONVENTIONAL COSTS					
******************					
FUEL	-11,153	-11,153	-11,153	-11,153	-11,153
BOILER	-559	-559	-559	-559	-559
	----------	----------	----------	----------	----------
2) TOTAL	-11,713	-11,713	-11,713	-11,713	-11,713
TAX CALCULATION[a]					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-3,452	-2,982	-2,982	-2,982	-2,982
-DEPRECIATION	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	-16,500	-16,030	-16,030	-16,030	-16,030
-INCOME TAX	-8,250	-8,015	-8,015	-8,015	-8,015
-INVEST TAX CREDIT	0	0	0	0	0
	----------	----------	----------	----------	----------
3) TOTAL INCOME TAX	-8,250	-8,015	-8,015	-8,015	-8,015
CONVENTIONAL:					
TAXABLE INCOME	-11,713	-11,713	-11,713	-11,713	-11,713
4) TOTAL INCOME TAX	-5,856	-5,856	-5,856	-5,856	-5,856
AFTER TAX CASH FLOWS					
********************					
SOLAR, 1)-3)	4,797	5,032	5,032	5,032	5,032
CONVENTIONAL, 2)-4)	-5,856	-5,856	-5,856	-5,856	-5,856
NET CASH FLOW AFTER TAXES					
*************************	10,653	10,888	10,888	10,888	10,888
ACCUMULATED AT 0%	-67,702	-56,813	-45,924	-35,036	-24,147
ACCUMULATED NPV AT 10%	-152,831	-150,677	-148,719	-146,938	-145,320

ALBUQUERQUE: 5 PERCENT FUEL COST INCREASE

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS
****

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
***********								
FUEL	0	-1,673	-1,756	-1,844	-1,936	-2,033	-2,135	-2,241
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	0	-3,452	-3,536	-3,624	-3,716	-5,003	-3,915	-4,021
CONVENTIONAL COSTS								
******************								
FUEL	0	-11,153	-11,711	-12,296	-12,911	-13,556	-14,234	-14,946
BOILER	0	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	0	-11,713	-12,270	-12,856	-13,471	-14,116	-14,794	-15,506
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-3,452	-3,536	-3,624	-3,716	-5,003	-3,915	-4,021
-DEPRECIATION	0	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	0	-16,500	-16,584	-16,672	-16,764	-18,051	-16,962	-17,069
-INCOME TAX	0	-8,250	-8,292	-8,336	-8,382	-9,025	-8,481	-8,534
-INVEST TAX CREDIT	26,095	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-26,095	-8,250	-8,292	-8,336	-8,382	-9,025	-8,481	-8,534
CONVENTIONAL:								
TAXABLE INCOME	0	-11,713	-12,270	-12,856	-13,471	-14,116	-14,794	-15,506
4) TOTAL INCOME TAX	0	-5,856	-6,135	-6,428	-6,735	-7,058	-7,397	-7,753
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	-234,855	4,797	4,755	4,711	4,665	4,022	4,566	4,512
CONVENTIONAL, 2)-4)	0	-5,856	-6,135	-6,428	-6,735	-7,058	-7,397	-7,753
NET CASH FLOW AFTER TAXES								
************************	-234,855	10,653	10,890	11,139	11,401	11,080	11,963	12,266
ACCUMULATED AT 0%	-234,855	-224,201	-213,311	-202,171	-190,770	-179,689	-167,726	-155,460
ACCUMULATED NPV AT 10%	-234,855	-225,170	-216,169	-207,800	-200,013	-193,133	-186,379	-180,035

RATE-OF-RETURN FOR 20 YEARS = 1.3357773

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.9335057
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -8.3140962

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -5.8670115
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -14.628196
ANNUAL COST BEFORE TAX : SOLAR ONLY $/MBTU = -18.159162

ALBUQUERQUE: 5 PERCENT FUEL COST INCREASE

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-2,354	-2,471	-2,595	-2,725	-2,861	-3,004	-3,154	-3,312
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-960
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-700
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	-4,134	-4,251	-8,615	-4,505	-4,641	-4,784	-4,934	-6,282
CONVENTIONAL COSTS								
*****************								
FUEL	-15,693	-16,478	-17,302	-18,167	-19,075	-20,029	-21,031	-22,082
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	-16,253	-17,038	-17,862	-18,727	-19,635	-20,589	-21,591	-22,642
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-4,134	-4,251	-8,615	-4,505	-4,641	-4,784	-4,934	-6,282
-DEPRECIATION	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	-17,181	-17,299	-21,662	-17,552	-17,688	-17,832	-17,982	-19,329
-INCOME TAX	-8,590	-8,649	-10,831	-8,776	-8,844	-8,916	-8,991	-9,664
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-8,590	-8,649	-10,831	-8,776	-8,844	-8,916	-8,991	-9,664
CONVENTIONAL:								
TAXABLE INCOME	-16,253	-17,038	-17,862	-18,727	-19,635	-20,589	-21,591	-22,642
4) TOTAL INCOME TAX	-8,126	-8,519	-8,931	-9,363	-9,817	-10,294	-10,795	-11,321
AFTER TAX CASH FLOWS								
*******************								
SOLAR, 1)-3)	4,456	4,397	2,216	4,271	4,203	4,131	4,056	3,332
CONVENTIONAL, 2)-4)	-8,126	-8,519	-8,931	-9,363	-9,817	-10,294	-10,795	-11,321
NET CASH FLOW AFTER TAXES								
***********************	12,583	12,917	11,147	13,635	14,021	14,426	14,852	14,703
ACCUMULATED AT 0%	-142,876	-129,959	-118,811	-105,176	-91,155	-76,729	-61,877	-47,173
ACCUMULATED NPV AT 10%	-174,215	-168,736	-164,439	-159,660	-155,192	-151,013	-147,102	-143,582

