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**An Implementation Plan for the Demonstration
of a 50,000 ft² Solar Hot Water System
for the Textile Industry**

Final Report

August 1980

IDAHO OPERATIONS OFFICE

IDAHO NATIONAL ENGINEERING LABORATORY

DEPARTMENT OF ENERGY

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AN IMPLEMENTATION PLAN FOR THE DEMONSTRATION
OF A 50,000 FT² SOLAR HOT WATER SYSTEM
FOR THE TEXTILE INDUSTRY

Final Report

by

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August 1979

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I. INTRODUCTION

The textile industry is a significant element in the economic welfare of the Southeastern United States. It is an industry that uses large quantities of energy at temperatures of 350°F or less in the finishing phases of producing textiles. Further, it is an industry that has strict quality control standards and well established processes for meeting its quality standards. Many of these hot water textile processes evolved from the cheap energy era and industry is reluctant to, and sometimes unable to, change from these established processes. Thus, as an alternative to lowering process temperatures or changing hot water use rates, the textile industry is a good candidate to utilize alternate energy sources to provide this process heat.

The Department of Energy (DOE) recognized this opportunity for substitution of sources and funded three studies to: (1) determine the overall feasibility of using solar energy in the textile industry¹, and (2) demonstrate the ability of solar hardware to produce small quantities of process heat for dyeing², and for steam dry cans³. The latter two studies, conducted at La France, South Carolina and Fairfax, Alabama resulted in approximately 6,000 ft² collection fields being built at each of the two plant sites. While these demonstrations serve to provide solutions to technical problems associated with solar use, they are limited in impact because they supply such a small fraction of energy used at the two plants. Further, these two demonstrations

¹For References consult Section VIII.

do not address the interface with heat recovery systems that should be developed in the textile plants. In the present study we evaluated the means of combining heat recovery techniques with solar heating techniques on a large scale to produce a new approach to textile finishing which will result in reduced fossil fuel energy expenditure levels per unit of production.

A previous study (Reference 1) had address the textile industry in general. In the present study we attempted to:

- 1) Refine those previous results and identify an optimum application for the large scale ($\sim 50,000 \text{ ft}^2$) demonstration of solar energy,
- 2) Evaluate the heat recovery opportunities and interfaces that should be addressed in conjunction with the solar array,
- 3) Evaluate the technical and economic aspects of implementing such a demonstration in the textile industry.

The remainder of this report details our findings and recommendations with respect to these objectives.

II. EVALUATION OF CANDIDATE TEXTILE PROCESSES

An analysis of textile processes was conducted to determine their applicability to integration into a 50,000 ft² collector field and into a waste heat recovery system. One significant parameter in the evaluation of these processes was that the proposed demonstration must be significant to plant operations, i.e., visibility and impact of the solar field on the process was very important.

The analysis of the various textile processes was accomplished using the three typical plants as described in Reference 1. The three plants are shown in Figures 1, 2, and 3. Energy flows and requirements were first established from the schematics of the three plants. These schematics had to be supplemented with additional data, since they did not show process details and the values were averaged over several plants. The purpose then was to establish typical energy uses and temperatures for a particular process.

1. Analysis of Typical Carpet Finishing Plant

The typical carpet finishing plant consists of a tufting room, dye becks (atmospheric pressure), and finishing ranges. Only the dye becks use steam and hot water. Energy flows are as shown below:

Figure 1. Energy Schematic for a Typical Carpet Finishing Plant.

Figure 2. Energy Schematic for a Typical Cotton/Cotton Blend Finishing Plant.

Figure 3. Energy Schematic for a Typical 100% Synthetic Pressurized Beck Finishing Plant.

As shown in Figure 1 there is typically a waste heat recovery heat exchanger in use. Assuming that the present system should remain as it is, only a small amount of additional direct recovery or enhanced recovery using a heat pump could be employed.

To operate the dye becks currently requires steam @ 115 psig and energy of:

$$\text{Energy required} = (\dot{m}\Delta h) = 25 \times 10^3 (1190-180) = 2.5 \times 10^7 \text{ Btu/hr.}$$

Assuming a maximum insolation of 365 Btu/hr-ft², (which is very high) and typical time variations, and an efficiency of 50% for the collector, the required solar collector area to provide this 2.5×10^7 Btu/hr is 136,986 ft².

It is seen then that this typical atmospheric dye beck range would require almost 3 times the criteria value of 50,000 ft² of collectors to operate, even at a very high insolation. Other problems also arise from the batch nature of the operation of this system. Because the dye becks are generally operated in cycles, significant amounts of storage would be required for continuous operation of a collector field. Also general practice in the textile industry is to fill these becks with colder water and then heat to 200°F by the injection of steam, thereby controlling the dyeing process. This practice provides more difficulty in using the type of energy most readily available from solar collectors.

2. Analysis of a Typical Cotton/Cotton Blend Finishing Plant

This plant has four candidate processes: 1) scouring and bleaching ranges, 2) mercerizing ranges, 3) dye ranges, and 4) finishing ranges.

Scouring and Bleaching Ranges

Hot Water 185°F/370M	→	Scouring and Bleaching Range	→	44M Condensate @ 212°F
Steam 115 psig/66M	→		→	585M Effluent @ Avg. Temperature 130°F
Cold Water 77°F/230 M	→			

The total energy required by this process to generate the steam is:

$$44 \times 10^3 (1195-180) + 22 \times 10^3 (1195-153) = 6.756 \times 10^7 \text{ Btu/hr}$$

The maximum practical additional heat recovery would be

$$585(10^3)1(50) = 3 \times 10^3 \text{ Btu/hr}$$

which leaves 3.8×10^7 Btu/hr to be supplied by the solar collectors.

This would require $\approx 210,000 \text{ ft}^2$. Although this process seems ideal for application of solar energy and waste heat recovery from a temperature standpoint the collector field required would typically be prohibitively large for the demonstration as outlined above. As a general statement, scouring and bleaching use large quantities of hot water, heated by steam, and then the cloth is dried by dry cans heated by steam. Hot water could be supplied for the washing and lower temperature steam used for the drying process. This scouring and bleaching operation is a good potential application for the solar systems, but a smaller range would provide a better demonstration.

Mercerizing Ranges

Without detailed analysis of the mercerizing ranges, it may be seen that the energy use level is higher than could be provided by $50,000 \text{ ft}^2$ of collectors. Also mercerizing is restricted to cotton fabrics and is not common to the entire industry as would be desired for broad technology transfer.

Dye Ranges

Although these dye ranges are continuous in operation, they require larger amounts of energy than could be provided by 50,000 ft² as well as not being as universal in nature as a preparation range. Also some of the dyes could cause problems with application of heat recovery equipment, requiring special heat exchangers, etc.

Finishing Ranges

The finishing range provides a thermal demand that could be a reasonable candidate for the 50,000 ft² solar demonstration, but one problem that finishing has that the preparation range avoids is the variability in the process. The dyes and the dyeing processes vary greatly from one finishing range to another and therefore the direct transferability of demonstrated solar systems from one textile plant to another would be somewhat reduced.

3. Analysis of a Typical 100% Synthetic Fabric Pressurized Beck Finishing Plant

The typical synthetic pressurized beck finishing plant has three basic processes: 1) preparation, 2) dyeing, and 3) finishing.

Dyeing

Water 353M 58°F	→	<div style="border: 1px solid black; padding: 5px; display: inline-block;">Dye Beck</div>	→	226 106°F Hot Water to System after Heat Recovery
Steam 23M 175 psig	→		→	335 130°F Waste
Water 205M 112°F	→		→	18M 212°F Condensate

Again with this energy flow and reasonable heat recovery the collector field is $\sim 1.5 \times 10^5 \text{ ft}^2$ and the problems again arise with the batch process and the transient ramp heating of the water after filling the beck. If it were desired to operate a dye beck with solar energy, the heating presently accomplished by steam injection could be accomplished instead with a fluid circulating in a heating coil in the beck but this adds an additional temperature drop, and an additional heat exchanger.

Preparation Range

The typical preparation range, shown in Figure 4 uses hot water, cold water, and high temperature steam in its various processes. Preparation ranges generally perform the following processes, with their associated energy requirements.

1. Desizing

The desizing process uses 140°F hot water and 170°F-200°F hot water to wash the cloth and essentially atmospheric steam in a J-box to steam the cloth.

2. Scouring

Scouring requires 170°F-200°F wash water with a small amount of atmospheric steam.

3. Bleaching

Bleaching only requires hot water.

Figure 4. Operational Requirements for a Typical Preparation Range

4. Drying Cans

Drying cans use high temperature steam condensing on the inside of a roller to heat the roller to dry cloth passing over the outside of the roller.

After assessing the uses of steam and water presently practiced by the textile industry, several operational changes were found that would make the use of solar energy more practical. These changes are reflected in Figure 5.

Instead of using high temperature steam to heat water to higher temperatures by injection at the process, the solar system would provide hot water directly to the process. However, steam is still injected into the process water to make up any temperature deficiency, but much less steam will be required than before by the processes. Providing hot water provides for much more efficient utilization of the solar collectors than would the production of steam. Also if the steam load to the saturators and dry cans was to be provided by solar collectors, 280°F steam would be much easier to produce than would 350°F steam.

Although these are small changes in the process methods of operation, they provide for much more effective use of the solar collector fields. Other changes may be possible to further facilitate the use of solar collectors, however, the effects on the process would have to be ascertained by members of the industry.

Thus it appears that the preparation range activities are well suited to solar demonstration requirements by virtue of the following:

- 1) General applicability to all types of textile plants regardless

Figure 5. Suggested Operational Requirements for a Typical Preparation Range

of subsequent plant operations. (Good transfer possibilities).

- 2) Good compatability with solar temperature capabilities, i.e., much hot water @ approximately 200°F is used.
- 3) Good size match for typical preparation range flows of 200 gpm (a common size plant) to a 50,000 ft² array.
- 4) Good heat recovery opportunities in the preparation range to allow stand alone activity of the combined solar array/heat recovery system and separation of the preparation range from the textile plant boiler.

Table I illustrates the energy demands of the textile industry in several categories. The highlighted areas (*) represent the preparation range activities we favor for the textile demonstration of the 50,000 ft² system. Industry wide this 200°F hot water requirement is approximately 2.5×10^{10} gallons per year.

