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Report No. ISA-MA-IPH-001

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FINAL REPORT

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE-SPECIFIC INDUSTRIAL-PROCESS-HEAT APPLICATIONS

March 18, 1980

Submitted by: Orin L. Murray
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Contract: MA-SC-79-MO-0008

Solar Feasibility Study for Site Specific Industrial Process Heat Applications

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2. ABSTRACT

This study addresses the technical feasibility of solar energy in industrial process heat (IPH) applications in Mid-America. The effort was contracted by the Mid-American Solar Energy Center (MASEC) (to Industrial Solar Associates under Contract No. MA-SC-79-MO-0008. The study was one of two contracted efforts covering the MASEC 12-state region comprised of:

Illinois	Michigan	North Dakota
Indiana	Minnesota	Ohio
Iowa	Missouri	South Dakota
Kansas	Nebraska	Wisconsin

The results of our study are encouraging to the potential future role of solar energy in supplying process heat to a varied range of industries and applications. We identified and developed Case Study documentation of twenty (20) feasible solar IPH applications covering eight (8) major SIC groups within the Mid-American region. The geographical distribution of these applications for the existing range of solar insolation levels are shown in Figure 1. The characteristics of the applications are summarized in Table 1.

The results of the study include process identification, analysis of process heat requirements, selection of preliminary solar system characteristics, and estimation of system performance and cost. These are included in each of the 20 Case Studies which form a part of this report.

The body of the report is divided into two primary discussion sections dealing with the Study Methodology employed in the effort and the Follow-On Potential of the identified applications with regard to possible demonstration projects. The 20 applications are rated with respect to their relative overall viability and procedures are discussed for possible demonstration project embarkment. Also, a possible extension of this present feasibility study for late-comer industrial firms expressing interest appears worthy of consideration.

Figure 1
GEOGRAPHICAL DISTRIBUTION OF SITES

Table 1

SUMMARY OF IDENTIFIED APPLICATIONS

<u>FIRM & LOCATION</u>	<u>SIC</u>	<u>APPLICATION</u>	<u>COLLECTOR TYPE & SIZE</u>
1. American Can Company Pevely, Missouri	3411	Can Washing Steam at 250°F	Stationary Concentrator 11,200 Ft ²
2. Armour Pharmaceutical Co. Kankakee, Illinois	2834	PF Water Production to 200°F	Evacuated Tube 5,280 Ft ²
3. Stokely-Van Camp, Inc. Indianapolis, Indiana	2033	Bean Blanching to 190°F	Evacuated Tube 10,560 Ft ²
4. Mid-America Dairymen, Inc. El Dorado Springs, Missouri	2023	Milk Dehydration at 350°F	Line Concentrator 13,440 Ft ²
5. Armour Food Company St. Joseph, Missouri	2011	Hog Scalding at 140°F	Flat Plate 10,750 Ft ²
6. Hallmark, Inc. Leavenworth, Kansas	2621	Ink Drying at 125°F	Evacuated Tube 5,363 Ft ²
7. Vulcan Materials Company Wichita, Kansas	2812	Process Steam at 350°F	Line Concentrator 10,080 Ft ²
8. Ford Motor Company Saline, Michigan	3079	Parts Drying at 160°F	Evacuated Tube 7,013 Ft ²
9. Firestone Tire & Rubber Co. Decatur, Illinois	3011	Process Hot Water at 380°F	Line Concentrator 10,080 Ft ²
10. Western Food Products, Inc. So. Hutchinson, Kansas	2033	Process Steam at 330°F	Line Concentrator 11,200 Ft ²

Table 1 Continued

<u>FIRM & LOCATION</u>	<u>SIC</u>	<u>APPLICATION</u>	<u>COLLECTOR TYPE & SIZE</u>
11. Marsco Manufacturing Co. Chicago, Illinois	3231	Glass Rinsing at 140°F	Flat Plate 2,240 Ft ²
12. Borden Company Plymouth, Wisconsin	2022	Boiler Feedwater to 210°F	Evacuated Tube 4,043 Ft ²
13. American Crystal Sugar Co. Moorhead, Minnesota	2063	Waste Water Treatment at 95°F	Flat Plate 13,440 Ft ²
14. Dickson Forest Products Sturgis, South Dakota	2421	Lumber Kilning to 140°F	Flat Plate 3,640 Ft ²
15. Pan-O-Gold Baking Co. Fargo, North Dakota	2051	Bread Proofing Steam at 245°F	Stationary Concentrator 2,240 Ft ²
16. Crystal Tissue Company Middletown, Ohio	2621	Paper Stock Preparation to 140°F	Flat Plate 5,040 Ft ²
17. American Motors Corporation Kenosha, Wisconsin	3711	Car Body Washing at 180°F	Evacuated Tube 9,680 Ft ²
18. CF Industries, Inc. Fremont, Nebraska	2819	Boiler Feedwater to 105°F	Flat Plate 10,640 Ft ²
19. Viracon, Inc. Owatonna, Minnesota	3231	Glass Washing at 140°F	Evacuated Tube 3,300 Ft ²
20. Ralston Purina Company Iowa Falls, Iowa	2075	Soybean Meal Drying at 160°F	Evacuated Tube 10,780 Ft ²

3. STUDY METHODOLOGY

The procedures followed in identifying and developing the potential SIPH applications in this study were essentially broken down into four (4) task areas characterized by:

Identification

Analysis

Selection

Estimation

The efforts devoted to each task area were generally distinct unto themselves, although during the course of the study, certain complimentary regions of overlap and iteration emerged which facilitated the progress and viability of the overall effort. The work performed within each of these task areas is discussed below.

3.1 Task 1: Identification of Candidate Processes and Firms

This was the most time consuming of all the tasks. The results of this task constituted the foundation of the entire study. As such, the identified SIPH applications had to be carefully screened and evaluated before committing them to the remainder of the study. In effect, a little of each task had to be performed at this initial step, lest valuable time and effort be devoted to a non-viable application.

The initial thrust of this effort was directed at obtaining a good industrial and geographic "mix" in the potential applications to be evaluated. A pre-contract review by MASEC of industries and processes within the Mid-American Region showed promising potential in the following areas of industry:

Automotive and Truck Manufacturing

Glass Washing and Rinsing

Lumber Kilning and Conditioning

Paper Stock Preparation

Food Processing Applications

Other Selected Applications

Based on this groundwork and the recognized objectives of the study, the following criteria for the selected SIPH applications were set forth as guidelines in the study:

- 1) At least 6 firms in the food processing industry were to be identified, if possible.
- 2) At least 3 firms in the auto and truck industry.
- 3) Willingness of the firms to allow the information gathered to be made public was to be understood.
- 4) Sufficient and appropriate land or roof space should exist for solar retrofit.
- 5) All sites must be located in the 12-state Mid-American region.

The first step taken in pursuit of these objectives was to map out the geo-industrial characteristics of the Mid-American region. In this effort, Directories of Manufacturers from each of the 12 states provided an effective compliment to our industrial files. From existing and acquired information, a "target list" of industrial firms was compiled.

Our contracted objective in this study was to develop 20 feasible SIPH applications in the 12-state region. Realizing that there would probably be a fair amount of attrition, we initially compiled a listing of 65 industrial firms. During the course of the study, this list was expanded to include approximately 80 firms. After the indexing of the firms with respect to industry grouping (SIC codes), contact with the firms was started.

The initial contact was made by telephone; a personal conversation with the Corporate Energy Director, if one existed. If not, the Chief Engineer. From this conversation, valuable input was obtained relative to process potential and management attitude relative to alternate energy source development. If all indicators remained positive after this initial contact, a mailing was made detailing the program and requesting site-specific process information.