ALBUQUERQUE: 5 PERCENT FUEL COST INCREASE

	1992	1993	1994	1995	1996
SOLAR COSTS					
***********					
FUEL	-3,478	-3,651	-3,834	-4,026	-4,227
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
1) TOTAL	-5,256	-4,961	-5,144	-5,336	-5,537
CONVENTIONAL COSTS					
*****************					
FUEL	-23,186	-24,346	-25,563	-26,841	-28,183
BOILER	-559	-559	-559	-559	-559
2) TOTAL	-23,746	-24,906	-26,123	-27,401	-28,743
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-5,256	-4,961	-5,144	-5,336	-5,537
-DEPRECIATION	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	-18,305	-18,009	-18,192	-18,383	-18,585
-INCOME TAX	-9,152	-9,004	-9,096	-9,191	-9,292
-INVEST TAX CREDIT	0	0	0	0	0
3) TOTAL INCOME TAX	-9,152	-9,004	-9,096	-9,191	-9,292
CONVENTIONAL:					
TAXABLE INCOME	-23,746	-24,906	-26,123	-27,401	-28,743
4) TOTAL INCOME TAX	-11,873	-12,453	-13,061	-13,700	-14,371
AFTER TAX CASH FLOWS					
*********************					
SOLAR, 1)-3)	3,894	4,042	3,951	3,855	3,754
CONVENTIONAL, 2)-4)	-11,873	-12,453	-13,061	-13,700	-14,371
NET CASH FLOW AFTER TAXES					
************************	15,768	16,495	17,013	17,556	18,126
ACCUMULATED AT 0%	-31,405	-14,909	2,104	19,660	37,787
ACCUMULATED NPV AT 10%	-140,151	-136,807	-133,827	-130,956	-128,262

OMAHA: NO FUEL COST INCREASE

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS
****

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
***********								
FUEL	0	-4,686	-4,686	-4,686	-4,686	-4,686	-4,686	-4,686
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	0	-6,465	-6,465	-6,465	-6,465	-7,655	-6,465	-6,465
CONVENTIONAL COSTS								
******************								
FUEL	0	-11,157	-11,157	-11,157	-11,157	-11,157	-11,157	-11,157
BOILER	0	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	0	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-6,465	-6,465	-6,465	-6,465	-7,655	-6,465	-6,465
-DEPRECIATION	0	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	0	-19,513	-19,513	-19,513	-19,513	-20,703	-19,513	-19,513
-INCOME TAX	0	-9,756	-9,756	-9,756	-9,756	-10,351	-9,756	-9,756
-INVEST TAX CREDIT	26,095	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-26,095	-9,756	-9,756	-9,756	-9,756	-10,351	-9,756	-9,756
CONVENTIONAL:								
TAXABLE INCOME	0	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717
4) TOTAL INCOME TAX	0	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	-234,855	3,290	3,290	3,290	3,290	2,695	3,290	3,290
CONVENTIONAL, 2)-4)	0	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858
NET CASH FLOW AFTER TAXES								
************************	-234,855	9,149	9,149	9,149	9,149	8,554	9,149	9,149
ACCUMULATED AT 0%	-234,855	-225,706	-216,557	-207,407	-198,258	-189,704	-180,554	-171,405
ACCUMULATED NPV AT 10%	-234,855	-226,539	-218,976	-212,102	-205,853	-200,542	-195,377	-190,682

RATE-OF-RETURN FOR 20 YEARS = -2.3679674

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.0923469
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -8.7258581

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -4.1846938
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -17.451716
ANNUAL COST BEFORE TAX : SOLAR ONLY $/MBTU = -26.612565

OMAHA: NO FUEL COST INCREASE

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-4,686	-4,686	-4,686	-4,686	-4,686	-4,686	-4,686	-4,686
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-950
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-700
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	-6,465	-6,465	-10,705	-6,465	-6,465	-6,465	-6,465	-7,655
CONVENTIONAL COSTS								
*****************								
FUEL	-11,157	-11,157	-11,157	-11,157	-11,157	-11,157	-11,157	-11,157
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-6,465	-6,465	-10,705	-6,465	-6,465	-6,465	-6,465	-7,655
-DEPRECIATION	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	-19,513	-19,513	-23,753	-19,513	-19,513	-19,513	-19,513	-20,713
-INCOME TAX	-9,756	-9,756	-11,876	-9,756	-9,756	-9,756	-9,756	-10,351
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-9,756	-9,756	-11,876	-9,756	-9,756	-9,756	-9,756	-10,351
CONVENTIONAL:								
TAXABLE INCOME	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717	-11,717
4) TOTAL INCOME TAX	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	3,290	3,290	1,170	3,290	3,290	3,290	3,290	2,695
CONVENTIONAL, 2)-4)	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858
NET CASH FLOW AFTER TAXES								
************************	9,149	9,149	7,029	9,149	9,149	9,149	9,149	8,554
ACCUMULATED AT 0%	-162,256	-153,106	-146,077	-136,928	-127,778	-118,629	-109,480	-100,925
ACCUMULATED NPV AT 10%	-186,414	-182,534	-179,823	-176,617	-173,701	-171,051	-168,642	-166,594

OMAHA: NO FUEL COST INCREASE

	1992	1993	1994	1995	1996
OLAR COSTS					
**********					
FUEL	-4,686	-4,686	-4,686	-4,686	-4,686
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
1) TOTAL	-6,465	-5,995	-5,995	-5,995	-5,995
CONVENTIONAL COSTS					
*****************					
FUEL	-11,157	-11,157	-11,157	-11,157	-11,157
BOILER	-559	-559	-559	-559	-559
2) TOTAL	-11,717	-11,717	-11,717	-11,717	-11,717
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-6,465	-5,995	-5,995	-5,995	-5,995
-DEPRECIATION	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	-19,512	-19,043	-19,043	-19,043	-19,043
-INCOME TAX	-9,756	-9,521	-9,521	-9,521	-9,521
-INVEST TAX CREDIT	0	0	0	0	0
3) TOTAL INCOME TAX	-9,756	-9,521	-9,521	-9,521	-9,521
CONVENTIONAL:					
TAXABLE INCOME	-11,717	-11,717	-11,717	-11,717	-11,717
4) TOTAL INCOME TAX	-5,858	-5,858	-5,858	-5,858	-5,858
AFTER TAX CASH FLOWS					
********************					
SOLAR, (1)-3)	3,290	3,525	3,525	3,525	3,525
CONVENTIONAL, (2)-4)	-5,858	-5,858	-5,858	-5,858	-5,858
NET CASH FLOW AFTER TAXES					
*************************	9,149	9,384	9,384	9,384	9,384
ACCUMULATED AT 0%	-91,776	-82,392	-73,007	-63,623	-54,238
ACCUMULATED NPV AT 10%	-164,603	-162,746	-161,058	-159,524	-158,129