Table 1. CURRENT PROCESS WATER/ENERGY USE SUMMARY FOR FABRIC DYEING AND FINISHING

	Temp. (°F)	Use Rate Typical Mill (lbm H ₂ O/lbm product)	Use Rate Typical Mill (Gal/day)	Use Rate Industry Wide (Gal/year) (Btu/yr)	
<u>Continuous--Cotton Containing</u>					
Boiler Output	370°	25.	---	---	---
*Scouring and Bleaching	¹ 200°	58.4	1,332,000	196.8 x 10 ⁸	2.3 x 10 ¹³
*Mercerizing	210°	25.6	585,000	20.5 x 10 ⁸	2.5 x 10 ¹²
Dyeing	210°	51.3 } Dyeing	1,170,000	41.0 x 10 ⁸	5.1 x 10 ¹²
	160° ²	38.3 } Rinsing	873,000	30.6 x 10 ⁸	2.6 x 10 ¹²
Finishing	185°	2.7	60,000	2.2 x 10 ⁸	.2 x 10 ¹²
Sub-total		30,000 Btu/lbm	4,020,000	---	1.1 x 10 ¹⁴
<u>Pressurized Batch--Synthetics</u>					
Boiler Output	375°	7.3	---	---	---
Scouring	¹ 200°	16.7	225,000	24.8 x 10 ⁸	2.9 x 10 ¹²
Beck Dyeing	² 250°	45.5 } Dyeing	615,000	68.3 x 10 ⁸	10.6 x 10 ¹²
	140° ³	39.9 } Rinsing	525,000	58.3 x 10 ⁸	4.1 x 10 ¹²
Finishing	110°	2.2	30,000	3.3 x 10 ⁸	.2 x 10 ¹²
Sub-total		12,000 Btu/lbm	1,495,000	---	2.4 x 10 ¹³
<u>Atmospheric Batch--Carpets</u>					
Boiler Output	350°	5.7	75,000	---	---
Beck Dyeing	³ 212°	24.1 } Dyeing	324,000	39.0 x 10 ⁸	4.9 x 10 ¹²
	120° ³	24.1 } Rinsing	324,000	39.0 x 10 ⁸	2.1 x 10 ¹²
Finishing	N/A	0.0	0.0		
Sub-total		8,000 Btu/lbm	723,000	---	1.4 x 10 ¹³
¹ Supplied at lower temperature and heated with steam to use temperature.					
² Used at 250°F; Ramp from 110°F					
³ Used at 212°F; Ramp from 120°F					

III. COLLECTOR TECHNOLOGY EVALUATION

The technological readiness of various solar collecting concepts was evaluated in order to best match potential textile users of hot water to available solar components. The three major types of collectors readily available for purchase are the flat-plate, evacuated tube, and the parabolic trough concentrating collectors. Parabolic dish, focusing Fresnel lens, and focusing heliostat collectors are other concepts available for collecting solar energy; however, with the exception of a few manufacturers prepared to make parabolic dishes in limited numbers, these collectors have been built for research and test purposes only. In this report only the flat-plate, evacuated tube, and parabolic concentrator will be discussed. It is also felt that the flat-plate, evacuated tube, and parabolic trough concentrating collector will be suitable for the majority of industrial process applications, suitable in the sense that they will meet a large number of process temperature requirements. These collectors are most likely to be cost effective on a basis of Btu's per dollar invested. It should also be noted that this report is limited only to the discussion of liquid heating systems.

Flat-Plate Collectors

Several designs and concepts associated with different types of flat-plate collectors were considered. Generally, the majority of flat-plate collectors available today are aimed at the domestic or low temperature user. Most domestic hot water systems do not need to be above 140°F; most conventional flat-plate collectors are adequate for

heating water to 150°F. Slightly higher temperatures may be obtained by using a lithium bromide and water solution, but in general, a textile process temperature requirement of 200-230°F is above the limits for flat-plate collectors in any other than ideal conditions. Those models that are capable of attaining higher temperatures will generally require very large areas to meet the required flows. To sum up the use of flat-plate collectors for textile processes, one might conclude that the physical temperature limitations along with the vast required areas generally make the flat-plate collectors unattractive. However, flat-plates may find widespread use in textile applications if they are used to preheat fluids before entering some other type of collector or boiler.

Evacuated Tubes

Evacuated tube collectors have been and are being developed by several manufacturers. All of these collectors utilize a vacuum between the outer cover and the absorber. There are currently two prevalent designs of evacuated tube collectors. The first consists of all glass construction and the second uses a metal tube acting as a heat exchanger under the absorber. (See Figures 6 and 7). Both designs use a tubular structure since the round cross section is more adept at withstanding the strains produced by the high evacuation. Both designs use an outer glass cover for strength and optical characteristics. The designs are also similar in that they use a glass absorber tube coated with a selective absorber surface which absorbs most of the radiation in the solar spectrum and limits the amount of reradiation. Neither

design requires glass to metal seals; this rids the designs of one of its most troublesome and costly components.

Figure 6. SunPak Collectors - Owens-Illinois Incorporated

Figure 7. GE TC-100 General Electric Company's Evacuated Tube Collector

The all glass construction designs, such as the SunPak module being marketed by Owens-Illinois use another glass feeder tube to spread the working fluid against the absorber plate and thus collect the energy stored there. (See Figures 6 and 8) General Electric Company is marketing a model using metal tubes acting as heat exchangers. General

Electric's T.C. Series uses a metal fin attached to the inside of the absorber tube. The tubes transporting the fluid through the collector are then attached to this metal fin. (See Figure 7, 9, 11, 21) Flow patterns for the two designs are shown in Figures 10 and 11 respectively. Both designs are using specular reflectors (Figure 12 and 7). It has been found that performance is significantly improved with the specular reflector in collecting both direct and diffuse sunlight. Evacuated tube collectors are technologically ready to be used in low and high temperature applications (400°F). However, the evacuated tubes that are readily available for purchase are presently in the intermediate range of 250°F. In the not too distant future evacuated tube collectors attaining much higher temperatures should become available to the public. The actual energy collecting technology for high temperatures is already available but production processes and costs have kept high temperature evacuated tubes from becoming a reality. Typical operating and performance curves compiled from different manufacturers and studies are present in Figures 13 through 20. These curves show collection efficiency and energy collected, and compare evacuated tube and flat-plate designs.

The design concept for evacuated tubes is quite simple and can be produced using existing manufacturing technology. The glass in the array is easily formed, economically mass produced, its cost of manufacture is relatively low, and its life expectancy is long. The evacuated tubes have been forecast to have the lowest manufacturing cost in high volume production. Forecasts for consumer prices range

Figure 8. Structural Schematic for SunPak Collector - Owens-Illinois Incorporated

a. Serpentine Being Inserted

b. Serpentine Fully Inserted

c. Collector Tube Assembly

Figure 9. Internal Heat Exchanger (Serpentine) Being Inserted
GE TC100 - General Electric Company

Figure 10. Flow Schematics for SunPak Collectors - Owens-Illinois Incorporated

Figure 11. Internal Heat Exchanger Configuration for GE TC100 - General Electric Company

Figure 12. Specular Reflectors for SunPak Collectors - Owens-Illinois, Inc.

*Supplied by Corning

**From Solar Energy Thermal Processes, J.A. Duffie and W. Beckman, John Wiley and Sons, Inc., 1974

Figure 13. Performance of a Single Corning Evacuated Tube Solar Collector and a Typical Two Cover Flat-Plate Collector with a Non-Selective Surface

Figure 14. Various Performance Curves for SunPak Collector - Owens-Illinois Incorporated

SSR Reflector

- 1 $T_{OUT} - T_{IN} = 180^{\circ}F$
- 2 $T_{OUT} - T_{IN} = 240^{\circ}F$

Diffuse Reflector

- 3 $T_{OUT} - T_{IN} = 180^{\circ}F$
- 4 $T_{OUT} - T_{IN} = 240^{\circ}F$

SUNPAKTM Performance vs. Ambient Temperature

The SUNPAKTM Solar Reflector increases energy output of the SUNPAKTM collector 25-30% for the operating conditions shown. The collector is assumed to be tilted at the latitude on a clear equinox day.

Insolation in Collector Plant=2150 Btu/ft² day

Figure 15. Performance vs. Ambient for SunPak Collector - Owens-Illinois, Incorporated

- 3 Diffuse Reflector, $\Omega = 0$
 2 Diffuse Reflector, $\Omega = \pm 45^\circ$
 1 SSR

SUNPAKTM Efficiency with the SSR and Diffuse Reflectors - Data points correspond to inlet temperatures over the range 70°F-220°F and an average ambient temperature (T_A) of 55°F. The solid lines are best fits to the data. The diffuse reflector shows the efficiency increase with hour angle (Ω), while points for the SSR fall along the same line for all hour angles. S_p is the insulator in the tilt plane of the collector.

Figure 16. Efficiency Curves for SunPak Collector - Owens-Illinois Incorporated

Figure 17. Efficiency vs. Plate Temperature for TC 100 Collector - General Electric Company

Figure 18. Efficiency Curves for GE TC100 Evacuated Tube Collectors - General Electric Company

Figure 19. Efficiency Curves for GE TC100 Evacuated Tube Collectors (with no reflectors) -
General Electric Company

Figure 20. Efficiency vs. Collector Temperature for GE TC100 - General Electric Company

Figure 21. GE TC100 Tubular Collector -- General Electric Company

from \$10 to \$25 per square foot in 1977 dollars. The current price for all glass construction is around \$11 per square foot; it must be realized that this price does not include mounting and support structure. When adding the mounting structure cost to the collector cost, one obtains a cost that may be comparable to the present cost of concentrating parabolic collectors discussed in the next section. It has also been forecast that the installed system cost using evacuated tubes would range from \$25 to \$50 in 1977 dollars based on previous studies and manufacturers' estimates. A typical large system using evacuated tubes may cost from \$25 to \$80 per square foot today.

To conclude this section, evacuated tube collectors may offer a solution to the solar cost effectiveness problem, if manufacturing costs will continue to fall with increased volume and if collector mounting costs can be minimized. However, based on comparing the evacuated tube collectors to other mature glass and metal fabrication technologies, further reduction in price does not appear likely to be great. The evacuated tubes offer many of the same features as conventional flat-plate collectors. That is, they are stationary, have rigid piping, and no moving parts. Features such as these make evacuated tube collectors attractive from an installation and user standpoint. The present temperature range is attractive to a number of the basic textile processes. Therefore, if evacuated tubes capable of attaining higher temperatures can be competitively manufactured, they should become quite attractive to the textile industry, but the future costs competitiveness is uncertain.

Concentrators

There are a number of parabolic concentrating solar collectors on the market today. All are capable of attaining very high thermal fluid temperatures (600°F) and high water temperatures (350°F). These parabolic concentrators have many different designs and operating characteristics. The parabolic concentrators are also constructed out of a host of different materials. In this section of the report, various operating procedures and basic design differences of some of the major parabolic concentrator manufacturers will be briefly discussed.