Evaluation of the returned site-specific process information from the firms was made and, if a feasible potential was still indicated, the initial site visit was set up. During this visit, the plant and all heat processes within it were evaluated to the maximum extent possible. Also, important input was gained on the local plant management attitudes on energy and their receptiveness to a pilot solar application. Site photos were taken and any missing process data was noted and discussed with the plant management, requesting such data be gathered and forwarded at their earliest convenience.

By the process of elimination, either from the industrial side or because of poor feasibility evaluations, the initial 80 firms were pared down to 40. From this point, a second echelon re-evaluation was performed on each of the applications, considering the following factors:

- a) process temperatures (the lower the better)
- b) process adaptability (simple process/solar interface)
- c) process schedule (7 days, or storage required)
- d) process location (near to collector site)
- e) process size (can solar make a "dent"?)
- f) process potential (industry-wide)
- g) site environment (insolation, contamination)
- h) site characteristics (open, flat)
- i) site buildings (flat-roof, well constructed)
- j) corporate management (cooperative, receptive)
- k) plant management (cooperative, capable)
- l) industrial mix (maximum technology assessment)
- m) industrial visibility (commercialization aspects)
- n) geographic mix (good regional representation)

From this evaluation on each potential application, the final 20 processes and sites were selected. The industrial and geographic representation obtained in the selected applications are shown in Tables II and III respectively.

TABLE II - INDUSTRIAL MIX

8 - Food Processing

Stokely-Van Camp, Inc.	SIC 2033
Mid-America Dairymen, Inc.	SIC 2023
Armour Food Company	SIC 2011
Western Food Products	SIC 2033
Borden Company	SIC 2022
American Crystal Sugar Co.	SIC 2063
Pan-O-Gold Baking Co.	SIC 2051
Ralston Purina Company	SIC 2075

3 - Automotive Related

Ford Motor Company	SIC 3079
Firestone Tire & Rubber Co.	SIC 3011
American Motors Corp.	SIC 3711

2 - Glass Manufacturing

Marsco Manufacturing Co.	SIC 3231
Viracon, Inc.	SIC 3231

1 - Lumber

Dickson Forest Products	SIC 2421
-------------------------	----------

2 - Paper

Hallmark, Inc.	SIC 2621
Crystal Tissue Company	SIC 2621

3 - Chemical

Armour Pharmaceutical Co.	SIC 2834
Vulcan Materials Company	SIC 2812
CF Industries	SIC 2819

1 - Metal Containers

American Can Company	SIC 3411
----------------------	----------

TABLE III - GEOGRAPHICAL MIX

3 in Illinois

Marsco Manufacturing Co.	Chicago
Firestone Tire & Rubber Co.	Decatur
Armour Pharmaceutical Co.	Kankakee

1 in Indiana

Stokely-Van Camp, Inc.	Indianapolis
------------------------	--------------

1 in Iowa

Ralston Purina Company	Iowa Falls
------------------------	------------

3 in Kansas

Hallmark, Inc.	Leavenworth
Western Food Products	So. Hutchinson
Vulcan Materials Company	Wichita

1 in Michigan

Ford Motor Company	Saline
--------------------	--------

2 in Minnesota

American Crystal Sugar Co.	Moorhead
Viracon, Inc.	Owatonna

3 in Missouri

Mid-America Dairymen, Inc.	El Dorado Springs
American Can Company	Pevely
Armour Food Company	St. Joseph

1 in Nebraska

CF Industries	Fremont
---------------	---------

1 in North Dakota

Pan-O-Gold Baking Company	Fargo
---------------------------	-------

1 in Ohio

Crystal Tissue Company	Middletown
------------------------	------------

1 in South Dakota

Dickson Forest Products	Sturgis
-------------------------	---------

2 in Wisconsin

American Motors Corporation	Kenosha
Borden Company	Plymouth

3.2 Task 2: Analysis of Process Heat Requirements

Accomplishment of this task was very difficult and could not be performed to the author's satisfaction on most of the identified applications, within the scope of this study. The majority of the industrial organizations covered were found to be very poorly equipped to ascertain these data. Since the scope of this study did not permit detailed energy measurements to be made, we were forced to rely on essentially three sources of process energy consumption figures, estimated at the following applicable percentages in this study:

plant record keeping	15%
original equipment design	50%
engineering estimates	35%

Plant record keeping, where it existed was very useful and quite complete. In these instances, a high energy-consciousness was also in evidence at both the plant and corporate levels. Usually, these data had to be massaged slightly by the Plant Engineer and some judgment applied to the numbers for use in the case studies. Nevertheless, the data were quite useful and are considered to be reliable.

Original equipment design ratings, usually name-plate or equipment drawing data, were used in the majority of the cases. A considerable amount of engineering judgment also had to be applied to these data to arrive at realistic estimates for use in this study. For example, a given steam boiler might be rated at 50 BHP (boiler horsepower). This boiler supplied three processes, one of which ("process B") was selected for evaluation in this study. From discussions with the Plant Engineer and judgment on the relative energy consumption of each process, it was estimated that "process B" consumes 40% of the boiler output. Further, it was estimated that the boiler operates on a 70% duty cycle to support all three processes. The energy consumption rate of "process B" was therefore estimated at:

$$\begin{aligned} Q_{\text{proc.}} &= (50 \text{ BHP}) (33,520 \text{ BTU/hr -BHP}) (.40) (.70) \\ &= 4,692,800 \text{ BTU/hr} \end{aligned}$$

Engineering estimates were applied where no other means were available for determining process energy consumption rates. Heat balances were approximated on heat absorbed by the product being processed, heat lost to the environment and any other mode of heat exchange existing on a particular process, such as regeneration. As a second example, consider a pasteurizer that heats 4,000 gallons per hour of liquid from 40°F to 140°F. The liquid has a density of 8 pounds per gallon and an average specific heat capacity of 0.85 BTU/lb -°F. 30% regeneration of the pasteurization heat is achieved. The pasteurization is performed in a large uninsulated vat of approximately 1,000 square feet surface area. An "uncertainty factor" of 50% is added to the computation. The heat balance is:

$$\begin{aligned}
 Q_{\text{proc.}} &= (Q_{\text{stored}} - Q_{\text{regen}} + Q_{\text{lost}}) (1.50) \\
 &= [(4000 \text{ gal/hr}) (8 \text{ lb/gal}) (8.5 \text{ BTU/lb} - ^\circ\text{F}) (100^\circ\text{F}) (.70) \\
 &\quad + (1.0 \text{ BTU/Ft}^2 - ^\circ\text{F}) (1000 \text{ Ft}^2) (70^\circ\text{F})] (1.50) \\
 &= 2,961,000 \text{ BTU/hr}
 \end{aligned}$$

While the above methods are far from precise, they are deemed adequate for this feasibility study since the solar contribution for a pilot application is usually sized for only partial process support with no storage. However, more detailed determinations should be performed on any application which may progress to a potential design/build situation.

3.3 Task 3: Selection of Optimal Solar System Design

The optimal solar system designs for the selected applications were developed from primary considerations of efficiency and cost effectiveness. In every case, state-of-the-art components were specified in the final work-up of the designs for performance and cost estimates. No new development effort is anticipated for any of the systems conceived for the 20 applications covered in this study.