Omaha: 5% Fuel Cost Increase

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
FUEL	0	-4,686	-4,920	-5,166	-5,424	-5,695	-5,980	-6,279
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	0	-6,465	-6,700	-6,946	-7,204	-8,665	-7,760	-8,059
CONVENTIONAL COSTS								
FUEL	0	-11,157	-11,714	-12,300	-12,915	-13,561	-14,239	-14,951
BOILER	0	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	0	-11,717	-12,274	-12,860	-13,475	-14,121	-14,799	-15,511
TAX CALCULATION								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-6,465	-6,700	-6,946	-7,204	-8,665	-7,760	-8,059
-DEPRECIATION	0	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	0	-19,513	-19,747	-19,993	-20,252	-21,713	-20,808	-21,107
-INCOME TAX	0	-9,756	-9,873	-9,996	-10,126	-10,856	-10,404	-10,553
-INVEST TAX CREDIT	26,095	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-26,095	-9,756	-9,873	-9,995	-10,126	-10,856	-10,404	-10,553
CONVENTIONAL:								
TAXABLE INCOME	0	-11,717	-12,274	-12,860	-13,475	-14,121	-14,799	-15,511
4) TOTAL INCOME TAX	0	-5,858	-6,137	-6,430	-6,737	-7,060	-7,399	-7,755
AFTER TAX CASH FLOWS								
SOLAR, 1)-3)	-234,855	3,290	3,173	3,050	2,921	2,190	2,643	2,493
CONVENTIONAL, 2)-4)	0	-5,858	-6,137	-6,430	-6,737	-7,060	-7,399	-7,755
NET CASH FLOW AFTER TAXES	-234,855	9,149	9,311	9,480	9,659	9,251	10,043	10,249
ACCUMULATED AT 0%	-234,855	-225,706	-216,395	-206,914	-197,255	-188,003	-177,960	-167,710
ACCUMULATED NPV AT 10%	-234,855	-226,538	-218,843	-211,719	-205,122	-199,377	-193,708	-188,449

RATE-OF-RETURN FOR 20 YEARS = -.46116114

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.9344735
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -9.0795513

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -5.8689471
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -18.159103
ANNUAL COST BEFORE TAX : SOLAR ONLY $/MBTU = -26.612565

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-6,593	-6,923	-7,269	-7,632	-8,014	-8,415	-8,836	-9,277
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-960
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-700
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
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1) TOTAL	-8,373	-8,763	-13,269	-9,412	-9,794	-10,195	-11,416	-12,247
CONVENTIONAL COSTS								
*****************								
FUEL	-15,699	-16,485	-17,307	-18,173	-19,082	-20,036	-21,039	-22,090
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
	----------	----------	----------	----------	----------	----------	----------	----------
2) TOTAL	-16,259	-17,044	-17,866	-18,733	-19,642	-20,596	-21,596	-22,650
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-8,373	-8,763	-13,269	-9,412	-9,794	-10,195	-11,416	-12,247
-DEPRECIATION	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	-21,421	-21,760	-26,337	-22,460	-22,842	-23,242	-24,463	-25,295
-INCOME TAX	-10,710	-10,875	-13,169	-11,230	-11,421	-11,621	-11,831	-12,647
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
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3) TOTAL INCOME TAX	-10,710	-10,875	-13,169	-11,230	-11,421	-11,621	-11,831	-12,647
CONVENTIONAL:								
TAXABLE INCOME	-16,259	-17,044	-17,866	-18,733	-19,642	-20,596	-21,596	-22,650
4) TOTAL INCOME TAX	-8,129	-8,522	-8,934	-9,366	-9,821	-10,298	-10,799	-11,325
AFTER TAX CASH FLOWS								
*******************								
SOLAR, 1)-3)	2,336	2,172	-120	1,817	1,626	1,426	1,215	399
CONVENTIONAL, 2)-4)	-8,129	-8,522	-8,534	-9,366	-9,821	-10,298	-10,799	-11,325
NET CASH FLOW AFTER TAXES								
***********************	10,466	10,694	8,813	11,184	11,447	11,724	12,014	11,724
ACCUMULATED AT 0%	-157,243	-146,549	-137,736	-126,552	-115,104	-103,380	-91,765	-79,640
ACCUMULATED NPV AT 10%	-183,566	-179,030	-175,633	-171,713	-168,065	-164,669	-161,505	-158,698

	1992	1993	1994	1995	1996
SOLAR COSTS					
***********					
FUEL	-9,741	-10,228	-10,740	-11,277	-11,841
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
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1) TOTAL	-11,521	-11,538	-12,050	-12,587	-13,151
CONVENTIONAL COSTS					
******************					
FUEL	-23,194	-24,354	-25,572	-26,850	-28,193
BOILER	-559	-559	-559	-559	-559
	----------	----------	----------	----------	----------
2) TOTAL	-23,754	-24,914	-26,132	-27,410	-28,753
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-11,521	-11,538	-12,050	-12,587	-13,151
-DEPRECIATION	-13,047	-13,047	-13,047	-13,047	-13,047
TAXABLE INCOME	-24,568	-24,586	-25,097	-25,634	-26,198
-INCOME TAX	-12,284	-12,293	-12,548	-12,817	-13,099
-INVEST TAX CREDIT	0	0	0	0	0
	----------	----------	----------	----------	----------
3) TOTAL INCOME TAX	-12,284	-12,293	-12,548	-12,817	-13,099
CONVENTIONAL:					
TAXABLE INCOME	-23,754	-24,914	-26,132	-27,410	-28,753
4) TOTAL INCOME TAX	-11,877	-12,457	-13,066	-13,705	-14,376
AFTER TAX CASH FLOWS					
********************					
SOLAR, 1)-3)	762	754	498	230	-51
CONVENTIONAL, 2)-4)	-11,877	-12,457	-13,066	-13,705	-14,376
NET CASH FLOW AFTER TAXES					
*************************	12,640	13,211	13,564	13,935	14,324
ACCUMULATED AT 0%	-67,060	-53,788	-40,223	-26,288	-11,963
ACCUMULATED NPV AT 10%	-155,947	-153,333	-150,694	-148,615	-146,486

APPENDIX E

ECONOMIC ANALYSIS: SACRAMENTO

a. ERDA assumptions, no fuel cost increase

b. ERDA assumptions, 5% fuel cost increase

c. Industry assumptions, 3.4% fuel cost increase

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SACRAMENTO: NO FUEL COST INCREASE