The first major class of parabolic concentrators consists of a tracking absorber and trough focusing the sun's light on to the absorber. Acurex, Hexcel, Solar Kinetics, and others manufacture such designs. (See Figures 22, 23, 24, and 25) All designs feature a precisely shaped parabolic trough. All models use sun sensing electronic devices to position the parabolic troughs. The Acurex model uses a worm drive to keep the collector correctly aligned with the sun. The Hexcel model uses a gear chain drive for the same purpose. All models are designed so that a specified number of modules can be coupled together to form a group of collectors which is driven by a single drive system. This obviously saves in the amount of sun sensing and tracking equipment needed as well as a savings in the manifold arrangement. Absorber tubes with turbulence inducing devices that produce high heat transfer coefficients (See Figure 26) are used in all designs. Hexcel's absorber tube has selective black chrome covering. (See Figure 27) The Acurex model has one of two coatings on a mild steel tube depending on the tempera-

Figure 22. Acurex Model 30C1 Concentrating Solar Collector - Acurex Corporation

Figure 23. Hexcel Concentrating Solar Collector (Front View) - Hexcel Corporation.

Figure 24. Hexcel Concentrating Solar Collector (Back View) - Hexcel Corporation

Figure 25. Solar Kinetics Solar Collector

Figure 26. Cross Section of Hexcel Absorber Tube Construction

INTERNALLY FLUTED
TUBE, BLACK CHROME
PLATED

Figure 27. Cross Section of Hexcel Receiver Assembly

ture required, either black paint for low temperature applications or black chrome on a nickel plate for high temperature application. Solar Kinetics uses a black chrome-plated steel absorber assembly. Collector support structure for the Hexcel model consists of welded steel tubing. The model produced by Solar Kinetics is supported by vertical columns. Acurex's model is mounted on vertical steel columns. All models are built out of heavy duty components that are rugged and durable enough to insure a long working life and make the collectors suitable for a wide variety of industrial applications. Different performance curves and other information about these models are presented in Figures 28 through 35.

In the next design to be considered, energy is concentrated into one focal line by individually tracking mirror segments. Such a collector is currently being marketed by Suntec Systems Incorporated under the trade name Slats. (See Figures 36 and 37) The Slats design concept is to deliver the maximum amount of energy possible to a smaller absorber while minimizing the collector complexity. The individual slats mirror segments (see Figure 38) are designed to be

*Based on experimental data for a clear day, normal incidence, and no dust loss.

Figure 28. Efficiency Curve for Acurex Model 3001 Concentrating Solar Collector - Acurex Corporation

Figure 29. Hexcel Collector Efficiency vs. Output Temperature

Figure 30. Hexcel Solar Noon Efficiency

Figure 31. Hexcel Receiver Thermal Loss

Figure 32. Hexcel All Day Efficiency

Figure 33. Solar Kinetics Efficiency vs. Output Temperature

Figure 34. Solar Kinetics Collector Solar Noon Efficiency

Figure 35. Solar Kinetics All Day Efficiency

Figure 36. Slats Collector Array Configuration - Suntec Systems, Inc.

Figure 37. End View of Slats Solar Collector - Suntec Systems, Inc.

Figure 38. Slats Reflector Assembly Cross Section - Suntec Systems, Inc.

self-supporting optical concentrating devices. Since the mirror segments focus the light into one focal line, the absorber can be small and stationary. The effect of the smaller absorber is to reduce the overall thermal losses of the collector. (See Figure 39) Also since the absorber is stationary, pipe fittings are minimized and immovable, eliminating flexible pipe and couplings. The drive mechanism is simple since all mirror segments can be driven with one linkage after the segments are focused (see Figure 40). The mirror segments are controlled with sun density signals and demand sensors. The slats support structure is designed to be self contained. The slats design has most outstanding features and its design may prove to be durable. Performance curves and other information is included in Figures 41 through 44.

General Atomic Company manufactures the next type of parabolic collector to be discussed (see Figure 45). The collector is a concave array of long, narrow, flat mirror faces fixed on a cylindrical surface. The fixed mirror array produces a thin focal line and it is tracked by a movable absorber assembly that rotates about the center of the reflector module (see Figure 46). The heat receiver or absorber is quite different from any viewed so far and it is quite effective. The tube is black chrome plated and shaped in an oval fashion (see Figure 47). Performance curves are shown in Figures 48 through 50.

The last concept to be discussed is the biaxially-tracking solar concentrator (see Figure 51.) A design of this nature called Solar Carousel is being marketed by Sunpower Systems Corporation. The parabolic troughs are coupled together to form one axis for tracking the

Figure 39. Slats Receiver Assembly Cross Section - Suntec Systems, Inc.

Figure 40. Support Structure and Segment Drive, Inclined Version - Suntec Systems, Inc.

Figure 41. Slats Performance Characteristics - Suntec Systems, Inc.

Figure 42. Slats Efficiency vs. Output Temperature - Suntec Systems, Inc.

Figure 43. Slats Solar Noon Efficiency - Suntec Systems, Inc.

Figure 44. Slat Receiver Thermal Loss - Suntec Systems, Inc.

Figure 45. General Atomic Fixed Mirror Solar Concentrator (FMSC)

Figure 46. Annual and Daily Movement of FMSC Receiver - General Atomic Company

Figure 47. FMSC Heat Receiver Assembly Cross Section
General Atomic Company

Figure 48. General Atomic FMSC Efficiency vs. Output Temperature

Figure 49. General Atomic FMSC Solar Noon Efficiency

Figure 50. General Atomic FMSC Receiver Thermal Loss

Figure 51. Sunpower Systems Corporation Biaxially-Tracking Carousel Solar Collector (Sunpower Systems Corp.)

sun (see Figure 52). The second axis for tracking the sun is provided by resting the entire collector field on circular concrete tracks (see Figure 53). The outer track is provided with a linked chain and a motor. This provides the means to rotate the array into a horizontal plane with the sun. The absorber pipe used in the Sunpower carousel is either select black or black chrome piping. The efficiency of this collector is lower than many others because a less reflective aluminum sheeting is used so as to increase the collector's durability and decrease collector maintenance. Also the efficiency plot shown in Figure 54 is without an enclosing absorber housing. With an absorber housing, the efficiency would obviously increase. This may prove to be a highly cost effective and durable design.

Current price for concentrating collectors is about \$20 to \$22 per square foot and installed cost should not exceed \$40 per square foot. Total system cost will vary depending on what is required of the system. Based on comparing the concentrators to more mature technologies, the concentrator manufacturers should be able to reduce their price with increased production.

In summary, the parabolic trough concentrators are approaching the point where their collecting technology is essentially complete. Further, the temperatures attained by the collectors make them quite attractive to nearly all basic textile processes.

To conclude, the three major types of collectors available for purchase, flat-plate, evacuated tube, and parabolic concentrators, are at the point where they will technologically collect nearly all the energy their designs will feasibly allow. Various collector designs

Figure 52. Schematic of First Axis Tracking Device for Sunpower Systems Corporation Biaxially-Tracking Carousel Solar Collector

Figure 53. Schematic of Second Axis Tracking Device for Sunpower Systems Corporation Biaxially-Tracking Carousel Solar Collector

SUNPOWER SYSTEMS
Tracking Concentrator

B12151. 11-28-77

Gross Collector Area 38.3 Sq Ft

First order efficiency equation is:

$$\text{Effic.} = 0.495 - 0.237 \frac{T_{in} - T_a}{I} \quad (\text{F ft}^2 \text{ hr/Btu})$$

Tests conducted according to ASHRAE 93-77 and, as required, efficiency is calculated using GROSS collector area.

This plot is based on Direct Radiation.

* New curve adjusted for net effective area. (equals 34.16)

Figure 54. Efficiency Curve for Biaxially-Tracking Carousel Solar Collector - Sunpower System, Inc.

are compared in Figure 55.

Which of these systems prove to be most economical depends on the system performance, system life time, and the cost of the fuel it replaces.

Figure 55. Comparison of Collector Curve Efficiencies

IV. EVALUATION OF WASTE HEAT RECOVERY TECHNIQUES AS APPLIED TO TEXTILE PROCESSES

With the increasing interest in energy conservation, waste heat recovery techniques are providing energy savings and economic gains as they are applied to all industries. As the price of energy increases, it becomes economically feasible to recover energy from lower grade waste sources, and to apply enhancement techniques to upgrade this thermal energy. The primary sources of waste heat in the textile industry are liquid waste streams from the various processes. These streams generally range in temperature from 100 to 200°F, and in general contain various substances in solution or suspension with water. The different processes produce very different effluent streams, and this influences the type of waste heat recovery techniques which may be used.

Three basic methods of heat recovery are applicable to the textile industry. First there is direct heat exchange, whereby energy from an exiting waste stream exchanges energy with incoming water. The remaining two techniques involve enhancing the energy through the use of a heat pump device. Closed cycle, or second fluid, heat pumps employ a secondary fluid, generally a fluorinated hydrocarbon, operating in a cycle, to carry the energy from a low grade source and supply it to a receiving stream at an enhanced temperature. Open cycle, or through flow, heat pumps use the waste effluent as a working fluid and, by supplying work to a compressor, enhance the level at which the waste energy is available. Economic considerations, as well as source stream temperatures, dictate which method will be applied in a given situation. For the analyses in

this report, three "typical" plants were analyzed, as outlined in Section II of this report.

1. Sources of Waste Heat in the Textile Industry

To evaluate the potential heat recovery from textile waste streams, their content and thermal characteristics must be examined. The largest portion of the waste streams in the textile industry are water containing various impurities. Throughout the textile industry, the waste waters are highly variable in quantity and composition. The sources of these wastes are first, the natural impurities present in the fibers, and, second, the process chemicals. To determine the kind and amount of various impurities present in the waste streams, the specific plant and/or process in question must be examined. Some general statements may be made, however, concerning textile wastes and the various textile processes. A great many process chemicals are used industry-wide, and are the primary impurities in the waste streams from synthetic processing. Waste stream segregation is practiced to some extent in the textile industry, mainly where it provides for recovery of a useful substance, in some cases the hot water itself. At present hot water is not generally recovered, and waste heat recovery techniques can be highly productive. Overall availability gains can be realized by segregating high and low temperature streams for the purpose of waste heat recovery.

Pretreatment for some environmental control processes may neutralize acid wastes; this pretreatment could help prolong the life and reduce the cost of heat recovery equipment. Acidic effluents are

associated largely with the finishing of polyester knits, because of the acetic acid used in the dyeing process. Alkalinity is not generally a problem to heat recovery in the textile industry; however, each situation should be analyzed for dangerous combinations of dissolved solids, pH, suspended solids, etc. which may damage equipment.

The two largest producers of waste heat in the textile industry are the various dyeing and preparation processes. The dyeing process generally takes place at 200°F, followed by a rinse at 100°F. The effluents from both dyeing and rinsing are often dumped into a common drain, and in batch operations could produce widely varying flows and temperatures. Dyeing effluents generally contain the coloring agent, a high level of dissolved solids and in some cases acetic acid. Preparation of fabrics consists of several steps and produces several temperature levels and effluent characteristics. The first basic step in preparation is generally desizing, where starches, called sizing, polyvinyl alcohol (PVA) and lubricants are removed from the cloth. Starches are removed with enzyme systems or sulfuric acid solutions, while PVA is removed by washing with a hot detergent solution (190°F). It is possible to recover the PVA for future reuse, and this is being done at present in some plants.