The efficiency of a solar system is influenced by many factors. Assuming that proper consideration has been given to good basic component design (collectors, heat exchangers, etc.) and to

proper thermal insulation (pipes, tanks, etc.), probably the two most important remaining factors affecting system efficiency are collector/process temperature matching and system simplicity,

Collector/process temperature matching means that a line concentrating collector is not specified for a low-to-medium range hot water application or equivalent. Likewise, a flat plate collector cannot be expected to perform well for a high temperature water of a low pressure steam application. In this study, the type of collector specified for each application was governed by the following guidelines.

<u>Process Temperature</u>	<u>Collector Type</u>
< 120°F	Flat Plate
120 - 140°F	Flat Plate or Evacuated Tube
140 - 212°F	Evacuated Tube
212 - 300°F	Stationary Concentrator
> 300°F	Line Concentrator

System simplicity was a prime consideration in this feasibility study. A solar application is only feasible if it is reliable. An overly complex system with intricate operational modes is not only unreliable and costly, but also inefficient. In this study, applications were sought out which could be satisfied by a simple solar system design. Usually, this meant a process that could absorb all of the heat supplied by the solar system without the need for elaborate controls and daily storage. Where storage was required for weekend heat capture in this investigation, a simple use for this heat following weekend shut-down was sought, such as a boiler feedwater supply on Monday morning.

The cost effectiveness of a solar system, while affected greatly by efficiency after it is put into operation, is primarily determined at the outset by installed cost. Minimizing the installed cost of a system embraces the factors discussed previously of component matching and simplicity. Also, the method of mounting the collectors and their location relative to the process is significant.

With all other factors being equal, a ground-mounted collector array can be installed at a lower cost than a roof-mounted array. Of course, this assumes that no extensive grading or site preparation work is required for ground-mounting and that a roof-mounted array is retrofitted to an existing building. All applications selected for this study were retrofit situations. Even though a good ground installation is cost effective, uncommitted vacant ground is usually scarce. Out of the 20 applications covered in this study, 6 collector fields would be ground-mounted and 14 would be roof-mounted.

The location of the collector field relative to the process is a significant piping cost factor, as well as an efficiency consideration. This was an important factor in the selection process for the chosen sites in this study. For the majority of the cases selected, the collector field could be located less than 150 feet from the process.

System Performance Estimation

Performance estimates for the installed systems of the characteristics outlines in the 20 case studies were based on catalogued computer analysis of the respective collector types specified for the selected applications. The basis of all performance calculation procedures is the standard ASHRAE geometrical manipulation (Reference 1), to normalize measured horizontal insolation data (Reference 2) to incident solar flux perpendicular to the plane of the collector. This model is summarized in Figure 2.

In this study, the collector tilt angle (angle of the collector plane above the horizontal) was always considered to be the next steepest degree greater than the latitude of the site. Thus, the winter insolation conditions were favored very slightly over the summer. Based on the geometrical normalization, two types of performance were estimated for each application; maximum clear day performance and annual average weather performance. Each collector type was handled separately.

The solar insolation normal to the tilted collector surface is given by:

$$I_{b, \text{coll}} = I_b \cos i$$

where I_b is the beam, or direct, component of insolation at the earth's surface and

$$\cos i = \cos (\alpha_s - \alpha_w) \cos \alpha \sin \beta + \sin \alpha \cos \beta$$

where α_s = azimuth of the sun, i.e., the angle of the sun measured in the horizontal plane westward from due south

α_w = azimuth angle of the normal to the insulated surface, measured in the same way as solar azimuth

and

$$\alpha_s = \sin^{-1} \frac{\cos \delta \sin H}{\cos \alpha}$$

Figure 2
Solar Geometry Model

For the flat plate and evacuated tube collectors, an average overall efficiency was estimated, based on analytical histories of instantaneous performance under the applicable operating temperatures and insolation conditions. See Figures 3 and 4. These efficiencies are applied to the normalized insolation values from the ASHRAE model to derive the predicted clear day and average performance. This procedure has proven quite accurate in similar analyses, with better than 90% accuracy being obtained between estimated and actual measured system performance (Reference 3).

Figure 3

FLAT PLATE COLLECTOR EFFICIENCY

Figure 4

EVACUATED TUBE COLLECTOR EFFICIENCY

For the stationary concentrator, also referred to as a flat plate concentrator, the analytical procedure becomes slightly more complex because of the greater difference between performance under direct and diffuse insolation conditions. This type of collector is normally mounted with the concentrator trough axes oriented in the east-west direction. The assembly is tilt-mounted in the same manner as a flat plate collector. The performance analytical procedure is a semi-empirical procedure based on measured performance under various operational conditions. It uses a combination of flat plate and ray tracing techniques based on an insolation model for the particular location being analyzed with appropriate direct/diffuse contributions. A modified Lambert-cosine distribution is applied for diffuse gains and position-variable concentration/tracing techniques for direct gains. Figure 5 shows typical performance characteristics for 0 and 40% diffuse, a range covering the majority of the insolation models encountered.

The tracking line concentrator analysis is similar to that of the stationary concentrator, with the most significant difference being alignment with the normal radiation vector, because of the greater concentration. This analysis uses a basic efficiency curve, as a function of temperature, generated from a mathematical model based on experimental receiver loss rates. Further, an angle of incidence modifier curve is applied, which varies the intercept factor with angle of collector aperture plane from the normal radiation vector. See Figures 6 and 7. An empirical cloudiness factor is applied for average weather performance using local diffuse/direct insolation models.

Table IV summarizes the performance estimates for each of the 20 applications covered.

System Cost Estimation

Installed cost estimates of the postulated solar systems to interface with each of the 20 selected processes were made, based on documented cost data (References 4, 5, 6 and 7) and experience on similar applications. The proposed solar system designs outlined

Figure 5

STATIONARY CONCENTRATOR EFFICIENCY

LINE CONCENTRATOR CHARACTERISTICS

TABLE IV - SYSTEM PERFORMANCE ESTIMATES

<u>Application</u>	<u>Collector Type</u>	<u>Field Size</u>	<u>Clear Day Coll. (10⁶ BTUs/Day)</u>	<u>Average Coll. (10⁹ BTUs/Year)</u>
1. American Can Co.	Stat. Conc.	11,200 Ft ²	12.0	2.3
2. Armour Pharmaceutical	Evac. Tube	5,280 Ft ²	6.2	1.6
3. Stokely-Van Camp	Evac. Tube	10,560 Ft ²	12.1	3.0
4. Mid-America Dairymen	Line Conc.	13,440 Ft ²	13.7	3.1
5. Armour Foods	Flat Plate (2)	10,750 Ft ²	9.5	2.4
6. Hallmark, Inc.	Evac. Tube	5,363 Ft ²	6.6	1.7
7. Vulcan Materials	Line Conc.	10,080 Ft ²	11.0	2.7
8. Ford Motor Co.	Evac. Tube	7,013 Ft ²	7.3	1.9
9. Firestone T & R	Line Conc.	10,080 Ft ²	10.8	2.3
10. Western Foods	Line Conc.	11,200 Ft ²	12.6	3.0
11. Marsco Mfg. Co.	Flat Plate (2)	2,240 Ft ²	2.0	0.4
12. Borden Company	Evac. Tube	4,043 Ft ²	5.1	1.1
13. American Cr. Sugar	Flat Plate (2)	13,440 Ft ²	13.6	3.1
14. Dickson Forest Prod.	Flat Plate (2)	3,640 Ft ²	3.2	0.8
15. Pan-O-Gold Baking	Stat. Conc.	2,240 Ft ²	2.1	0.4
16. Crystal Tissue	Flat Plate (2)	5,040 Ft ²	4.5	1.0
17. American Motors	Evac. Tube	9,680 Ft ²	12.2	2.7
18. CF Industries	Flat Plate (1)	10,640 Ft ²	12.1	3.0
19. Viracon Inc.	Evac. Tube	3,300 Ft ²	4.2	0.9
20. Ralston Purina	Evac. Tube	10,780 Ft ²	13.6	3.1

(1) Single Glazed

(2) Double Glazed

in the 20 case studies are strictly no-frill systems designed to produce the "most BTUs per buck" and, as such, include no elaborate control on data acquisition features. Storage is minimized and operation is kept simple, so that self-contained control valves can be used for all operational modes (no micro-processor). Pipe runs have been minimized by attention to the collector field layouts and their proximity to the supported processes.