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS
****

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
***********								
FUEL	0	-2,566	-2,566	-2,566	-2,566	-2,566	-2,566	-2,566
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
	----------	----------	----------	----------	----------	----------	----------	----------
1) TOTAL	0	-4,345	-4,345	-4,345	-4,345	-5,535	-4,345	-4,345
CONVENTIONAL COSTS								
******************								
FUEL	0	-11,156	-11,156	-11,156	-11,156	-11,156	-11,156	-11,156
BOILER	0	-559	-559	-559	-559	-559	-559	-559
	----------	----------	----------	----------	----------	----------	----------	----------
2) TOTAL	0	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-4,345	-4,345	-4,345	-4,345	-5,535	-4,345	-4,345
-DEPRECIATION	0	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986
TAXABLE INCOME	0	-19,332	-19,332	-19,332	-19,332	-20,522	-19,332	-19,332
-INCOME TAX	0	-9,666	-9,666	-9,666	-9,666	-10,261	-9,666	-9,666
-INVEST TAX CREDIT	29,973	0	0	0	0	0	0	0
	----------	----------	----------	----------	----------	----------	----------	----------
3) TOTAL INCOME TAX	-29,973	-9,666	-9,666	-9,666	-9,666	-10,261	-9,666	-9,666
CONVENTIONAL:								
TAXABLE INCOME	0	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716
4) TOTAL INCOME TAX	0	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	-269,759	5,320	5,320	5,320	5,320	4,725	5,320	5,320
CONVENTIONAL, 2)-4)	0	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858
NET CASH FLOW AFTER TAXES								
************************	-269,759	11,178	11,178	11,178	11,178	10,583	11,178	11,178
ACCUMULATED AT 0%	-269,759	-258,581	-247,402	-236,223	-225,045	-214,461	-203,283	-192,104
ACCUMULATED NPV AT 10%	-269,759	-259,597	-250,358	-241,960	-234,325	-227,753	-221,443	-215,707

RATE-OF-RETURN FOR 20 YEARS = -1.8060029

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.0922360
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -9.4652286

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -4.1844719
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -18.930457
ANNUAL COST BEFORE TAX : SOLAR ONLY $/MBTU = -22.949574

SACRAMENTO: NO FUEL COST INCREASE

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-2,566	-2,566	-2,566	-2,566	-2,566	-2,566	-2,566	-2,566
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-960
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-700
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	-4,345	-4,345	-8,565	-4,345	-4,345	-4,345	-4,345	-5,535
CONVENTIONAL COSTS								
*****************								
FUEL	-11,156	-11,156	-11,156	-11,156	-11,156	-11,156	-11,156	-11,156
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-4,345	-4,345	-8,565	-4,345	-4,345	-4,345	-4,345	-5,535
-DEPRECIATION	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986
TAXABLE INCOME	-19,332	-19,332	-23,572	-19,332	-19,332	-19,332	-19,332	-20,522
-INCOME TAX	-9,666	-9,666	-11,786	-9,666	-9,666	-9,666	-9,666	-10,261
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-9,666	-9,666	-11,786	-9,666	-9,666	-9,666	-9,666	-10,261
CONVENTIONAL:								
TAXABLE INCOME	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716	-11,716
4) TOTAL INCOME TAX	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	5,320	5,320	3,200	5,320	5,320	5,320	5,320	4,725
CONVENTIONAL, 2)-4)	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858	-5,858
NET CASH FLOW AFTER TAXES								
************************	11,178	11,178	9,058	11,178	11,178	11,178	11,178	10,583
ACCUMULATED AT 0%	-180,926	-169,747	-160,688	-149,510	-138,331	-127,153	-115,974	-105,390
ACCUMULATED NPV AT 10%	-210,492	-205,751	-202,258	-198,340	-194,779	-191,541	-188,597	-186,063

SACRAMENTO: NO FUEL COST INCREASE

	1992	1993	1994	1995	1996
SOLAR COSTS					
***********					
FUEL	-2,566	-2,566	-2,566	-2,566	-2,566
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
	----------	----------	----------	----------	----------
1) TOTAL	-4,345	-3,875	-3,875	-3,875	-3,875
CONVENTIONAL COSTS					
*****************					
FUEL	-11,156	-11,156	-11,156	-11,156	-11,156
BOILER	-559	-559	-559	-559	-559
	----------	----------	----------	----------	----------
2) TOTAL	-11,716	-11,716	-11,716	-11,716	-11,716
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-4,345	-3,875	-3,875	-3,875	-3,875
-DEPRECIATION	-14,986	-14,986	-14,986	-14,986	-14,986
TAXABLE INCOME	-19,332	-18,862	-18,862	-18,862	-18,862
-INCOME TAX	-9,666	-9,431	-9,431	-9,431	-9,431
-INVEST TAX CREDIT	0	0	0	0	0
	----------	----------	----------	----------	----------
3) TOTAL INCOME TAX	-9,666	-9,431	-9,431	-9,431	-9,431
CONVENTIONAL:					
TAXABLE INCOME	-11,716	-11,716	-11,716	-11,716	-11,716
4) TOTAL INCOME TAX	-5,858	-5,858	-5,858	-5,858	-5,858
AFTER TAX CASH FLOWS					
********************					
SOLAR, 1)-3)	5,320	5,555	5,555	5,555	5,555
CONVENTIONAL, 2)-4)	-5,858	-5,858	-5,858	-5,858	-5,858
NET CASH FLOW AFTER TAXES					
************************	11,178	11,413	11,413	11,413	11,413
ACCUMULATED AT 0%	-94,212	-82,798	-71,385	-59,971	-48,558
ACCUMULATED NPV AT 10%	-183,630	-181,372	-179,320	-177,453	-175,757

Sacramento: 5% Fuel Cost Increase

CAMPBELL-SACRAMENTO;SOLAR HOT WATER ECONOMICS

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
FUEL	0	-2,566	-2,694	-2,829	-2,970	-3,118	-3,274	-3,438
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	0	-4,345	-4,474	-4,609	-4,750	-6,088	-5,054	-5,218
CONVENTIONAL COSTS								
FUEL	0	-11,156	-11,714	-12,300	-12,915	-13,560	-14,238	-14,950
BOILER	0	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	0	-11,716	-12,274	-12,860	-13,475	-14,120	-14,798	-15,510
TAX CALCULATION								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-4,345	-4,474	-4,609	-4,750	-6,088	-5,054	-5,218
-DEPRECIATION	0	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986
TAXABLE INCOME	0	-19,332	-19,460	-19,595	-19,737	-21,075	-20,041	-20,205
-INCOME TAX	0	-9,666	-9,730	-9,797	-9,868	-10,537	-10,020	-10,102
-INVEST TAX CREDIT	29,973	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-29,973	-9,666	-9,730	-9,797	-9,868	-10,537	-10,020	-10,102
CONVENTIONAL:								
TAXABLE INCOME	0	-11,716	-12,275	-12,860	-13,475	-14,120	-14,798	-15,510
4) TOTAL INCOME TAX	0	-5,858	-6,137	-6,430	-6,737	-7,060	-7,399	-7,755
AFTER TAX CASH FLOWS								
SOLAR, 1)-3)	-269,759	5,320	5,256	5,188	5,118	4,448	4,965	4,803
CONVENTIONAL, 2)-4)	0	-5,858	-6,137	-6,430	-6,737	-7,060	-7,399	-7,755
NET CASH FLOW AFTER TAXES	-269,759	11,178	11,393	11,618	11,855	11,509	12,365	12,639
ACCUMULATED AT 0%	-269,759	-258,581	-247,187	-235,568	-223,713	-212,204	-199,838	-187,199
ACCUMULATED NPV AT 10%	-269,759	-259,597	-250,181	-241,451	-233,354	-226,208	-219,228	-212,742