Scouring is another common process in preparation, which removes impurities from the fabric. A caustic, a solvent, and a suitable detergent is applied to the fabric, which is then washed in hot water (170°F) to remove the scouring solution. Bleaching is accomplished with hydrogen peroxide and is accompanied by more washing (170°F). It is apparent then that many types of effluents occur in the textile

industry, ranging from very acid to very alkaline, and containing dissolved solids, suspended solids, and various other chemicals.

For the purposes of this discussion it will be assumed that the heat recovery equipment can be designed so as to accommodate the various effluent streams as they exist. Vendors of direct heat recovery "package" units for the textile industry have successfully addressed these problems with materials appropriate to the effluent, and various cleaning and flushing procedures. Similar approaches would prove successful in waste heat enhancement systems. The focus of the analysis of waste heat recovery for the proposed system assumes that the preparation range produces two streams which may or may not be segregated, at temperatures of 140°F and 170°F. Direct heat recovery can meet the established energy recovery goal if the entire effluent stream is at 140°F when mixed, therefore the assumption of segregation is not necessary in that analysis.

2. Evaluation of Waste Heat Recovery Techniques

The advantages of the application of waste heat recovery techniques to waste effluent streams in the textile industry are many and varied. First, the economic gains in reduced energy costs can be very significant, and will become more substantial as energy prices increase. Reduction of the effluent temperature may reduce thermal pollution of the environment, and the plant's sewer taxes, because of a cooler sewage effluent. A continuous dye plant saved approximately \$600 per day and delayed the construction of an additional steam plant for five years by the use of waste stream segregation and heat recovery equipment. As

energy prices continue to rise, more applications of enhanced heat recovery will be found, and heat energy can be removed economically from lower grade waste heat sources. Enhanced recovery techniques can provide water in the temperature range of 140 to 160°F from waste streams as low as 70°F. Economics will dictate the cut-off point for the recovery of heat from these streams. The technology of industrial grade heat pumps is at this time just emerging, but should be available as the economics of enhanced recovery improve.

A. Direct Heat Exchange Concepts

1. General Considerations

The technology of direct exchange waste heat recovery systems is well developed and established with many heat exchanger manufacturers offering "package" systems, including controls and hardware for installation and monitoring. Such package systems offer the advantages of mass-produced items, reducing the cost while still allowing for adaptation to a specific process and set of needs. The recovery energy is generally of a low grade, and there must be ample opportunity to use the energy before such direct exchange can be applied. Because the textile industry uses so much process hot water, the pre-heating of incoming city water by direct exchange with the hot waste streams is the ideal application of liquid to liquid waste heat recovery systems.

Several considerations must enter into the design of a direct exchange system. Materials must be selected to stand up under any corrosive components in the effluent. A solids removal system may be required to eliminate plugging and storage may be required in batch

operated processes to assure maximum energy recovery is realized. The companies which produce these package heat recovery units are capable of resolving all of these issues when provided with appropriate information. Therefore a detailed treatment of how to avoid the various problems would not be useful in this report. Rather emphasis is placed on what type of performance can be expected, and where the greatest applicability exists. Included in Appendix A is literature from vendors, illustrating what the state-of-the-art is in direct exchange systems.

2. Applications to Textile Processes

The greatest potential for application of direct heat recovery lies in high temperature large volume waste effluent streams. Dyeing and preparation produce such streams and are the primary candidates for the application of these techniques. For the purposes of this report, the preparation range of the 100% Synthetic Pressurized Beck Finishing Plant was analyzed in detail. The effluents were assumed to consist of three segregated streams. First the condensate from the drying processes was assumed to return directly to the steam producing process equipment and not available for heat recovery. The other two streams were available for heat recovery before being eliminated. They were assumed to consist of 41×10^3 lb/hr of 140°F effluent, and 41×10^3 lb/hr of 170°F effluent. A typical heat exchange unit designed for use with textile processes was analysed for application in this situation.

To feed the solar collectors in this design, it is desired to produce 120°F water from the heat recovery system. An estimate was

obtained from Ludell Manufacturing Company for the performance and price of the desired equipment. A system guaranteed to produce 120°F water when supplied 82 x 10³ lb/hr of 140°F water cost approximately \$31,000.00. Based on incoming water at 60°F the reclaimed heat is equivalent to 140 boiler horsepower or 5072 lbm of steam per hour. If steam costs \$3.00 per thousand pounds, the recovered heat has a value of \$91,298.00 per annum based on 120 hours per week, 50 weeks per year.

3. Opportunities for Other Applications

Direct exchange waste heat recovery should be widely applied to the processes in the textile industry to make the overall energy usage lower, and in the long term to reduce plant costs of operation. The overall energy savings for the preparation range analyzed was 35% of the total process usage, and almost 50% of the hot water requirements for that process. As energy costs continue to rise, the attractiveness of waste heat recovery investments will increase. Technologies such as hyperfiltration offer the possibility of recovering not only hot water, but also the process chemicals, allowing their reuse. As the economics of energy change vary rapidly with rising fuel costs, continual re-evaluation of opportunities for waste heat recovery by direct methods is necessary to insure that maximum savings are realized, and no economical application is missed. In any given situation, direct heat recovery will require the lowest initial capital investment per unit of energy produced, and therefore will be the first type of heat recovery to become economically feasible for a given application as energy costs increase. This is provided, of course, that the recovered energy is of a high enough quality to find uses in the plant.

Example of Application of Direct Waste Heat Recovery to a Preparation Range

The preparation range was analyzed to determine how the waste effluents could best be used.

The preparation process is assumed to consist of three separate segments.

The waste can be assumed separated or mixed. Because 120°F feed water to the solar collectors is desired, the streams may be mixed.

This system recovers 4.92×10^6 Btu/hr of energy at \$2.53/million Btu.

This translates to a yearly savings of \$74,685/year, provided the system operates 120 hrs/week, 50 weeks/year.

B. Closed Cycle Enhanced Recovery

The basic principle behind the closed cycle enhancement system is the same as any heat pump or refrigeration cycle. A working fluid, working in a closed loop of compression, condensation, expansion and evaporation carries energy from a low temperature, low availability source to a higher temperature receiving stream by the addition of mechanical work. The most practical application at the present time for industrial heat pumps is to provide hot water (150°F) from a low temperature waste heat source (90°F). A typical coefficient of performance at this operating point would be 3.3. Working fluid limitations presently require that for good COP's the exiting process water be less than 160°F. Source fluids can be utilized down to 60°F with process fluids heated as high as 230°F. However, when heating fluids to this high temperature the coefficient performance is very low. The low COP's are a direct result of the presently available working fluids and compressors and if suitable working fluids and newer compressors are developed this upper temperature limit would no longer apply.

Several factors contribute to the attractiveness of the industrial heat pump concept for use as a waste heat recovery technique. An industrial heat pump operating at a COP of 4.5 can provide a 150°F delivery using .72 Btu of input fuel at the generation site for the electricity, per Btu of useful energy delivered. A fuel fired boiler would use more than one Btu of fuel per Btu of useful energy produced; for an efficiency of 70%, 1.43 Btu's would be required to produce 1 Btu of energy as heat. So the potential exists for overall fuel savings and

reduced costs over conventional fossil fuel boilers, if they are used to produce hot water. As it relates to the textile industry, the industrial heat pump should find widespread use because of the large amounts of hot water used. Economic considerations dictate that direct recovery will be the first heat recovery technique applied. Generally then heat pumps in the textile industry will be coupled with direct exchange to produce the most economical system. The same effluent streams from the assumed preparation range described in the direct exchange section are used. The streams remain segregated while passing through direct heat exchanges and then mix and pass through the heat pump. At present the only commercially available heat pump is the Westinghouse Templifier; therefore, its operating characteristics and price were used. Operating 120 hours/week, 50 weeks/year, the Templifier saved the equivalent of \$44,000 in energy at \$2.53/million Btu. The cost of such a Templifier would be about \$35,000. If a stainless steel evaporator were required, it would add \$15,000 to the price. These data were obtained as follows:

Example of Templifier Application

This application consists of a combination of direct heat recovery and a Templifier heat pump. The effluent streams are assumed to be produced by a preparation range..

Effluent 1 = 130°F, Flow: 82.33 gpm

Effluent 2 = 170°F, Flow: 82.33 gpm

System Schematic

The COP of this heat pump in this application is 5. The total Btu/hr supplied is 6.2×10^6 . With the energy supplied as follows:

Effluent 1 → 1.24×10^6 Btu/hr

Effluent 2 → 2.06×10^6 Btu/hr

Templifier → 2.9×10^6 Btu/hr

The price of the Templifier without a stainless steel evaporator for this application would be \$35,000. If the energy replaced costs \$2.53/million Btus and the system operated 120 hours/week, 50 weeks/year, the value of the recovered energy would be \$44,022/year by the Templifier only.

Open Cycle Enhanced Heat Recovery

The open cycle approach to waste heat recovery uses the waste effluent stream as the working fluid for the heat pump cycle. A through-flow system utilizing water as the working fluid is capable of producing much higher temperatures than can be obtained with conventional closed cycle systems using presently available working fluids. The basic principle is to use a flash evaporator to produce

saturated vapor from the water. The vapor is then compressed producing high temperature, superheated vapor, which can be used to heat a process fluid. If the water used as the working fluid is of sufficient purity, the vapor may be used directly.

According to Reference 11 the open cycle concept was superior above about 200°F. However, the flash evaporation of water requires large amounts of waste effluent to be effective. Many questions arise concerning application to the textile industry. The widely varying content of the effluents will affect the flash evaporation characteristics and could adversely affect the equipment itself. Also the amount of energy reclaimable with this approach is less than with the other approaches discussed. There is the possibility, however, of producing higher temperatures.

Example of Open Cycle Heat Pump Applied to Textile Waste Effluent From 100% Synthetic Energy Flow Schematic

This vapor could then be compressed for example to 14.7 psi.

If the stream thus produced at 480°F could exchange energy with stream of 60°F water ($\dot{m} = 82 \times 10^3 \text{ lb/hr}$) and reduce its temperature to 100°F, the 60°F stream would be heated to 85°F. Therefore more benefit is obtained by direct heat recovery. At this time the flow-through system is conceptual in nature only and not to be considered as a practical alternative.