The cost increments were broken down into four categories with the following sub-divisions:

Collector Field

Collector Supports

Collectors

Piping, Insulation

Mechanical

Solar Heat Exchanger

Pumps, Controls

Storage

Tank, Insulation

Instrumentation

Sensors

Data Logger

The Collector Field costs vary with collector type and mounting configuration. In every case, the collector supports include the collector trusses or pylons and the sub-structure required, including tie-ins to existing building roof structure or ground support pads (earth piers). The collector costs were perturbed with collector type and include any piping costs that are required to provide flow from the main supply and return runs (i.e. east-west manifolds). The tabulation below gives the resulting cost structure. The remaining piping costs include the supply and return runs from the collector field to the solar loop pump.

<u>Collector Type</u>	<u>Base Collector Cost</u>	<u>Installation Cost</u>
Flat Plate (single glazed)	\$14/Ft ²	\$6/Ft ² (incl. manifold)
Flat Plate (double glazed)	\$16/Ft ²	\$6/Ft ² " "
Evacuated Tube	\$22/Ft ²	\$5/Ft ²
Stationary Concentrator	\$24/Ft ²	\$4/Ft ²
Line Concentrator	\$27/Ft ²	\$2/Ft ²

The Mechanical costs vary slightly in \$/Ft² with field size, but this was not a large perturbation within the range considered. They include the components (heat exchanger, pumps, control valves) and all associated piping, insulation and electrical service required for the pumps and valves. The costs are representative of a rack-mounted component assembly, built up by the component supplier and installed as one assembly. This is an important money-saving consideration. Again, it is emphasized that it is a bare-bones assembly providing the basic heat transfer, pumping and control capability.

The Storage costs (if any) include the specified tank size, insulation and solar loop heat coil or pump, installed above ground. In every case covered requiring new storage tank installations (10 out of 20), there is adequate room and an identified location for above-ground installation.

The Instrumentation costs include collector field and mechanical area temperature and pressure sensors and a simple data logger for data acquisition with no control capability. Again, bare minimum requirements to monitor the system performance.

Table V summarizes the installed cost estimates for each of the 20 applications, compared with applicable referenced costs.

3.4 Task 4. Estimate of Energy Savings

An original intent of this task was to perform a life-cycle cost analysis on each identified application to determine savings resulting from fossil fuel displacement and to arrive at a

TABLE V - INSTALLED COST ESTIMATES

<u>Application</u>	<u>Collector Type</u>	<u>Field Size</u>	<u>Storage</u>	<u>\$/Ft²</u>	<u>Total \$</u>
1. American Can Co.	Stat. Conc.	11,200 Ft ²		41.75	467,600
2. Armour Pharmaceutical	Evac. Tube	5,280 Ft ²		40.25	212,520
3. Stokely-Van Camp	Evac. Tube	10,560 Ft ²	Yes	42.50	448,800
4. Mid-America Dairymen	Line Conc.	13,440 Ft ²	Yes	42.25	567,840
5. Armour Foods	Flat Plate (2)	10,750 Ft ²	Yes	37.00	397,750
6. Hallmark, Inc.	Evac. Tube	5,363 Ft ²	Yes	43.50	233,290
7. Vulcan Materials	Line Conc.	10,080 Ft ²		41.25	415,800
8. Ford Motor Co.	Evac. Tube	7,013 Ft ²		40.25	282,273
9. Firestone T & R	Line Conc.	10,080 Ft ²	Yes	43.25	435,960
10. Western Foods	Line Conc.	11,200 Ft ²	Yes	43.75	490,000
11. Marsco Mfg. Co.	Flat Plate (2)	2,240 Ft ²	Existing	35.75	80,080
12. Borden Company	Evac. Tube	4,043 Ft ²	Yes	43.00	173,849
13. American Cr. Sugar	Flat Plate (2)	13,440 Ft ²		33.25	446,880
14. Dickson Forest Prod.	Flat Plate (2)	3,640 Ft ²		34.75	126,490
15. Pan-O-Gold Baking	Stat. Conc.	2,240 Ft ²	Yes	46.00	103,040
16. Crystal Tissue	Flat Plate (2)	5,040 Ft ²	Existing	35.00	176,400
17. American Motors	Evac. Tube	9,680 Ft ²	Yes	42.50	411,400
18. CF Industries	Flat Plate (1)	10,640 Ft ²		31.25	332,500
19. Viracon, Inc.	Evac. Tube	3,300 Ft ²		43.25	142,725
20. Ralston Purina	Evac. Tube	10,780 Ft ²		39.00	420,420

Average 39.98

Ref. 4 39.41

Ref. 5 39.90

Ref. 6 40.83

(1) Single Glazed
(2) Double Glazed

theoretical optimal system design and size. On December 21, 1979 a meeting was held at MASEC in which this aspect of the study was discussed; specifically the future cost model of fossil fuels. It was subsequently concluded that, due to the uncertainty of future energy prices and sources, it was not possible to perform a meaningful economic analysis and that any such analysis would detract from the real technical objectives of the study. The life-cycle cost analysis was, therefore, deleted from the study.

Another related output of this task was to determine, for potentially attractive applications, what additional incentive(s) would be necessary for the respective industrial firm(s) to adopt solar energy for the particular processes identified. This aspect is discussed in Section 4, following a complete ordered rating of all 20 applications.

4. FOLLOW-ON POTENTIAL

It is recognized that certain of the solar applications identified in this study are potentially more attractive than others by virtue of their greater overall viability relative to the objectives of this study and solar commercialization efforts. The purpose of this section is to determine, to the best extent possible, the factors pointing toward the better applications identified in this study and some considerations on the manner of pursuit of these applications.

4.1 Viability Factors

Of the varied factors that should be considered in recommending candidate solar IPH applications for further effort toward developing a demonstration project, they can generally be divided into three categories:

- Process Potential
- Site Suitability
- Management Attitudes

Process potential deals primarily with the quantity of energy consumed in a certain industrial segment and the amount of this energy that may be supportable by solar energy. The literature shows 4 of the industries covered in this study as consumers of 33% of the total industrial energy consumption in the U.S. If we assign numerical weighting factors of 1 through 4 to applications in these industries and a factor of 5 to all other applications, we arrive at the following distribution:

<u>Industry</u>	<u>Energy Fraction</u>	<u>Rating Factor</u>
Chemicals	12%	1
Stone, Clay Glass, Concrete	8%	2
Food and Kindred Products	7%	3
Paper and Pulp	6%	4
Other Individual	6%	5

A second factor that should be considered under process potential is a qualitative assessment of industrial visibility. This pertains to the commercialization aspects of the selected process and the relative stature of the particular firm within the industrial sector. If a rating scale of 1 through 5 is assigned to industrial visibility, the following range of factors seems appropriate:

<u>Rating Factor</u>	<u>Industrial Visibility</u>
1	Excellent
2	Very Good
3	Good
4	Fair
5	Insignificant