RATE-OF-RETURN FOR 20 YEARS = -.24413168

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.9343158
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -9.6589072

A . COST BEFORE TAX : CONVENTIONAL $/MBTU = -5.8686315
A . COST BEFORE TAX : SOLAR $/MBTU = -19.317814
A... COST BEFORE TAX : SOLAR ONLY $/MBTU = -22.949574

	1992	1993	1994	1995	1996
SOLAR COSTS					
***********					
FUEL	-4,237	-4,381	-4,530	-4,664	-4,843
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
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1) TOTAL	-6,017	-5,691	-5,840	-5,994	-6,153
CONVENTIONAL COSTS					
******************					
FUEL	-18,422	-19,048	-19,695	-20,365	-21,058
BOILER	-559	-559	-559	-559	-559
	----------	----------	----------	----------	----------
2) TOTAL	-18,982	-19,608	-20,255	-20,925	-21,618
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-6,017	-5,691	-5,840	-5,994	-6,153
-DEPRECIATION	-6,171	-5,554	-4,997	-4,498	-4,049
TAXABLE INCOME	-12,188	-11,245	-10,837	-10,492	-10,202
-INCOME TAX	-6,216	-5,735	-5,527	-5,351	-5,203
-INVEST TAX CREDIT	0	0	0	0	0
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3) TOTAL INCOME TAX	-6,216	-5,735	-5,527	-5,351	-5,203
CONVENTIONAL:					
TAXABLE INCOME	-18,982	-19,608	-20,255	-20,925	-21,618
4) TOTAL INCOME TAX	-9,680	-10,000	-10,330	-10,672	-11,025
AFTER TAX CASH FLOWS					
********************					
SOLAR, 1)-3)	198	43	-312	-642	-950
CONVENTIONAL, 2)-4)	-9,301	-9,608	-9,925	-10,253	-10,592
NET CASH FLOW AFTER TAXES					
*************************	9,500	9,652	9,613	9,610	9,642
ACCUMULATED AT 0%	-70,454	-60,802	-51,189	-41,578	-31,935
ACCUMULATED NPV AT 10%	-162,309	-160,400	-158,671	-157,099	-155,666

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-3,610	-3,791	-3,980	-4,179	-4,388	-4,608	-4,838	-5,080
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-960
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-700
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
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1) TOTAL	-5,390	-5,571	-10,000	-5,959	-6,168	-6,388	-6,618	-8,050
CONVENTIONAL COSTS								
******************								
FUEL	-15,698	-16,483	-17,307	-18,172	-19,081	-20,035	-21,037	-22,089
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
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2) TOTAL	-16,258	-17,043	-17,867	-18,732	-19,641	-20,595	-21,597	-22,649
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-5,390	-5,571	-10,000	-5,959	-6,168	-6,388	-6,618	-8,050
-DEPRECIATION	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986	-14,986
TAXABLE INCOME	-20,377	-20,557	-24,987	-20,946	-21,155	-21,374	-21,605	-23,037
-INCOME TAX	-10,188	-10,278	-12,493	-10,473	-10,577	-10,687	-10,802	-11,518
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
	----------	----------	----------	----------	----------	----------	----------	----------
3) TOTAL INCOME TAX	-10,188	-10,278	-12,493	-10,473	-10,577	-10,687	-10,802	-11,518
CONVENTIONAL:								
TAXABLE INCOME	-16,258	-17,043	-17,867	-18,732	-19,641	-20,595	-21,597	-22,649
4) TOTAL INCOME TAX	-8,129	-8,521	-8,933	-9,366	-9,820	-10,297	-10,798	-11,324
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	4,798	4,707	2,492	4,513	4,408	4,299	4,184	3,468
CONVENTIONAL, 2)-4)	-8,129	-8,521	-8,933	-9,366	-9,820	-10,297	-10,798	-11,324
NET CASH FLOW AFTER TAXES								
************************	12,927	13,229	11,426	13,879	14,229	14,596	14,982	14,792
ACCUMULATED AT 0%	-174,272	-161,042	-149,616	-135,736	-121,506	-106,909	-91,926	-77,134
ACCUMULATED NPV AT 10%	-206,711	-201,101	-196,695	-191,930	-187,296	-183,069	-179,123	-175,581

Sacramento: Industry Assumptions

CAMPBELL-SACRAMENTO;SOLAR HOT WATER ECONOMICS
****

	1976	1977	1978	1979	1980	1981	1982	1983
SOLAR COSTS								
***********								
FUEL	0	-2,566	-2,653	-2,743	-2,836	-2,933	-3,032	-3,136
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	0	-4,345	-4,433	-4,523	-4,616	-5,903	-4,812	-4,916
CONVENTIONAL COSTS								
*****************								
FUEL	0	-11,156	-11,535	-11,928	-12,333	-12,752	-13,186	-13,634
BOILER	0	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	0	-11,716	-12,095	-12,488	-12,893	-13,312	-13,746	-14,194
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-4,345	-4,423	-4,523	-4,616	-5,903	-4,812	-4,916
-DEPRECIATION	0	-29,973	-26,975	-24,278	-21,850	-19,665	-17,698	-15,929
TAXABLE INCOME	0	-34,318	-31,408	-28,801	-26,467	-25,568	-22,511	-20,845
-INCOME TAX	0	-17,502	-16,016	-14,688	-13,498	-13,040	-11,481	-10,630
-INVEST TAX CREDIT	29,973	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-29,973	-17,512	-16,018	-14,688	-13,498	-13,040	-11,481	-10,630
CONVENTIONAL:								
TAXABLE INCOME	0	-11,716	-12,095	-12,489	-12,893	-13,312	-13,746	-14,194
4) TOTAL INCOME TAX	0	-5,975	-6,168	-6,368	-6,575	-6,789	-7,010	-7,239
AFTER TAX CASH FLOWS								
*******************								
SOLAR, 1)-3)	-269,759	13,156	11,585	10,165	8,881	7,136	6,664	5,714
CONVENTIONAL, 2)-4)	0	-5,741	-5,926	-6,119	-6,317	-6,523	-6,735	-6,955
NET CASH FLOW AFTER TAXES	-269,759	18,897	17,512	16,284	15,199	13,660	13,403	12,670
***********************								
ACCUMULATED AT 0%	-269,759	-250,861	-233,349	-217,064	-201,865	-188,205	-174,801	-162,130
ACCUMULATED NPV AT 10%	-269,759	-252,579	-238,106	-225,871	-215,490	-207,008	-199,442	-192,940