V. SYSTEM CONCEPTUAL DESIGNS

Design Philosophy

Since the preparation range was identified as the primary end user process, two energy level products were considered. The preparation range uses hot water at a maximum temperature of 210°F and steam at 325-350°F. Since any industrial process will require 100% backup of the solar system by a standard boiler it was decided to use the boiler as the source of steam for the process rather than complicate the solar design by producing both steam and hot water. Thus the designs presented here use a solar array to produce hot water and use standard boilers to produce process steam and to augment the hot water output when insolation values are insufficient to meet process demands. Economic evaluations are then based upon fuel substitution levels and avoid the question of credit for reduced boiler capacity, etc.

All systems are designed so that all of the energy provided by the collectors can be immediately used. Even under ideal weather conditions, the solar collectors will just approach delivering the amount of energy required by the selected process. Thus no storage capacity is included beyond minimal transient effects.

These conceptual designs were then evaluated by economic analysis techniques based on manufacturers' literature, previous designs, and the various authors best estimates of how the systems should be designed. The economic assumptions used to determine the probable installed system costs for non-solar items are plant cost ratios. These plant cost ratios are factors used to obtain total installed costs from major equipment

item cost. Final installed costs are obtained by multiplying the cost of delivered equipment by the plant cost ratios. Some suggested plant cost ratios are as follows¹

3.10 For solid process plants

3.63 For solid-fluid process plants

4.74 For fluid process plants

It was felt that the solar collector systems did not really fit these categories. It is a fluid system but no chemicals are being processed. Therefore, it was felt that the 4.74 figure was too great but that the solid-fluid factor was probably not large enough. Thus a plant cost ratio of 4 was selected for use with the non-solar elements of the system.

The plant cost ratio approach was used in an economic analysis to yield a Rate of Return vs. Installed Collector Cost. For these designs the installed cost for all other non-solar system components, i.e., heat exchangers, valves, etc. is obtained by the plant cost ratio method. This figure is then added to different installed collector costs in order that different rates of return can be obtained for the various total costs.

Another set of curves was generated to show Rate of Return vs. Installed System Cost (per square foot). This set of curves does not distinguish between fixed cost and collector cost. Thus the plant cost ratio method is not used for these curves and for a given Rate of Return, the system cost per square foot can be read directly from the graph.

J. C. Jelen (Editor), Cost and Optimization Engineering, Copyright 1970, (McGraw-Hill Book Company, 1970), p. 316.

Maintenance, operating, and electrical cost are assumed to be \$.25 per square foot of collector area per year. This is based on a previous study done at Riegel Textile, La France project.

Solar Environment Definition

To predict actual energy provided by the solar collector systems, solar insolation data contained in Reference 1 was used. This is Greenville, South Carolina weather data for a ten year period for "typical" days of each season. The results of this analysis for "typical" days provide daylight mean flux data and average hours of sunlight per day for each season. Also produced by the analysis of weather data was the mean ambient temperature, used in predicting solar collector efficiency. These data are given in Figures 56 through 58.

Manufacturer's data was used to predict the collector efficiency for both evacuated tube collectors and parabolic tracking concentrators.

Design Considered

Process water and boiler feedwater heater designs were considered in the initial conceptual phase of the study. In the process water design an interface with a heat recovery system providing 120°F inlet water to the collectors was used. For ideal weather conditions a 200°F product was prescribed. In the feedwater systems condensate at 212°F was introduced into the collector array and heated to 340°F for the same ideal weather conditions by the collectors. The following paragraphs give the specifics of the designs that evolved.

Figure 56. Solar Radiation Potential for a Fixed Horizontal Surface at Greenville, SC

Figure 57. Solar Radiation Potential for a 45° South Facing Surface at Greenville, SC

Figure 58. Solar Radiation Potential for a "Sun Normal" Tracking Surface at Greenville, SC

Process Water Systems with Evacuated Tube Solar Collectors

The evacuated tube collector hot water system is designed to be a simple single pass field. Typical water requirements of the preparation ranges can be met by delivering 82×10^3 lb/hr of 200° water. In our design assumptions, we assumed that existing main boiler capacity is available as back up since in the case of a retrofit, needed capacity should be available and for a new facility a total central boiler would undoubtedly be planned for. Thus any deficiency in the temperature of the water leaving the collector field would be offset by injecting steam (typically 350°F). The conceptual design for controlling the hot water output temperature, which will be discussed later, will use a central microcomputer. The microcomputer will have the capability of providing control for the total energy system as well as for the hot water system.

The hardware in this design is based on standard components that are readily available. The design of the system is based on the Owens-Illinois Sunpak-Evacuated Tube Collector. All components used in the design are selected to satisfy Owens-Illinois suggested operating characteristics. All pumps in the system are assumed to be end suction centrifical of AVS design with starters. It is also assumed that all controls normally associated with pump safety, failure, etc. can be controlled for all the pumps by the central microcomputer. The pipe used in the evacuated tube design is assumed to be various sizes of low pressure tubing/piping since the evacuated tubes themselves must operate at a low pressure.

A schematic of the system is shown in Figure 59. Basically the

FIGURE 59. HOT WATER SYSTEM WITH EVACUATED TUBE CONCENTRATORS - No Scale

system will operate as follows. Source water at 120°F from the heat recovery equipment will be pumped into a header to allow for even distribution to the various fields. The water then flows from the first header to the smaller pumps. These smaller pumps insure even distribution through the various fields and raise the pressure of the water to a level required by collectors. The smaller pumps move the water into a second header which will disperse the fluid through the headers contained in each collector module. The fluid travels through the collectors and into the outlet header contained in the module. From the self-contained outlet header, water will flow into a collection header. The water will then flow into an exit header. (See Figure 59) As the water leaves the exit header, it enters the valve and tank arrangements where it can be mixed with steam from the boiler facility.

The microcomputer will monitor the temperature and total flow downstream of where mixing would occur as well as the total flow in the steam line. If the temperature is found to be below desired level the microcomputer signals the valve on the steam line to slowly open until the necessary temperature is achieved. The total flow downstream of mixing and flow from the steam line are both being monitored. As steam is injected into the hot water coming from the collector fields, the microcomputer senses an increase in the steam flow and signals the valve in the hot water line to slowly close until the required total flow after mixing is achieved. The opposite will occur as the temperature of the water leaving the collector field approaches 200°F. That is, the microcomputer will sense an increase in outlet temperature and reduce the steam input while increasing the hot water input to maintain

the total flow after mixing. It should be pointed out that by controlling the flows in the above manner, the maximum output temperature for the given conditions is achieved from the collectors. This means that as insolation increases, more fluid will pass through the collector field, and as insolation decreases the flow through the collector field is reduced allowing the fluid to remain in the collector field for a longer period of time. Therefore, the small pumps servicing the secondary distribution header should be capable of attaining slightly more head than required and the pressure in the header will be regulated by a pressure control valve. By regulating the pressure in this manner there should be no problems with any pressure changes due to mixing. Also a by-pass should be present for use in periods of little or no insolation. The microcomputer must also control the by-pass valve in a fashion similar to the hot water valve in order to provide the necessary freeze protection by allowing some of the hot fluid to pass through the collector field in the winter months. After mixing, the 200°F water is available for the textile processes.

TABLE 2. COST ESTIMATES

Process Water System with Evacuated Tube Collectors

1.	There is no charge for the equipment provided to supplement the collector field, since the boiler capacity would have to be in place.	
2.	Cost of microcomputer and control hardware	\$20,000
3.	Pumps	
	1 - 163 gpm	2,000
	1 - 33 gpm	7,800
4.	6 Expansion Tanks	5,000
5.	20 Valves @ \$50	1,000
6.	Low Pressure Headers - 70 ft each, welded 3" Schedule 40	
	10 - 2" headers	1,700
	5 - 3" headers	1,000
7.	300 ft of 7" pipe	3,000
	1000 ft of 2" pipe	<u>1,400</u>
	Total Material Cost	\$42,900
	Total Cost = 4X total material (not including collectors)	\$171,600

TABLE 3. SOLAR ENVIRONMENT DEFINITION AND ENERGY COLLECTED FOR
EVACUATED TUBE COLLECTOR - HOT WATER SYSTEM

Evacuated Tube Collectors - 45° Angle
Entering Temperature - 120°F
Collector Area - 37520 ft
Maximum Outlet Temperature - 200°F

Season	Daylight Mean Flux Btu/hr/ft ²	Hrs/day of Sunlight	Days/yr for each season	Mean Ambient Temperature	Collector η
Winter	161	8.9	91	46°F	60%
Spring	157	11.0	93	65°F	63%
Summer	109	13.1	92	79°F	62%
Fall	150	10.0	89	64°F	62%

*Collector η from Owens-Illinois Literature - SSR Sunpack

Season	Daily Insolation Btu/ft	Total Energy Collected ($\times 10^{-9}$)
Winter	1433	2.9356
Spring	1727	3.7965
Summer	1428	3.0561
Fall	1500	3.105

Total Energy Collected per year - 12.8937×10^9 Btu/year

Process Water System with Concentrating - Tracking Solar Collectors

The hot water system with concentrating tracing collectors is essentially the same system as the hot water system with evacuated tube collectors. The concentrating collectors could be substituted for the evacuated tube collectors in the hot water system and the systems would operate similarly. The requirements of the system and initial assumptions about the system are identical to the hot water system with evacuated tubes.

The hardware in this design is again based upon standard components and are all readily available. The design of the system is based upon the Acurex model 3001 Concentrating Tracking Solar Collector. The assumptions about pumps are identical to the evacuated tube system design. The pipe used in this design may be mixed seamless schedule 40 and seamless schedule 80. Since the concentrators are normally operated under high pressures to avoid flashing, the seamless schedule 80 should be used immediately around the collector and the seamless schedule 40 may be used elsewhere when the pressure is not as high.

The system schematic is shown in Figure 60. The system will operate on a single pass as follows. The 120°F source water enters the system and is pumped on a distribution header. From the distribution header, the water is distributed by smaller pumps at a higher pressure to a secondary distribution header. In the secondary distribution header the water is distributed through the individual collector arrays. After passing through the individual collector arrays the water moves into a collection header, then into an exit

FIGURE 60. HOT WATER SYSTEM WITH CONCENTRATORS

TABLE 4. COST ESTIMATES

Process Water System with Concentrating Collector

1. Control - Microcomputer	\$20,000
2. Pumps	
3 @ 55 gpm	5,100
1 @ 16 gpm	2,000
3. Headers	
3 - 4" high pressure feedwater headers	
780 ft of seamless schedule 80 pipe	6,000
4. Tanks	
1. 3 Sump Tanks @ \$1,000	3,000
2. Expansion Tank	2,500
5. Piping - 3000 ft of 2" and 1/2"	4,500
6. 15 Valves @ \$50	<u>1,500</u>
Total Material Cost	\$24,600
Total Costs - 4X Equipment	\$98,400

TABLE 5. SOLAR ENVIRONMENT DEFINITION AND ENERGY COLLECTED FOR CONCENTRATING COLLECTORS - HOT WATER SYSTEM

Collector Area - 37520 ft²

Entering Water Temperature

Maximum Existing Temperature - 200°F

Season	Daylight Mean Flux Btu/hr/ft ²	Hrs/day of Sunlight	Days/yr for each season	Mean Ambient Temperature	Collector η^*	Daily Insolation Btu/hr/ft ²	Total Energy Collected $\times 10^{-9}$
Winter	209	8.9	91	46°F	55.0%	1863	3.498
Spring	214	11.0	93	65°F	57.5%	2357	4.729
Summer	171	13.1	92	79°F	56.0%	2240	4.330
Fall	192	10.0	89	64°F	56.0%	1927	3.603

*from Acurex literature

Total Energy Collected per year - 1.616×10^{10} Btu/year

header. Valves for controlling the output temperature are identical to the hot water system with evacuated tube collectors. The by-pass line and its additional functions will also operate similar to the previously mentioned tube system.