Site suitability pertains to all factors that render a particular site more viable than others. There is undoubtedly a certain amount of overlap between the three selected evaluation categories and some question as to where a particular factor really belongs, relative to the three categories. However, as long as the relevant factors all receive due consideration, it really doesn't matter how they are categorized. Accordingly, site suitability seems appropriately summed up with the consideration of two factors: the average solar insolation of the location and the installed cost per square foot of collector at the site. Table VI shows the variation of these two parameters for the 20 selected applications. If we divide the maximum encountered range of measured horizontal insolation and estimated system installed cost into a rating scale of 1 through 5, the following distribution is developed:

<u>Rating Factor</u>	<u>Insolation Range (BTUs/Day)</u>	<u>Cost Range (\$/Ft²)</u>
1	1520 - 1400	31 - 34
2	1399 - 1300	34 - 37
3	1299 - 1200	37 - 40
4	1199 - 1100	40 - 43
5	1099 - 1000	43 - 46

TABLE VI - AVERAGE INSULATION & ESTIMATED COST

<u>Application</u>	<u>Horizontal Insulation (BTU/Ft²-Day)</u>	<u>System Cost (\$/Ft²)</u>
1. American Can Co.	1410	41.75
2. Armour Pharmaceutical	1310	40.25
3. Stokely-Van Camp	1280	42.50
4. Mid-America Dairymen	1440	42.25
5. Armour Foods	1405	37.00
6. Hallmark, Inc.	1375	43.50
7. Vulcan Materials	1520	41.25
8. Ford Motor Co.	1180	40.25
9. Firestone Tire & Rubber	1340	43.25
10. Western Foods	1520	43.75
11. Marsco Manufacturing	1010	35.75
12. Borden Company	1200	43.00
13. American Cr. Sugar	1300	33.25
14. Dickson Forest Products	1455	34.75
15. Pan-O-Gold Baking	1300	46.00
16. Crystal Tissue	1280	35.00
17. American Motors	1250	42.50
18. CF Industries	1405	31.25
19. Viracon, Inc.	1280	43.25
20. Ralston Purina	1290	39.00

Management attitudes are very important to the success of any industrial solar project. If they are favorable, they can compensate for many obstacles in the incorporation of solar energy into a given process or plant. Conversely if they are unfavorable, there is little that can be done to overcome them, even with the most favorable conditions existing otherwise with a particular process and site. The attitudes should be evaluated at both the local plant and the corporate headquarters level. Also, something that is closely tied to local attitude is capability. Enthusiasm should be accompanied (and usually is) by the technical capability to properly operate and maintain the system once it is in place. There were no totally unfavorable attitudes encountered in the selected applications of this study, either at the corporate or plant level. If we assign rating factors of 1 through 5 to the observed management attitudes, we get:

<u>Rating Factor</u>	<u>Corporate Attitude</u>	<u>Plant Attitude</u>
1	Excellent	Excellent
2	Very Good	Very Good
3	Good	Good
4	Neutral	Neutral
5	Unknown	Unknown

Having developed a rating system, we can apply it to the results of this study to get the Relative Overall Viability (ROV) rating of the identified solar applications. Table VII compares the ROV ratings of the 20 applications.

As might be expected, Table VII shows several "ties", with the same rating being shared by more than one organization. At this point, certain 2nd-order factors can be brought into play, such as geographical mix and an overall judgment factor by the investigator as to the favorable aspects of one application versus another. Performing these fine-tuning adjustments results in the following ROV rating alignment of the 20 applications studies.

1. American Crystal Sugar	Moorhead, Minnesota
2. CF Industries	Freemont, Nebraska
3. Ralston Purina Co.	Iowa Falls, Iowa
4. American Can Co.	Pevely, Missouri

TABLE VII - RELATIVE OVERALL VIABILITY (ROV)

<u>Application</u>	<u>Proc. Potential</u>		<u>Site Suit.</u>		<u>Mgt. Att.</u>		<u>Total</u>	<u>Rating</u>
	<u>Energy</u>	<u>Vis.</u>	<u>Insol.</u>	<u>Cost</u>	<u>Corp.</u>	<u>Mgt.</u>		
American Can Co.	5	1	1	4	1	1	13	4
Armour Pharmaceutical	1	3	2	4	3	2	15	5
Stokely-Van Camp	3	2	3	4	5	3	20	9
Mid-America Dairymen	3	2	1	4	1	2	13	4
Armour Foods	3	2	1	2	2	3	13	4
Hallmark, Inc.	4	3	2	5	2	2	18	7
Vulcan Materials	1	3	1	4	2	2	13	4
Ford Motors	5	1	4	4	3	2	19	8
Firestone T & R	5	1	2	5	3	4	20	9
Western Foods	3	4	1	5	4	4	21	10
Marsco Mfg. Co.	2	5	5	2	1	1	16	6
Borden Company	3	2	3	4	2	2	16	6
American Cr. Sugar	3	2	2	1	1	1	10	1
Dickson Forest Prod.	5	5	1	2	4	2	19	8
Pan-O-Gold Baking	3	4	2	5	2	2	18	7
Crystal Tissue	4	4	3	2	1	1	15	5
American Motors	5	2	3	4	4	2	20	9
CF Industries	1	3	1	1	3	2	11	2
Viracon, Inc.	2	4	3	5	2	2	18	7
Ralston Purina	3	1	3	3	1	1	12	3

5. Vulcan Materials Co.	Wichita, Kansas
6. Mid-America Dairymen	El Dorado Springs, Missouri
7. Armour Foods Company	St. Joseph, Missouri
8. Armour Pharmaceutical Co.	Kankakee, Illinois
9. Crystal Tissue Co.	Middletown, Ohio
10. Borden Company	Plymouth, Wisconsin
11. Marsco Manufacturing Co.	Chicago, Illinois
12. Hallmark, Inc.	Leavenworth, Kansas
13. Pan-O-Gold Baking Co.	Fargo, North Dakota
14. Viracon, Inc.	Owatonna, Minnesota
15. Ford Motor Company	Saline, Michigan
16. Dickson Forest Products	Sturgis, South Dakota
17. Stokely-Van Camp	Indianapolis, Indiana
18. Firestone Tire & Rubber	Decatur, Illinois
19. American Motors	Kenosha, Wisconsin
20. Western Foods Company	Hutchinson, Kansas

4.2 Continuance Procedure

The number of applications that are considered for continued effort toward defining demonstration projects depends upon many conditions beyond the scope of this study. The objective here is to assemble our findings and observations in such a manner as to allow an orderly and intelligent pursuit of a deeper thrust, if and when it is deemed appropriate.

First of all, the candidate applications to be pursued should be verified. This should be done with a review of the results of this feasibility study and preliminary discussions with the candidate industrial firms with MASEC/DOE input.

The actual study procedure to be followed in any continued effort should be directed toward a more precise definition of the qualitative and quantitative characteristics associated with each application. It starts and ends with money, with finer engineering definitions sandwiched in between.

The money situation is paramount to everything else in today's industrial community. Of the 80-odd firms contacted in this

study, not one expressed willingness to seriously consider any alternate energy source project with a pay-back longer than 5 years. More usually, it was 3 years. The first step in any program continuance with the firms cited here should be a serious attempt to define exactly what the corporate committment might be if a cost-sharing arrangement on a demonstration system could be developed. The timing would be right to broach the financial aspects in the early stage of a follow-on effort. The firms have had a chance to consider the situations laid out in the case studies and they would be ready for more discussion while it is still fresh in their mind. An early discussion of financial committment will be helpful in verifying the project scope.