RATE-OF-RETURN FOR 20 YEARS = -1.3206378

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.5646349
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -9.0948259

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -5.1292697
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -18.189652
ANNUAL COST BEFORE TAX : SOLAR ONLY $/MBTU = -21.883482

	1992	1993	1994	1995	1996
SOLAR COSTS					
***********					
FUEL	-5,334	-5,601	-5,881	-6,175	-6,484
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
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1) TOTAL	-7,114	-6,911	-7,191	-7,485	-7,794
CONVENTIONAL COSTS					
******************					
FUEL	-23,193	-24,353	-25,570	-26,849	-28,191
BOILER	-559	-559	-559	-559	-559
	----------	----------	----------	----------	----------
2) TOTAL	-23,753	-24,913	-26,130	-27,409	-28,751
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-7,114	-6,911	-7,191	-7,485	-7,794
-DEPRECIATION	-14,986	-14,986	-14,986	-14,986	-14,986
TAXABLE INCOME	-22,101	-21,897	-22,177	-22,472	-22,780
-INCOME TAX	-11,050	-10,948	-11,088	-11,236	-11,390
-INVEST TAX CREDIT	0	0	0	0	0
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3) TOTAL INCOME TAX	-11,050	-10,948	-11,088	-11,236	-11,390
CONVENTIONAL:					
TAXABLE INCOME	-23,753	-24,913	-26,130	-27,409	-28,751
4) TOTAL INCOME TAX	-11,876	-12,456	-13,065	-13,704	-14,375
AFTER TAX CASH FLOWS					
********************					
SOLAR, 1)-3)	3,936	4,037	3,897	3,750	3,596
CONVENTIONAL, 2)-4)	-11,876	-12,456	-13,065	-13,704	-14,375
NET CASH FLOW AFTER TAXES					
************************	15,812	16,494	16,963	17,455	17,972
ACCUMULATED AT 0%	-61,321	-44,827	-27,863	-10,409	7,563
ACCUMULATED NPV AT 10%	-172,140	-168,877	-165,826	-162,972	-160,300

	1984	1985	1986	1987	1988	1989	1990	1991
SOLAR COSTS								
***********								
FUEL	-3,242	-3,352	-3,466	-3,584	-3,706	-3,832	-3,962	-4,097
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-960
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-700
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
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1) TOTAL	-5,022	-5,132	-9,486	-5,364	-5,486	-5,612	-5,742	-7,067
CONVENTIONAL COSTS								
*****************								
FUEL	-14,098	-14,577	-15,073	-15,595	-16,115	-16,653	-17,230	-17,816
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
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2) TOTAL	-14,658	-15,137	-15,633	-16,145	-16,675	-17,223	-17,790	-18,376
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-5,022	-5,132	-9,486	-5,364	-5,486	-5,612	-5,742	-7,067
-DEPRECIATION	-14,336	-12,902	-11,612	-10,451	-9,405	-8,465	-7,618	-6,856
TAXABLE INCOME	-19,358	-18,035	-21,098	-15,815	-14,892	-14,078	-13,361	-13,924
-INCOME TAX	-9,872	-9,198	-10,760	-8,066	-7,595	-7,179	-6,814	-7,101
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
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3) TOTAL INCOME TAX	-9,872	-9,198	-10,760	-8,066	-7,595	-7,179	-6,814	-7,101
CONVENTIONAL:								
TAXABLE INCOME	-14,658	-15,137	-15,633	-16,145	-16,675	-17,223	-17,790	-18,376
4) TOTAL INCOME TAX	-7,475	-7,720	-7,973	-8,234	-8,504	-8,784	-9,073	-9,371
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	4,856	4,065	1,273	2,701	2,108	1,567	1,071	33
CONVENTIONAL, 2)-4)	-7,182	-7,417	-7,660	-7,911	-8,171	-8,439	-8,717	-9,004
NET CASH FLOW AFTER TAXES								
************************	12,032	11,482	8,934	10,612	10,279	10,006	9,788	9,038
ACCUMULATED AT 0%	-150,097	-138,614	-129,680	-119,068	-108,788	-98,781	-88,992	-79,954
ACCUMULATED NPV AT 10%	-187,326	-182,457	-179,012	-175,292	-172,017	-169,118	-166,541	-164,377

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APPENDIX F

ECONOMIC ANALYSIS: SACRAMENTO

a. Sacramento, $188,200 investment, 1980 Time Frame

b. Sacramento, $112,920 investment, 1980 Time Frame

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Sacramento: $188,200 Investment, 1980 Time Frame

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS
****

	1980	1981	1982	1983	1984	1985	1986	1987
SOLAR COSTS								
FUEL	0	-2,725	-2,817	-2,913	-3,012	-3,114	-3,220	-3,330
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	0	-4,504	-4,597	-4,693	-4,792	-6,084	-5,000	-5,110
CONVENTIONAL COSTS								
FUEL	0	-11,847	-12,250	-12,667	-13,097	-13,543	-14,003	-14,479
BOILER	0	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	0	-12,407	-12,810	-13,227	-13,657	-14,103	-14,563	-15,039
TAX CALCULATION								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	0	-4,504	-4,597	-4,693	-4,792	-6,084	-5,000	-5,110
-DEPRECIATION	0	-18,820	-16,938	-15,244	-13,719	-12,347	-11,113	-10,001
TAXABLE INCOME	0	-23,324	-21,535	-19,937	-18,512	-18,432	-16,113	-15,112
-INCOME TAX	0	-11,662	-10,767	-9,968	-9,256	-9,216	-8,056	-7,556
-INVEST TAX CREDIT	37,639	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-37,639	-11,662	-10,767	-9,968	-9,256	-9,216	-8,056	-7,556
CONVENTIONAL:								
TAXABLE INCOME	0	-12,407	-12,810	-13,227	-13,657	-14,103	-14,563	-15,039
4) TOTAL INCOME TAX	0	-6,203	-6,405	-6,613	-6,828	-7,051	-7,281	-7,519
AFTER TAX CASH FLOWS								
SOLAR, 1)-3)	-150,560	7,157	6,170	5,275	4,463	3,131	3,056	2,445
CONVENTIONAL, 2)-4)	0	-6,203	-6,405	-6,613	-6,828	-7,051	-7,281	-7,519
NET CASH FLOW AFTER TAXES	-150,560	13,361	12,575	11,888	11,292	10,183	10,337	9,965
ACCUMULATED AT 0%	-150,560	-137,198	-124,623	-112,734	-101,441	-91,258	-80,920	-70,955
ACCUMULATED NPV AT 10%	-150,560	-138,413	-128,020	-119,087	-111,374	-105,052	-99,216	-94,192