Feedwater System with Concentrating-Tracking Solar Collectors

The feedwater system is also designed to be a single pass field. The design is also based upon the Acurex Model 3001 Concentrating-Tracking Solar Collector. The typical steam requirements of the preparation ranges can be fulfilled by supplying 2.63×10^3 lb/hr of 280°F saturated steam. It was decided in preliminary planning not to make steam with solar collectors. Thus, it was felt that if the same amount of energy could be required as boiler feedwater, the main goal in providing all the energy needed in preparation ranges could still be met. In essence, this concept could not operate as an independent steam producing facility as it is designed but this design does provide the energy that would be required to make the steam in an indirect way.

All hardware assumptions are identical to the assumptions made in the water system with concentrating-tracking solar collectors. It is also assumed that a general microcomputer can provide all necessary control capability.

A schematic of the feedwater system with concentrating-tracking solar collectors is shown in Figure 61. Water enters the system from two sources. The first is a 2.63×10^3 lb/hr 212°F condensate from a preparation range source and the other is 3×10^4 lb/hr of additional 212°F feedwater from other parts of the textile plant. The 3×10^4 lb/hr was chosen to make the flow through the collections in the suggested range. The temperature of the other stream can be somewhat variable without affecting collector efficiency, however, it would be desirable to get relatively high temperature water from another waste heat source. The

FIGURE 61. BOILER FEEDWATER SYSTEM

TABLE 6. FEEDWATER SYSTEM COSTS

1. Pumps	
5 gpm High Pressure	\$3,700
62 gpm Low Pressure	2,300
2. Headers	
4" High Pressure 260 ft Seamless Schedule 80	2,000
3. Expansion Tanks	1,000
4. Piping	
1000 ft 2"	1,500
5. 10 Valves @ \$50	<u>500</u>
Total Cost (not including collectors)	\$42,000

water is then highly pressurized by a pump and it enters a distribution header. After traveling through the distributing header the water moves through the individual collector flow paths and then to the collection header. The temperature of the water leaving the collector field is not of concern so long as the pressure in the system is high enough to prevent flashing. A by-pass line and its additional functions is provided for and operated in the same manner as described in the preceding sections.

Templifier and Direct Exchange Waste Heat Recovery System

The Templifier system, manufactured by Westinghouse Corporation, is an industrial waste heat enhancement heat pump. It is a standard component that is readily available for industrial use. As the system is designed, 4.91×10^6 Btu/hr needs to be delivered to meet the evaporator requirements of the Templifier unit at 160°F condenser temperature. When coupled with the necessary direct heat exchange equipment the Templifier system can easily meet these requirements.

Pumps associated with the Templifier system are again assumed to be end suction centrifical pumps that can be controlled by a central microcomputer. The pipe associated with the system is assumed to be welded schedule 40 since the system is a low pressure system.

A system schematic is shown in Figure 62. The schematic shows a 65°F water source entering the first heat exchanger in the systems. Two waste streams at 130°F and 170°F enter the first and second heat exchanger respectively. The 65°F water entering the first heat exchanger exchanges heat with the 130°F waste stream which exits at approximately 100°F and the water then leaves the heat exchanger at near 80°F. The 80°F then enters the second heat exchanger. There the water exchanges heat with the 170°F waste heat stream and it leaves the heat exchanger at 120°F. The clean water leaves the second heat exchanger at 105°F. Waste streams from both heat exchangers are mixed to form a 110°F waste stream. Both the 110°F waste stream and the 105°F clean water enters the Templifier. The Templifier, with an approximate C.O.P. of 5, transfers the energy from the 110°F waste stream to the clean water. The two streams then

Heat Exchanger 1	—	1.24×10^6	Btu/hr
Heat Exchanger 2	—	2.06×10^6	Btu/hr
Templifier	—	2.9×10^6	Btu/hr

Total Energy Recovered — 6.2×10^6 Btu/hr

FIGURE 62. INTEGRATED "TEMPLIFIER" AND DIRECT EXCHANGE WASTE HEAT RECOVERY SYSTEM

TABLE 7. SYSTEM AND ENERGY COLLECTION DATA CONCENTRATING COLLECTORS -
FEEDWATER SYSTEM

Collector Area - 12480 ft²

Entering Water Temperature - 212°F

Maximum Exiting Temperature - 340°F

Solar Environment as Defined for Concentrators (Table 5)

Season	Energy Collected x 10 ⁻⁹
Winter	1.1637
Spring	1.5730
Summer	1.4403
Fall	1.1986

Total Energy Collected per year - 5.3756 x 10⁹ Btu/year

TABLE 8. COST ESTIMATES

Templifier and Direct Exchange Waste Heat Recovery Systems

1. Cost of Temp	\$50,000
2. Cost of Heat Exchanger	<u>26,000</u>
Total Cost	\$76,000

Note: Cost of installation assumed negligible on this waste heat enhancement system.

leave the heat pump, the waste stream at 88°F and the clean stream at 140°F. The water is then available for use in the process.

It should be pointed out that this type of heat pump technology is in its infancy. In the future industrial grade heat pumps should be capable of achieving higher water temperature from lower temperature waste streams.

Direct Heat Recovery Systems

The direct heat exchange system is a very simple system. The system is required to deliver at least 4.91×10^6 Btu/hr as was the Templifier system. All other hardware assumptions for this system are the same as the Templifier system.

The system (schematic in Figure 63) simply consists of 60°F source entering the direct heat exchanger and exchanging heat with a 140°F waste stream. The clean water will then exit at 120°F and the waste stream will exit at 80°F.

This technology is totally developed and numerous manufacturers are available. This particular design is based on information furnished by Ludell, Inc., Manufacturing Company.

FIGURE 63. DIRECT HEAT RECOVERY SYSTEM

TABLE 9. DIRECT HEAT RECOVERY SYSTEM

Cost of Heat Exchangers	\$30,923
-------------------------	----------

Total Cost	\$30,923
------------	----------

Note: Cost on installation assumed negligible on this direct heat recovery system

Integrated Systems

The integrated systems considered are merely various combinations of the previously discussed basic component systems. Since the discussion of the basic component systems are fairly detailed, the discussion of the various integrated systems will be quite general. Reference back to the various basic systems may be required. Schematics of the systems will be shown with mass flows and temperatures.

Integrated System Using Enhanced Heat Recovery and Concentrating-Tracking Solar Collectors

The system schematic is shown in Figure 64. This schematic shows 60°F water entering the Templifier system where it receives energy from the waste stream. The 140°F water then enters the concentrator field used to produce the hot water. After passing through the hot water system with the concentrating-tracking solar collectors, its temperature is monitored and steam is injected to offset a temperature deficiency. The 212°F condensate from the preparation ranges is mixed with additional boiler feedwater. This mix then passes through the smaller concentrating-tracking collector field used to heat the boiler feedwater. The feedwater then enters the boiler to be made into steam of which 2.63×10^3 lb/hr of 280°F steam is made available to the preparation ranges. The microcomputer shown in the schematic should be capable of providing all the necessary control functions.

Installed Cost Estimates Integrated System Using Enhanced Heat Recovery and Concentrating-Tracking Solar Collectors Minus Actual Installed Collector Cost

Hot water system with concentrating-tracking solar collectors	\$98,000.00
Feedwater system with concentrating-tracking solar collectors	42,000.00
Enhanced heat recovery	<u>50,000.00</u>
Total cost minus collectors	\$190,000.00
Annual quantity of fuel saved 8.92×10^{10} Btu/yr

FIGURE 64. INTEGRATED SYSTEM USING ENHANCED HEAT RECOVERY AND CONCENTRATING-TRACKING SOLAR COLLECTORS

Integrated System Using Direct Heat Recovery and Concentrating-Tracking Solar Collectors

This integrated system is identical to the integrated system using enhanced heat recovery and concentrating-tracking solar collectors with the exception that the direct heat recovery system is used instead of the Templifier system. The only other difference is that a change in the temperature of the water leaving the heat recovery system. This temperature changes from 140°F for the Templifier system to 120°F for the direct system. All flows and their routing are identical to the aforementioned system. (See Figure 65)

Installed Cost Estimates for Integrated System Using Direct Heat Recovery and Concentrating-Tracking Solar Collectors Minus Actual Installed Collector Cost

Hot water system with concentrating-tracking solar collector	\$98,000.00
Feedwater system with concentrating-tracking collectors	42,000.00
Direct heat recovery	<u>30,923.00</u>
Total cost minus collectors	\$170,923.00

Annual quantity of fuel saved 7.46×10^{10} Btu/yr

FIGURE 65. INTEGRATED SYSTEM USING DIRECT HEAT RECOVERY AND CONCENTRATING-TRACKING SOLAR COLLECTORS

Integrated System Using Direct Heat Recovery, Evacuated Tube Solar Collectors and Concentrating-Tracking Solar Collectors

This integrated system is nearly identical to the second integrated system examined which was direct heat recovery. The only difference being that evacuated tube collectors are used for the hot water field rather than the concentrating-tracking solar collectors. (See Figure 66)

Installed Cost Estimates for Integrated System Using Direct Heat Recovery, Evacuated Tube Collectors, and Concentrating-Tracking Solar Collectors Minus Installed Collector Cost

Hot water system with evacuated tube solar collector	\$171,600.00
Feedwater system with concentrating-tracking solar collectors	42,000.00
Direct heat recovery system	<u>30,923.00</u>
Total minus collectors	\$244,523.00

Annual quantity of fuel saved 7×10^{10} Btu/yr

FIGURE 66. INTEGRATED SYSTEM USING DIRECT HEAT RECOVERY, EVACUATED TUBE SOLAR COLLECTORS, AND CONCENTRATING-TRACKING SOLAR COLLECTORS

Integrated System Using Enhanced Heat Recovery, Evacuated Tube Collectors, and Concentrating-Tracking Source Collectors

This system is nearly identical to the first integrated system examined which uses the Templifier system. The only difference being that evacuated tube collectors are used for the hot water field rather than the concentrated-tracking solar collectors. (See Figure 67)

Installed Cost Estimates for Integrated System Using Enhanced Heat Recovery, Evacuated Tube Collectors, and Concentrating-Tracking Solar Collectors Minus Actual Installed Collective Cost

Hot water system with evacuated tube solar collectors	\$171,600.00
Feedwater system with concentrating-tracking solar collectors	42,000.00
Enhanced heat recovery	<u>50,000.00</u>
Total cost minus collectors	\$263,600.00

Annual quantity of fuel saved 8.64×10^{10} Btu/yr

FIGURE 67. INTEGRATED SYSTEM USING ENHANCED HEAT RECOVERY EVACUATED TUBE SOLAR COLLECTORS, AND CONCENTRATING-TRACKING SOLAR COLLECTORS

VI. ECONOMIC EVALUATION OF VARIOUS DESIGNS

Calculating the rate of return for a system on a life cycle cost basis was the method of measuring an investment's attractiveness in this study. In previous studies, it has been found that the majority of textile companies base their criteria for investments either on fixed rate of return on the system for its life cycle or a set pay back period. When dealing with energy conservation systems, the initial costs are high and the system's useful life is long compared with other investments the companies may consider. Thus it was felt that the rate of return method was superior to the pay back period method for accessing the various possible energy investments.