Engineering definitions of the quantities needed to pursue a hardware program are the next order of business. The case studies documented here contain more estimates than facts, as far as energy quantities and precise interface requirements are concerned. These should be thoroughly developed and actual measurements of energy should be taken on the specific process under study. Most of the firms expressed willingness to assist in energy measurements and cooperate in interface definitions.

Depending upon the scope of the effort, a complete Engineering Design Phase could be performed at this stage. If so, a full set of engineering drawings should be prepared for the collector field, intermediate piping runs, and all mechanical and electrical details of the process interface. If the definition is sufficiently complete, firm quotes should be obtained on exact quantities of hardware and all labor required for system installation. Detailed system performance predictions should be made on the solar system, based on the final design configuration.

Money becomes the subject matter again, following the engineering definition effort. Whether this definition effort is a second iteration of the case study or a full-blown design phase, a finer assessment of system costs will be possible and should be provided to the industrial organization. At this point, a re-evaluation

of the industrial commitment should be made and final discussions should be conducted with the industrial corporate management on the timing and conduct of any anticipated hardware program.

The industrial commitment is not all that should be sought in any continuance effort that is pursued. If we go back to the firms for any additional cooperation, whether it be a second iteration of the case studies or a detailed design effort, they are going to want a reasonable idea of the cost-sharing money that is available. Whether it is a total budget for X-number of systems or an approximate share per project, the industrial firms will be hesitant to open their doors again unless they are convinced that something will probably come of it.

4.3 Design Principles

The observation of certain design principles for both new and retrofit applications is important to cost-effectiveness and reliability. The general categories of system design can be broken down into five (5) areas:

1. Collector Field
2. Storage (if any)
3. Piping
4. Mechanical
5. Control

The collector field design should look at both ground-mounting and roof-mounting. The most economical of the two should be chosen. Often, the choice is already made by the absence of either suitable ground or roof space for collector mounting. Whether ground or roof mounted, the collector field should be located as close as possible to the process to be supported. The field should be laid out to require the shortest length of intra-field piping runs. Finally, the support structure should be carefully designed, but not over-designed. Wind loads and dead loads should be considered along with interface points with the industrial property (how many and where). Modularization and shop

assembly of the support hardware, as opposed to field assembly is usually a significant cost factor.

Storage, if it is used, should be as simple as possible and as small as possible. If a water tank is used, it should be above ground and inside a building. It should be as close as possible to the process that it supports, whether it be boiler feedwater or the active collector-supported process. The operation of the storage mode should be simple and not require additional parasitic loads (pump power, etc.) over and above the loads associated with regular process support. Internal tank coils are good for this purpose if instantaneous rate is not important. Unless the system design is developmental, only state-of-the-art sensible storage techniques should be considered.

The piping design can have a significant impact on system cost. The minimum size piping should be used for all piping runs to maintain a fluid velocity range at rated flow conditions of 6-9 feet per second. Piping runs should be brought inside the building as soon as possible, easing insulation and jacket requirements. Use of existing utility or process piping run-ways should be made, if possible, eliminating the need for new hangers and also reducing thermal losses by clustering. Modular shop-buildup of subassemblies also has some merit here, especially where intricate turns are involved. Black steel pipe should be used if at all possible. Since the collector loop fluid will probably be inhibited, corrosion should not be a problem. Copper and plastic pipe should be avoided because of cost and poor durability, respectively.

The mechanical components in the system (heat exchanger, pumps, valves), should be carefully sized to produce the required performance, but no significant excess capability over and above degradation allowances due to scaling, etc. Excess heat conditions in a solar loop usually represent an emergency condition that is handled by a simple heat-dump provision to the atmosphere or sewer. If the process being supported is regular in operation, no additional solar heat depository, except possibly storage, need

be incorporated in the design. However, if the process is sporadic and subject to intermittent operation, an alternate process to receive the heat should be sought. All mechanical components should be selected with due consideration to their operating environment. If they are near the supported process, as they should be, they will probably be hosed down or steam-cleaned daily. Modular rack-mounted assemblies are definitely cost effective over install-in-place assemblies.

System control and instrumentation should be the bare minimum required to efficiently operate the solar system and assure its intended support of the process. Remote monitoring capability or sophisticated microprocessor control should be avoided unless the industrial organization is willing to pay for it. All thermostatic valves should be self-contained and rugged. The instrumentation should be minimal but sufficient to evaluate system performance and to locate gross trouble spots. An insolation pyronometer should be included only if the local municipal weather station does not have one. All instrumentation data should be input to a small data logger located at a point that will minimize wire runs. As a rule, visual pressure gauges and flow gauges should be used rather than wired instrumentation sensors.

4.4 Management Incentives

Little can be said about management incentives that hasn't already been covered. Money is the main driving force behind the adoption of solar energy. Until solar can pay for itself in 3-5 years, financial incentives will be required. The current inflationary condition of our economy is aggravating this situation, with capital expenditures receiving very close scrutiny.

Without exception, all of the industrial organizations selected for inclusion in this study were cooperative and very open-minded when considering the integration of solar energy in their plants. Also, solar has earned their respect as a viable form of industrial process heat. No problems of attitude are anticipated in this regard.

5. CONCLUSION AND RECOMMENDATIONS

The Mid-American region is well-endowed with feasible potential solar energy applications in a variety of industrial process heat uses. Twenty (20) applications covering 12 states and 8 major SIC groups were developed, ranging in collector field size from 2,240 to 13,440 square feet, with estimated costs from \$31.25 to \$46.00 per square feet.

It is not surprising that the most feasible (and the most cost effective) applications identified were also the simplest. The 6 best rated applications from an overall viability standpoint are re-capped as follows:

<u>Rating</u>	<u>Firm</u>	<u>Application</u>
1.	American Crystal Sugar Moorhead, Minnesota	Waste Water Treatment at 95°F
2.	CF Industries, Inc. Fremont, Nebraska	Boiler Feedwater at 105°F
3.	Ralston Purina Co. Iowa Falls, Iowa	Soybean Meal Drying at 160°F
4.	American Can Company Pevely, Missouri	Can Washing Steam at 250°F
5.	Vulcan Materials Co. Wichita, Kansas	Process Steam at 350°F
6.	Mid-America Dairymen El Dorado Springs, Mo.	Milk Dehydration at 350°F

Some interesting statistical characteristics are noted in these top-rated 6 applications:

- 4 collector types are represented
- 5 are ground-mounted
- 5 require no storage
- 5 are in different states, all in western segment
- 6 are over 10,000 square feet in size
- 6 show inverse rating/temperature trend (high/low)

These results seem to show good diversity and are consistent with common-sense judgment. It is gratifying to see them borne out in this study.

The following recommendations for future effort are made:

- a) that the results of this study form the basic foundation for continued and intensified development of SIPH potential in the Mid-American region.
- b) that additional potential applications emerging late in this study be developed as an extension of the current effort.
- c) that every attempt be made to escalate the top-rated applications in this study to cost-shared demonstration projects.

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APPENDIX

20 Case Studies

Industrial
Solar
Associates

2155 SOMERSET DR.
FLORISSANT, MO. 63033
PHONE (314) 921-5029

FIRST CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

January 15, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington MN 55420

Application: Can Washing
Steam at 250°F

Collector Type: Stationary Concentrator

Field Size: 11,200 Ft²

AMERICAN CAN COMPANY
Gateway Plant
Pevely, Missouri 63070

Solar Industrial Process Steam for Can Washing: A Feasibility
Study at the American Can Company

Firm Background

American Can and its subsidiaries employ over 50,000 people in 37 states and 6 provinces of Canada, and have affiliations in 29 countries. The company has expanded its packaging capability from metal food containers to a variety of private brand consumer products.