RATE-OF-RETURN FOR 20 YEARS = 2.8344586

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.7729365
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -5.3594927

ANNUAL COST BEFORE TAX : CONVENTIONAL $/MBTU = -5.5458730
ANNUAL COST BEFORE TAX : SOLAR $/MBTU = -10.718985
ANNUAL COST BEFORE TAX : SOLAR ONLY $/MBTU = -11.678672

	1988	1989	1990	1991	1992	1993	1994	1995
SOLAR COSTS								
***********								
FUEL	-3,443	-3,560	-3,681	-3,806	-3,936	-4,070	-4,208	-4,351
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-960
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-700
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
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1) TOTAL	-5,223	-5,340	-9,701	-5,586	-5,716	-5,850	-5,988	-7,321
CONVENTIONAL COSTS								
******************								
FUEL	-14,972	-15,481	-16,007	-16,551	-17,114	-17,696	-18,298	-18,920
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
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2) TOTAL	-15,532	-16,041	-16,567	-17,111	-17,674	-18,256	-18,858	-19,480
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-5,223	-5,340	-9,701	-5,586	-5,716	-5,850	-5,988	-7,321
-DEPRECIATION	-9,003	-8,101	-7,291	-6,562	-5,905	-5,315	-4,783	-4,305
TAXABLE INCOME	-14,225	-13,442	-16,992	-12,149	-11,622	-11,165	-10,772	-11,627
-INCOME TAX	-7,112	-6,721	-8,496	-6,074	-5,811	-5,582	-5,386	-5,813
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
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3) TOTAL INCOME TAX	-7,112	-6,721	-8,496	-6,074	-5,811	-5,582	-5,386	-5,813
CONVENTIONAL:								
TAXABLE INCOME	-15,532	-16,041	-16,567	-17,111	-17,674	-18,256	-18,858	-19,480
4) TOTAL INCOME TAX	-7,766	-8,020	-8,283	-8,555	-8,837	-9,128	-9,429	-9,740
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	1,889	1,380	-1,205	487	94	-267	-602	-1,508
CONVENTIONAL, 2)-4)	-7,766	-8,020	-8,283	-8,555	-8,837	-9,128	-9,429	-9,740
NET CASH FLOW AFTER TAXES								
************************	9,655	9,400	7,078	9,043	8,932	8,860	8,826	8,231
ACCUMULATED AT 0%	-61,300	-51,899	-44,820	-35,777	-26,845	-17,984	-9,157	-925
ACCUMULATED NPV AT 10%	-89,598	-85,611	-82,882	-79,712	-76,866	-74,300	-71,975	-70,005

	1996	1997	1998	1999	2000
SOLAR COSTS					
***********					
FUEL	-4,499	-4,652	-4,810	-4,974	-5,143
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
	----------	----------	----------	----------	----------
1) TOTAL	-6,279	-5,962	-6,120	-6,284	-6,453
CONVENTIONAL COSTS					
******************					
FUEL	-19,563	-20,226	-20,916	-21,627	-22,362
BOILER	-559	-559	-559	-559	-559
	----------	----------	----------	----------	----------
2) TOTAL	-20,123	-20,788	-21,476	-22,187	-22,922
TAX CALCULATION					
***************					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-6,279	-5,962	-6,120	-6,284	-6,453
-DEPRECIATION	-3,874	-3,487	-3,138	-2,824	-2,542
TAXABLE INCOME	-10,154	-9,449	-9,259	-9,109	-8,995
-INCOME TAX	-5,077	-4,724	-4,629	-4,554	-4,497
-INVEST TAX CREDIT	0	0	0	0	0
	----------	----------	----------	----------	----------
3) TOTAL INCOME TAX	-5,077	-4,724	-4,629	-4,554	-4,497
CONVENTIONAL:					
TAXABLE INCOME	-20,123	-20,788	-21,476	-22,187	-22,922
4) TOTAL INCOME TAX	-10,061	-10,394	-10,738	-11,093	-11,461
AFTER TAX CASH FLOWS					
********************					
SOLAR, 1)-3)	-1,202	-1,237	-1,491	-1,729	-1,955
CONVENTIONAL, 2)-4)	-10,061	-10,394	-10,738	-11,093	-11,461
NET CASH FLOW AFTER TAXES					
************************	8,859	9,156	9,247	9,364	9,505
ACCUMULATED AT 0%	7,933	17,090	26,337	35,701	45,207
ACCUMULATED NPW AT 10%	-68,077	-66,255	-64,602	-63,071	-61,658