The basic thrust of this economic analysis of the systems proposed for use by the textile industry consisted of generating rates of return for various installed collector costs for the system life cycle. Various methods of generating these rates of return were considered. First it was desired to demonstrate the effect of varying installed collector costs on the system rate of return. In order to generate curves of rate of return versus installed collector cost, the cost of all items in the system other than collectors was fixed. These items have established price patterns and the cost for support equipment for the collector field should not vary substantially in the future. The collector cost, including installation cost, then became the variable to be analyzed in computing rates of return.

The second set of curves generated simply incorporated the fixed costs into the abscissa coordinate, producing a plot of system rate of

return versus system installed cost. Both of these sets of curves are plotted for cost per square foot of collector area. The hot water system curves analyze systems of roughly 35,000 ft² collector area. The feedwater system contained 12,500 ft² of collector areas, and the integrated systems, 50,000 ft² of collector area.

The curves should be valid for a general range about these system sizes, but care should be taken before using these curves as estimates of system rate of return for vastly different size systems.

In order to produce the most realistic curves of ROR vs. Installed Collector Cost, the price of fuel was allowed to escalate each year, and the economic analysis included an inflation rate. The inflation rate was assumed to be 10% annually, and the fuel escalation rate varied from 8 to 12%. The tax structure was assumed to be the same as that of South Carolina in 1979. A South Carolina profit tax rate of 7% was assumed. The Federal Profit Tax Rate was assumed 50%. An investment tax credit of 10% was assumed plus an additional 10% for energy conservation as per 1979 tax law. The initial 10% investment tax credit is affected by an annual investment tax credit limit of \$25,000.00 with a carry forward limit of 7 years and an excess investment tax credit factor of 60%. Essentially this means that in the first year you can take the initial tax credit limit plus 60% of the remaining initial 10%. Then in the ensuing years you subject the remaining amount of the initial tax credit to the same criteria. This process can be repeated annually until the total tax credit is deducted; but may not extend over the 7 year carry forward period.

The additional 10% tax credit for the energy conservation system can be used to eliminate 100% of the company's tax liability. For this analysis, it was assumed that the company's tax liability was such that their investment tax credit would be the same as a 20% investment tax credit subject to the same limitations as the original 100%. This basically assumes that the company has sufficient tax liability to warrant such an assumption. Although the tax structure is subject to change, not allowing for any tax structure at all would be a big mistake, because of the large impact of tax credits on rates of return for various systems.

Based upon a discount rate of 10%, a depreciation schedule was chosen on the basis of present worth calculations. Double declining balance and sum-of-years digits methods were compared and the more favorable method chosen.

1979 fuel saved was assumed to cost \$17 per barrel and produce 5.8×10^6 Btu/barrel. This assumption translates to \$2.93 per million Btu's of energy. The boiler efficiency of the textile plant boiler was assumed to be 70%; this produces a cost per thousand pounds of steam of \$4.20. The resulting return on investments for various candidate solar/heat recovery systems are shown in Figures 68 through 81.

Figure 6R. RATE OF RETURN VS. INSTALLED COLLECTOR COST (\$/SQ. FT.)

Figure 69. RATE OF RETURN VS. INSTALLED COLLECTOR COST (\$/SQ. FT.)

Figure 70. RATE OF RETURN VS. INSTALLED COLLECTOR COST (\$/SQ. FT.)

Figure 71. RATE OF RETURN VS. INSTALLED COLLECTOR COST (\$/SQ. FT.)

Figure 72. RATE OF RETURN VS. INSTALLED COLLECTOR COST (\$/SQ. FT.)

Figure 73. RATE OF RETURN VS. INSTALLED COLLECTOR COST (\$/SQ. FT.)

Figure 74. RATE OF RETURN VS. INSTALLED COLLECTOR COST (\$/SQ. FT.)

Figure 75. RATE OF RETURN VS. INSTALLED SYSTEM COST (\$/SQ. FT.)

Figure 76. RATE OF RETURN VS. INSTALLED SYSTEM COST (\$/SQ. FT.)

Figure 77. RATE OF RETURN VS. INSTALLED SYSTEM COST (\$/SQ. FT.)

Figure 78. RATE OF RETURN VS. INSTALLED SYSTEM COST (\$/SQ. FT.)

Figure 79. RATE OF RETURN VS. INSTALLED SYSTEM COST (\$/SQ. FT.)

Figure 80. RATE OF RETURN VS. INSTALLED SYSTEM COST (\$/SQ. FT.)

Figure 81. RATE OF RETURN VS. INSTALLED SYSTEM COST (\$/SQ. FT.)

VII. RESULTS AND RECOMMENDATIONS

A number of discussions were held with textile industry representatives to determine the acceptance criteria that the proposed systems would be judged by. It was found that the following points will govern the viability of the proposed solar demonstration:

- 1) Economic rate of return (ROR) on investment is the primary factor that the solar demonstration will be judged by. Although the demonstration has much greater significance to DOE, to the public, etc., the industry representatives universally reflected a position that their stockholders would view funds spent for solar projects in the same way as funds spent to increase plant production, i.e., on a ROR basis. An investment hurdle of 15%, corresponding to a 4.5 - 5.0 year payback, was judged by the industry as a proper competitive position.

- 2) There exists in the view of industry no opportunity to demonstrate the solar array in a coal fired application. Admittedly this should be judged on the same ROR basis as previously discussed, but there seems to be no industry interest in the demonstration except as a substitution for oil fired systems.

- 3) The retrofit application is viewed by industry as the basic application although in reality there is no difference in retrofit and new installations (except that coal is more likely the fuel in new installations) because full fossil capacity is required in new installations also and no solar credit may be claimed for reduction in fossil plant capacity.

4) Industry has little concern over the complexity, durability, etc. of the solar hardware as compared to their normal equipment and does not seem apprehensive about solar performance predictions.

The various systems discussed in previous sections were analyzed for ROR values based upon these industry positions. The results were presented in Figures 68 through 81. Figures 68 through 74 show system rate of return versus installed collector costs per square foot for a system fixed cost as indicated on the respective figures. Then the system rate of return is plotted versus the total installed system cost per square foot of collector in Figures 75 through 81.

The results of these analyses show that a preparation range application making 200°F hot water (and boiler feedwater at 340°F) would be highly attractive to industry at a collector cost of \$7-8.00 per square foot, installed cost above system fixed cost. Thus for a 200 gpm preparation range that already has waste heat recovery hardware in place a system cost of \$490,000-\$540,000 is acceptable for a 50,000 ft² system. An additional cost of operating the system, use of land, etc. might be considered as indirect industry costs. Therefore, a total industry contribution of \$590,000-\$640,000 is a target for the solar demonstration.

For those installations that do not currently have heat recovery equipment in place the integrated package could be installed at an acceptable industry cost of approximately 1.5×10^6 and yield a good payback. This higher figure is due to the fact that heat recovery pays back at a rate significantly greater than the 15%⁺ used as the ROR hurdle.

In summary, the following recommendations are made relative to a large scale solar demonstration in the textile industry:

- 1) A preparation range application should be made because:
 - a) The use temperature of 140-200°F is a good match to solar hardware that is available.
 - b) The preparation area is common to most textile finishing plants regardless of what type of finishing process is used and therefore the transferability from one site to another is enhanced.
 - c) A typical preparation range uses approximately 200 gpm of hot water and this matches a 50,000 ft² array nicely if a direct heat recovery system is used to preheat the process water to 120-130°F.
- 2) The solar demonstration could expect an approximate cost sharing level of \$490,000 to \$540,000 on the part of the textile industry.
- 3) A concentrating collector array interfaced with the 130°F direct heat recovery systems appears to offer maximum potential in the textile industry.
- 4) No storage, etc. is envisioned in the demonstration and temperatures should be restricted such that only hot water is produced and that steam is produced by the existing boilers, using feedwater preheating by a part of the solar array.
- 5) DOE should expect little resistance on the part of the textile industry to solar concepts based upon fears of performance, durability, complexity, etc. The only factor restricting industry wholesale interest in the solar demonstration is their allowed ROR.

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APPENDIX A
HEAT RECOVERY TECHNIQUES

Westinghouse
Electric Corporation

TEMPLIFIER Department

Box 2510
Staunton Virginia 24401
(703) 886 0711
Telex 822447

February 23, 1979

Mr. Don Beasley
Clemson University
318 Riggs Hall
Clemson, South Carolina 29631

Dear Don:

After I received your letter, I recalled that we had talked one day about the Templifier heat pump relative to a project with which you were involved, so it was nice to hear from you again.

Using the data provided, I made a sketch (attached) of the approach we would take to this problem. Obviously, I have taken a "ball park" approach on the heat exchanger selections but I should be close enough to convey the idea. Undoubtedly, you will make your selections more carefully.

The budget price for a Templifier heat pump for this application would be roughly \$35,000. A stainless steel evaporator would add \$15 to 20,000 because this is a very special item for us at present.

Any increase in supply temperature reduces the COP but, also, it necessitates a change in refrigerant and step-up in the cost curve. This was my reason for stopping at 140°F. We can provide considerably higher temperatures, if required.

I trust this provides the information you require.

Sincerely yours,

G. L. Biehn
Templifier Department

GLB/dwk

Enclosure

PROPOSAL

by

Ludell Manufacturing Company

5200 west state street

milwaukee, wisconsin 53208

476-9934, area code 414

To CLEMSON UNIVERSITY
318 Riggs Hall
Clemson, SC 29631

Proposal No. H-5135

Date January 30, 1979

Page No. 1

Model No.