In 1972, an energy conservation program was started that has resulted in a 20 percent overall reduction in energy use. In 1978 alone, an energy savings of 4 percent over the previous year's level was achieved, amounting to more than a trillion BTU's.

American Can's most modern and technologically advanced facility is the Gateway Plant at Pevely, Missouri. The cans produced at Gateway require one-third less metal than those of a decade ago because of the new technology brought to bear in the plant's operations. Completely automated and computer controlled, its production capacity is over one billion cans per year.

Site Description

Pevely, Missouri is located approximately 30 miles southwest of St. Louis, at a latitude of 39° N with an annual average daily

horizontal solar insolation of 1410 BTU/square foot. The mean annual ambient temperature is 56°F. The long axis of the American Can process building runs east-west. There is an unobstructed area of the roof on the south side directly over the boiler room where the proposed solar system mechanical components would be located. This roof area is structurally sound and could easily support the solar collectors.

A collector field size of 11,200 square feet, sized on the basis of reasonable process load support and immediate roof area availability, could be efficiently installed in the discussed area. A feasible collector field layout would consist of 6 rows of 20 panels and 5 rows of 16 panels each, based on a two-high stacked mounting arrangement with each panel having an aperture area of 28 square feet.

Process Description

The process selected for potential solar support in this study is steam production at 15 psig (250°F) for can washing. The steam is presently supplied by two 150 hp gas-fired boilers, with condensate return at the boilers. The boilers alternate in duty to supply steam at a total of 3,600 pounds per hour to four can washing machines which use hot water at 140°F for washing. The water is heated by steam plate coils in the water reservoirs of the machines. The spent water is cleaned and returned to the reservoirs.

Interfacing the solar system with the main steam production facility, rather than at one or more of the individual heat consumption points, would assure efficient use of all heat produced by the solar system without the need for storage.

Process Energy Profile

The can washing steam load is steady at 3,600,000 BTU/hr, 24 hours per day, 7 days per week.

Solar System Design

The solar system design would be based on 100 percent utilization of all solar-produced heat with no storage. The solar loop would be designed for complete self-sufficiency, creating the least possible disturbance to the existing mechanical systems and controls.

A conceptual schematic of the system is shown in Figure 1. In operation, the solar heat transfer fluid (Therminol 66 or equivalent) would be pumped through the solar collector array on the roof at a controlled rate and would rise in temperature from an inlet of 250°F to an outlet of 300°F. The fluid would then go down to the solar boiler in the boiler room and would give up its heat to treated boiler feedwater, which would be converted to saturated steam at 15 psig, 250°F. The transfer fluid, having been reduced to 250°F, would travel back to the roof to repeat the cycle. The solar produced steam would go into the main steam supply header just downstream of the existing gas-fired boilers.

Components shown in the schematic include an expansion tank with nitrogen ullage for oxidation protection, a water conditioning (softening) subsystem, a boiler feedwater preheater to prevent tube thermal shock and associated pumps and controls. A boiler blow-down subsystem would also be provided for scheduled boiler maintenance.

Because of the diffuse nature of the solar radiation at this site and the moderate temperature requirements of the process, a

mid-range solar concentrator is recommended which can perform reasonably well under diffuse as well as direct radiation. A stationary concentrating flat plate collector using parabolic concentrators is recommended. Since the collectors are stationary, complex tracking rquipment is not required. There are several such collector designs available. The one recommended for this application employs evacuated tubes completely enclosed in a 104 x 47 x 6 inch assembly and topped off by a tempered glass weather cover.

Performance Estimation

The system performance is estimated form two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 40° . Based on an average collector temperature of 275°F , the performance for a total aperture area of 11,200 square feet is estimated to be:

Maximum Clear Day Contribution = 11.97 million BTU's per day

Average Annual Contribution = 2.31 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing an 11,200 square foot solar system of the characteristics described above, with associated mechanical components and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.00	78,400
Collectors	28.00	313,600
Piping, Insulation	3.50	39,200

Cost Estimation (con't)

Boiler Room

Solar Boiler	1.50	16,800
Preheater, Pumps, Controls	1.00	11,200

Instrumentation

Sensors	.25	2,800
Data Logger	<u>.50</u>	<u>5,600</u>

Total	41.75	467,600
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Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

The production of process steam such as discussed in this application is difficult, if not impossible, to achieve with waste heat. Certainly, no known source exists at this site that could produce the required temperatures. Therefore, solar substitution is considered to be a viable alternative to fossil fuel in this application.

SYSTEM SCHEMATIC

Figure 1

Industrial
Solar
Associates

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SECOND CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

January 31, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

ARMOUR PHARMACEUTICAL COMPANY
Kankakee, Illinois

Application:	PF Water Production to 200°F
Collector Type:	Evacuated Tube
Field Size:	5,280 Ft ²

ARMOUR PHARMACEUTICAL COMPANY
P.O. Box 511
Kankakee, Illinois 60901

Solar Industrial Process Heat for Pyrogen Free Water Production:
A Feasibility Study at the Armour Pharmaceutical Company.

Firm Background

Armour Pharmaceutical, a Revlon, Inc. company employs approximately 675 people. The plant produces prescription drugs. It forms an important part of the Revlon Health Care Group, comprised of the following businesses with world-wide representation:

Prescription Drugs	Armour Pharmaceutical Company
Prescription Drugs	USV Laboratories
Specialty Drugs	Barnes-Hind Pharmaceuticals
Optical Products	Coburn Optical Industries
Propriety Drugs	Norcliff Thayer
Clinic Diagnostic Labs	National Health Laboratories
Daignostic Reagents	Meloy Laboratories
Over the Counter Drugs	Lewis Howe

The Kankakee plant of Armour Pharmaceutical Company was completed early in 1953 and has since enjoyed a steady growth. The complex presently consists of twelve integrated buildings situated on a 65-acre tract of land directly north of Kankakee.

Energy conservation and alternate source development is a committment taken seriously at Armour Pharmaceutical, as evidenced by the fine cooperation extended during this solar feasibility study.

Site Description

Kankakee, Illinois is located approximately 60 miles southwest of Chicago, at a latitude of $41^{\circ} 30'N$. The average annual daily horizontal solar insolation for the area is 1310 BTU/square foot, with a mean annual ambient temperature of $51^{\circ}F$. The plant is well-constructed with approximately 150,000 square feet of flat roof area. There is an unobstructed area of 80,000 square feet available on the main process building which is situated on the southeast corner of the plant complex.

A collector field size of just over 5,000 square feet, sized on the basis of 1-shift heat utilization with no storage could easily be accommodated near the process area. A feasible collector field layout would consist of 12 rows of 16 collectors each, based on a collector aperture area of 27.5 square feet and resulting in a total field size of 5,280 square feet.

Process Description

The process which we feel would be most feasible for a pilot solar application at this site is Pryogen Free (PF) Water production. PF water is used as a base for the majority of the pharmaceutical preparations produced by the plant. This water is produced in several steps, starting with the distillation of service water, then deionization and finally, storage at $180^{\circ}F$.

The distillation of the PF water is performed in three (3) stills, producing a total of approximately 700 gallons per hour of PF water. The existing heat source for the stills is 100 psig ($338^{\circ}F$) steam, produced in gas fired boilers.

The specific part of the process selected for potential solar support in a pilot application is the pre-heat of the service water before it enters the stills. The total pre-heat load, assuming a temperature increase of the incoming service water from an average of 70°F to 200°F, is 760,000 BTU/hr. The remaining distillation load following pre-heat is approximately 5.7 million BTU/hr, which represents a good potential future growth application for solar heat. Sufficient roof area exists for 1-shift support of this entire load.