Sacramento: $112,920 Investment, 1980 Time Frame

CAMPBELL-SACRAMENTO:SOLAR HOT WATER ECONOMICS
****

	1980	1981	1982	1983	1984	1985	1986	1987
SOLAR COSTS								
***********								
FUEL	0	-2,725	-2,817	-2,913	-3,012	-3,114	-3,220	-3,330
MAINTENANCE	0	-420	-420	-420	-420	-960	-420	-420
REPLACEMENT	0	-50	-50	-50	-50	-700	-50	-50
FIXED CHARGES	0	-350	-350	-350	-350	-350	-350	-350
BOILER	0	-559	-559	-559	-559	-559	-559	-559
INSURANCE	0	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	0	-4,504	-4,597	-4,693	-4,792	-6,084	-5,000	-5,110
CONVENTIONAL COSTS								
******************								
FUEL	0	-11,847	-12,250	-12,667	-13,097	-13,543	-14,003	-14,479
BOILER	0	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	0	-12,407	-12,810	-13,227	-13,657	-14,103	-14,563	-15,039
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT.	0	-4,504	-4,597	-4,693	-4,792	-6,084	-5,000	-5,110
-DEPRECIATION	0	-11,292	-10,142	-9,146	-8,231	-7,408	-6,667	-6,001
TAXABLE INCOME	0	-15,796	-14,760	-13,839	-13,024	-13,493	-11,668	-11,111
-INCOME TAX	0	-7,898	-7,380	-6,919	-6,512	-6,746	-5,834	-5,555
-INVEST TAX CREDIT	22,583	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-22,583	-7,898	-7,380	-6,919	-6,512	-6,746	-5,834	-5,555
CONVENTIONAL:								
TAXABLE INCOME	0	-12,407	-12,810	-13,227	-13,657	-14,103	-14,563	-15,039
4) TOTAL INCOME TAX	0	-6,203	-6,405	-6,613	-6,828	-7,051	-7,281	-7,519
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	-90,336	3,303	2,782	2,226	1,719	661	533	445
CONVENTIONAL, 2)-4)	0	-6,203	-6,405	-6,613	-6,828	-7,051	-7,281	-7,519
NET CASH FLOW AFTER TAXES								
************************	-90,336	9,597	9,187	8,840	8,548	7,713	8,115	7,965
ACCUMULATED AT 0%	-90,336	-80,739	-71,550	-62,710	-54,161	-46,448	-38,333	-30,367
ACCUMULATED NPV AT 10%	-90,336	-81,611	-74,017	-67,376	-61,537	-56,747	-52,166	-48,079

RATE-OF-RETURN FOR 20 YEARS = 6.5173326

ANNUAL COST AFTER TAX : CONVENTIONAL $/MBTU = -2.7729365
ANNUAL COST AFTER TAX : SOLAR $/MBTU = -3.6083327

AL COST BEFORE TAX : CONVENTIONAL $/MBTU = -5.5458730
AL COST BEFORE TAX : SOLAR $/MBTU = -7.2166654
AL COST BEFORE TAX : SOLAR ONLY $/MBTU = -7.3302054

	1988	1989	1990	1991	1992	1993	1994	1995
SOLAR COSTS								
***********								
FUEL	-3,443	-3,560	-3,681	-3,806	-3,936	-4,070	-4,208	-4,351
MAINTENANCE	-420	-420	-3,360	-420	-420	-420	-420	-960
REPLACEMENT	-50	-50	-1,350	-50	-50	-50	-50	-790
FIXED CHARGES	-350	-350	-350	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400	-400	-400	-400
1) TOTAL	-5,223	-5,340	-9,701	-5,586	-5,716	-5,850	-5,989	-7,321
CONVENTIONAL COSTS								
*****************								
FUEL	-14,972	-15,481	-16,007	-16,551	-17,114	-17,696	-18,298	-18,920
BOILER	-559	-559	-559	-559	-559	-559	-559	-559
2) TOTAL	-15,532	-16,041	-16,567	-17,111	-17,674	-18,256	-18,858	-19,480
TAX CALCULATION								
***************								
SOLAR:								
BEFORE TAX AND DEBT REPAYMT	-5,223	-5,340	-9,701	-5,586	-5,716	-5,850	-5,989	-7,321
-DEPRECIATION	-5,400	-4,860	-4,374	-3,937	-3,543	-3,189	-2,870	-2,583
TAXABLE INCOME	-10,624	-10,201	-14,076	-9,524	-9,259	-9,039	-8,858	-9,904
-INCOME TAX	-5,312	-5,100	-7,038	-4,762	-4,629	-4,519	-4,429	-4,952
-INVEST TAX CREDIT	0	0	0	0	0	0	0	0
3) TOTAL INCOME TAX	-5,312	-5,100	-7,038	-4,762	-4,629	-4,519	-4,429	-4,952
CONVENTIONAL:								
TAXABLE INCOME	-15,532	-16,041	-16,567	-17,111	-17,674	-18,256	-18,858	-19,480
4) TOTAL INCOME TAX	-7,766	-8,020	-8,283	-8,555	-8,837	-9,128	-9,429	-9,740
AFTER TAX CASH FLOWS								
********************								
SOLAR, 1)-3)	88	-239	-2,663	-824	-1,086	-1,330	-1,559	-2,369
CONVENTIONAL, 2)-4)	-7,766	-8,020	-8,283	-8,555	-8,837	-9,128	-9,429	-9,740
NET CASH FLOW AFTER TAXES								
***********************	7,854	7,780	5,620	7,731	7,750	7,797	7,869	7,370
ACCUMULATED AT 0%	-22,513	-14,732	-9,112	-1,381	6,369	14,167	22,037	29,408
ACCUMULATED NPV AT 10%	-44,415	-41,115	-38,948	-36,238	-33,769	-31,510	-29,438	-27,673

	1996	1997	1998	1999	2000
SOLAR COSTS					
FUEL	-4,499	-4,652	-4,810	-4,974	-5,143
MAINTENANCE	-420	0	0	0	0
REPLACEMENT	-50	0	0	0	0
FIXED CHARGES	-350	-350	-350	-350	-350
BOILER	-559	-559	-559	-559	-559
INSURANCE	-400	-400	-400	-400	-400
1) TOTAL	-6,279	-5,962	-6,120	-6,284	-6,453
CONVENTIONAL COSTS					
FUEL	-19,563	-20,229	-20,916	-21,627	-22,362
BOILER	-559	-559	-559	-559	-559
2) TOTAL	-20,123	-20,788	-21,476	-22,187	-22,922
TAX CALCULATION					
SOLAR:					
BEFORE TAX AND DEBT REPAYMT	-6,279	-5,962	-6,120	-6,284	-6,453
-DEPRECIATION	-2,324	-2,092	-1,883	-1,694	-1,525
TAXABLE INCOME	-8,604	-8,055	-8,003	-7,979	-7,978
-INCOME TAX	-4,302	-4,027	-4,001	-3,989	-3,989
-INVEST TAX CREDIT	0	0	0	0	0
3) TOTAL INCOME TAX	-4,302	-4,027	-4,001	-3,989	-3,989
CONVENTIONAL:					
TAXABLE INCOME	-20,123	-20,788	-21,476	-22,187	-22,922
4) TOTAL INCOME TAX	-10,061	-10,394	-10,738	-11,093	-11,461
AFTER TAX CASH FLOWS					
SOLAR, 1)-3)	-1,977	-1,935	-2,118	-2,294	-2,464
CONVENTIONAL, 2)-4)	-10,061	-10,394	-10,738	-11,093	-11,461
NET CASH FLOW AFTER TAXES	8,084	8,459	8,619	8,799	8,997
ACCUMULATED AT 0%	37,492	45,951	54,571	63,370	72,367
ACCUMULATED NPV AT 10%	-25,914	-24,240	-22,690	-21,251	-19,914

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