Salesman TMS/VBW/egh

Attention: Mr. Don Beasley

Unless otherwise specified, standard terms are 30 days net from date of shipment and all machinery will be shipped F.O.B. our plant Milwaukee, Wisconsin.

This LUDELL SYSTEM OF HEAT RECOVERY, to be installed by the purchaser, is designed on the basis of information supplied to us by your plant, to handle the following approximate quantities and temperatures and to accomplish the following guaranteed results:

Waste Water	9,840 GPH	164 GPM
Preheated Water	9,840 GPH	164 GPM
Waste Water Temperature		140 Deg. F.
Cold Water Temperature (Average)		60 Deg. F.
(Minimum)		60 Deg. F.

TEMPERATURE RISE GUARANTEE:

We guarantee that this system of heat recovery will raise the temperature of 164 GPM of incoming fresh water from 60 Deg. F. to 120 Deg. F. when 164 GPM of waste water passes through at an average temperature of 140 Deg. F. with a discharge temperature of 80 Deg. F.

ADDITIONAL GUARANTEE:

This Ludell System of Heat Recovery is guaranteed not to plug, stop up, or require manual cleaning when operated in accordance with instructions, and that the fouling of internal surfaces can be cleaned chemically by mechanical recirculation and will not require rodding or other manual cleaning.

ESTIMATED ANNUAL VALUE OF HEAT RECOVERY:

Based on incoming fresh water at 60 Deg. F., this reclaimed heat is equivalent to 147 boiler horsepower or 5,072 pounds of steam per hour. Based on average annual temperature of 60 Deg. F. for the incoming fresh water, and with a steam cost of \$3.00 per thousand pounds, the recovered heat has a value of \$91,298.00 per annum, based on 120 hours per week, 50 weeks per year operation.

THIS CONTRACT INCLUDES THE FOLLOWING:

- One (1) Set of Ludell Heat Exchanger Sections complete with multi-tube waste water connectors, waste water adaptors and pressure relief valve. Materials of Construction shall be stainless steel for the tubes, shells, tubesheets, baffles, and nozzles; balance shall be carbon steel.
- One (1) Waste water pump set, semi-steel construction, complete with motor, base, sheaves, and belts.
- One (1) Set of pump controls to include magnetic starter, selector switch, automatic shut-off control, and compound gauge.
- One (1) Four-way backflushing valve complete with automatic operator and controls.
- Four (4) Thermometers - range 20 Deg. F. to 240 Deg. F.
- One (1) Waste water rough screening device
- One (1) Chemical tank.
- One (1) Flow switch.
- One (1) Diaphragm valve, pneumatically operated and level controlled for waste water level modulation.

PREWIRED CONTROL PANEL

We are pleased to quote the following electrical panel for the Ludell System as covered by this proposal. Components shall be mounted and connected both electrically and pneumatically. Panel to consist of the following:

One (1) Wall mounted enclosure.

One (1) Set of pump controls to include selector switch and indicating light.

One (1) Set of pneumatic controls consisting of a filter, regulator, air flowmeter, pressure switches, solenoid valves, tank level indicator, and selector switch.

One (1) 30 minute reversing timer.

One (1) Terminal block for connecting externally mounted accessories.

One (1) Complete set of black and white plastic laminated nameplates.

One (1) Time delay relay

One (1) Pneumatic level controller.

One (1) Dual pen recording thermometer with 30' of capillary.

Of the above items, the selector switches, pilot lights, air flowmeters, and tank level indicating devices shall be flush mounted on the face of the panel for convenience of operation. All other items shall be mounted within the panel. The pneumatic hook-up to the panel and from the panel to valves, etc., is to be done by others. Wiring to any external devices from the panel is also to be done by others.

NOTE: Starters to be mounted remote from the panel. Wiring between panel and starters by others. Disconnect switches and breakers as required to be furnished by others.

Ludell Manufacturing Company

Milwaukee, Wisconsin 53208

Page No. 4

Proposal No. H-5135

Date Jan. 30, 1979

ENGINEERING SERVICES:

One (1) Set of schematic flow diagram drawings and operating instructions.

NOTE: A Ludell factory field service engineer will be furnished, without added cost, to inspect the installation of the equipment for proper hook-up, advise as to, and/or supervise any necessary changes, and instruct purchaser's personnel on its features, maintenance, and proper operation. However, any additional trips thereafter will be billed on separate billing at the rate of \$150.00 per day plus hotel and living expenses at \$50.00 per day plus all transportation expenses.

TERMS: 15% Cash with order;
85% Cash (30 days) after notification of shipment.

Current Characteristics: POWER: 230 Volts, 3 Phase, 60 Hertz
CONTROL: 24 Volts, 1 Phase, 60 Hertz

PRICE: \$30,923.00

(State and local taxes extra, if any)

TERMS: As stated above

Approximate Date of Shipment: 8 to 12 weeks F.O.B. Shipping Point:
after receipt of order.

We hereby certify that these goods were produced in compliance with all applicable requirements of sections 6, 7 and 12 of the Fair Labor Standards Act, as amended, and all regulations and orders of the United States Department of Labor issued under section 14 thereof.

IMPORTANT: Seller makes no warranty with respect to these goods other than that stated on the reverse side. The sale of such goods is subject to the terms and conditions stated on the reverse side.

Terms and conditions printed on the reverse side, unless explicitly excepted above, are part of this proposal.

ACCEPTED: _____

BY: _____

(Title)

DATE: _____

Ludell Manufacturing Company

By: _____

STANDARD CONDITIONS OF SALE

(A) **Warranty.** The Seller's warranty on any goods which are not of its manufacture (except Hot and Cold Water Tanks) is limited to the warranty furnished with respect to such goods by Seller's supplier and is subject to compliance by Buyer with all terms of the supplier's warranty. Warranty claims will be credited to Buyer's account only upon receipt of a corresponding credit from the supplier. Seller will repair or replace, at its option, F.O.B. its factory, any product of Seller's manufacture (and any Hot and Cold Water Tank purchased from Seller) which is proven within the warranty period to have been defective in materials or workmanship at the time it was shipped, provided Buyer has given Seller immediate written notice upon discovery of the defect and provided that a representative of Seller is given a reasonable opportunity to inspect the goods within the warranty period. The initial warranty period is one year from the date of shipment; the warranty period is 90 days from the date of shipment for replacement parts for machinery on which the initial warranty period has expired. Buyer shall bear the expense of packaging and shipping defective parts and the expense of installing replacement parts. Linings for Hot and Cold Water Tanks are furnished with no warranty. The provisions in any specifications or drawings are descriptive, unless expressly stated as warranties. This warranty is extended only to the original purchaser and is not transferable. **THE FOREGOING WARRANTIES ARE EXCLUSIVE AND IN LIEU OF ALL OTHER EXPRESS AND IMPLIED WARRANTIES WHATSOEVER, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.**

(B) **Delivery and Errors.** Unless otherwise expressly agreed by Seller, title and all risks of loss or damage in transit to goods sold hereunder shall pass to Buyer upon delivery of such goods to a carrier at Seller's premises. Seller may make delivery in installments; unless otherwise expressly stipulated on the face hereof, all such installments shall be separately invoiced and paid for when due per invoice, without regard to subsequent deliveries.

Claims for shortages or other errors must be made in writing to Seller within ten days after shipping date and failure to give such notice shall constitute unqualified acceptance and waiver of all such claims by Buyer.

(C) **Taxes and Other Charges.** Any manufacturer's tax, retailer's occupation tax, use tax, sales tax, excise tax, duty, custom, inspection or testing fee, or any other tax, fee or charge of any nature whatsoever, imposed by any governmental authority, on or measured by any transaction between Seller and Buyer, shall be paid by Buyer in addition to the prices quoted or invoiced. If Seller shall be required to pay any such tax, fee or charge, Buyer shall reimburse Seller therefor.

(D) **Delays.** Delay in delivery of any installment shall not relieve Buyer of its obligation to accept remaining deliveries. Seller shall not be liable for any damage as a result of any delay due to any cause beyond Seller's reasonable control. In the event of any such delay, the delivery date shall be extended for a period equal to the time lost by reason of the delay.

(E) **Return of Products.** Products may not be returned to Seller for credit except with Seller's written permission, and then only in strict compliance with Seller's return shipment instructions.

(F) **Consequential Damages.** Seller shall not be liable to Buyer or anyone claiming under Buyer for any consequential, contingent or incidental damages whatsoever.

(G) **Storage.** If the Seller shall be requested to hold or warehouse machinery for a stated or indefinite period after the date specified for shipment, the Seller may at its option retain the same, and Buyer shall pay Seller's storage charges at the Seller's conventional rates commencing from and after thirty days from the last date of shipment agreed to. When shipment shall be so deferred, payment for the machinery shall nevertheless become due and payable when Buyer is notified by Seller, by invoice or otherwise, that the machinery is ready for shipment.

(H) **Right to Changes.** Seller may at any time make such changes in design and construction of equipment as shall constitute an improvement in the judgment of Seller. Seller may furnish suitable substitutes for goods or materials unobtainable because of priorities or regulations established by governmental authority or the non-availability of goods or materials from suppliers.

(I) **Installation.** Seller will provide installation instructions, inspect completed installation and supervise any necessary repairs and adjustments, if such supervision is to be performed within 90 days after shipment and if it is to be performed within the continental United States and Canada. The Buyer is responsible for all other installation costs.

Installation conformance to the requirements of federal, state and local governing bodies or other organizations shall be the responsibility of the Buyer.

(J) **Non-Union Personnel.** Seller reserves the right to manufacture, service and supervise installation of all products sold by Seller with non-labor union affiliated personnel, unless Buyer expressly requests the use of union personnel.

(K) **Price Terms.** Unless otherwise expressly stated on the face hereof, all prices are subject to change without notice; and the price of goods on order but unshipped will be adjusted to the price in effect at the time of shipment. Quoted prices are, however, firm for 30 days.

(L) **Replacement Parts.** Parts for new equipment manufactured by Seller will be available for ten years after shipment. Parts for equipment remanufactured by Seller will be available for five years after shipment.

(M) **Terms of Acceptance, Modifications, Applicable Law, Cancellation and Corrections.** This writing when signed by Buyer becomes an offer on the part of Buyer to buy the equipment and services described herein in accordance with the terms and conditions of this proposal. Such offer becomes a contract binding upon Seller only when accepted by Seller at its home office in Milwaukee, Wisconsin.

This writing constitutes the entire agreement between the parties. No modified or other conditions will be recognized by Seller unless specifically agreed to in writing and failure of Seller to object to provisions contained in any purchase order or other communication from Buyer shall not be construed as a waiver hereof nor an acceptance of any such provisions. This contract shall be governed by and construed according to the laws of Wisconsin. No accepted order may be cancelled or terminated except upon payment of Seller's loss, damage and expense arising from such cancellation or termination. Seller reserves the right to correct all clerical errors.