Process Energy Profile

The PF water pre-heat process is continuous and has a steady demand of 760,000 BTU/hr, 24 hours a day, 7 days a week.

Solar System Design

The solar system would be designed to interface with the main service water inlet feeding three existing PF stills. Sizing the collector field to supply less than the total pre-heat load would make for efficient utilization of all heat collected with no requirement for storage. The resulting collector field size of 5,280 square feet would perform well under these conditions. The existing controls and steam heat exchange elements in the stills would remain undisturbed. A schematic diagram of the conceived system is shown in Figure 1.

In operation, the solar fluid (e.g. 50% water/propylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 70-200°F to an outlet of 90-225°F. The fluid would then progress to the PF water distillation area

where it would transfer its heat to the service water via a plate-frame heat exchanger. The solar fluid would then progress back to the collector field to repeat the cycle. The service water would simply proceed to the PF water stills, where it would be boiled and distilled.

An evacuated-tube type of solar collector is recommended for this application because of the relatively high sensible-range temperature involved and the ability of this type of collector to collect diffuse as well as direct radiation. There are several evacuated-tube collector designs available on the market. For this application, a tube spacing of 50% with shaped reflectors would probably prove most effective.

Performance Estimation

The system performance is estimated from two aspects, maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 42° and a mean collection efficiency of 50%. Under these conditions, the performance for an aperture area of 5,280 square feet is estimated to be:

Maximum Clear Day Contribution = 6.2 million BTU's per day

Average Annual Contribution = 1.6 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 5,280 square foot solar system of the characteristics described above, with associated mechanical components and instrumentation/control functions and based on first quarter 1980 component and labor costs are as follows:

Cost Estimation (cont'd.)

<u>Collector Field</u>	<u>S/Ft²</u>	<u>Total \$</u>
Collector Supports	7.50	39,600
Collectors	27.00	142,560
Piping, Insulation	3.00	15,840
<u>Mechanical</u>		
Solar Heat Exchanger	1.00	5,280
Pumps, Controls	.73	3,960
<u>Instrumentation</u>		
Sensors	.25	1,320
Data Logger	<u>.75</u>	<u>3,960</u>
Total	40.25	212,520

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial heat application.

Refrigeration waste heat is a potential source at Armour Pharmaceutical. However, this could supply heat only up to 150°F maximum. If this option were adopted at some point in the future, the solar contribution could be extended into multi-shift operation with the addition of a small (6,000 gal.) storage tank.

SYSTEM SCHEMATIC

Figure 1

Industrial
Solar
Associates

2155 SOMERSET DR.
FLORISSANT, MO. 63033
PHONE (314) 921-5029

THIRD CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

January 31, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

STOKELY-VAN CAMP, INC.
Indianapolis, Indiana

Application:	Bean Blanching at 185°F
Collector Type:	Evacuated Tube
Field Size:	10,560 Ft ²

STOKELY-VAN CAMP, INC.
2002 South East Street
Indianapolis, Indiana 46225

Solar Industrial Process Heat for Bean Blanching: A Feasibility Study at Stokely-Van Camp, Inc.

Firm Background

Stokely-Van Camp has been in the food processing industry since its start in 1898. The company is headquartered in Indianapolis, Indiana and has operating facilities in seventeen states and Canada. It employs approximately 5,800 full-time employees and an additional 10,000 temporary employees each year. With annual sales of approximately 500 million dollars, it is one of the largest processors of canned and frozen foods in the United States. Its product labels include Stokely's Finest, Van-Camp's Pictsweet, Popeye, Sunshine, Kuner, Graves and others.

The food processing operations of Stokely-Van Camp, like other food processors, are very energy-intensive. As a result, energy conservation and alternate energy source development are topics of significant interest with the company.

Site Description

Indianapolis, Indiana is located at a latitude of 39° 44'N with a mean daily horizontal solar insolation of 1280 BTU/square foot and a mean ambient temperature of 56°F. The Stokely-Van Camp plant at 2002 South East Street is a combined food processing and can manufacturing facility. Although the identified solar application would be in food processing, the solar collectors would be

mounted on the roof of the can manufacturing plant, adjoining the process building on the south. The available roof area on this plant is approximately 40,000 square feet of flat, well-constructed roof.

A collector field size of approximately 10,500 square feet, sized on the basis of 1-shift support with no storage, could easily be accommodated on the available roof area. A feasible collector field layout would consist of 24 rows of 16 collectors each, based on a collector aperture area of 27.5 square feet and resulting in a total field size of 10,560 square feet.

Process Description

The process identified as a feasible solar application at this site is bean blanching. This is currently being done in four (4) pairs of "blanchers" where the dried beans are submerged and agitated in hot water. The water temperature varies from 160°F in the first of the pair of blanchers to 190°F in the second. The system takes 135°F water at 60 gpm per pair of blanchers from the plant hot water system and boosts it to the required temperature in each blancher by injection of 150 psig, 350°F steam produced in gas-fired boilers. It is an open-loop system with no recirculation, due to starch build-up in the water from the dried beans.

The solar application would involve one pair of the four pairs of bean blanchers. The incoming hot water at 135°F would be circulated through and modulated around a shell-tube solar loop heat exchanger to produce the required temperatures (160 and 190°F) into each of the two blanchers. Each pair of blanchers consumes approximately 2.0 million BTU/hr, which could absorb all of the heat generated by a 10,560 square foot solar collector field.

Process Energy Profile

The bean blanching process is a 2-shift operation that runs 5 days per week with a total running heat load of approximately 8 million BTU/hr, (2.0 million BTU/hr per pair of blanchers). Week-end heat requirements are limited to Saturday clean up operations.

Solar System Design

The solar system would be designed to supply heat for bean blanching 5 days per week, with sensible hot water storage for boiler feedwater for Saturday clean up and for Monday morning start up. Thus, an insulated water tank for week-end heat storage will be required for 7-day heat utilization. For the bean blanching support, the existing steam injection system, with associated controls, would remain unchanged and would serve as a top-off heat source to round out the solar input. For week-end storage of heat, a single 15,000 gallon water tank should be sufficient to store all heat collected by the system.

In process support operation, the heat transfer fluid (e.g. 50% water/propylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 190°F to an outlet of 210°F. The fluid would then progress to the bean blanching area where it would transfer its heat to the process water via a shell-tube heat exchanger. The solar fluid would then progress back to the collector field to repeat the cycle. The heated process water would go to the pair of blanchers, where any additional steam heat would be added to produce the required 160 and 190°F temperatures. During week-ends, soft hot water would be stored in the 15,000 gallon storage tank (new) to be used for boiler feedwater.

An evacuated-tube type of solar collector is recommended for this application because of the relatively high sensible range temperatures involved and the ability of this type of collector to collect diffuse as well as direct radiation. There are several evacuated-tube collector designs available on the market. For this application, a tube spacing of 50% with shaped reflectors would probably prove most effective.

Performance Estimation

The system performance is estimated from two aspects, maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 40° and a mean collection efficiency of 50%. Under these conditions, the performance for an aperture area of 10,560 square feet is estimated to be:

Maximum Clear Day Contribution = 12.1 million BTU's per day

Average Annual Contribution = 3.0 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 10,560 square foot solar system of the characteristics described above, with associated mechanical components, a 15,000 gallon insulated storage tank and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.50	79,200
Collectors	27.00	285,120
Piping, Insulation	3.00	31,680

Cost Estimation (con't)

Mechanical

Solar Heat Exchanger	1.00	10,560
Pumps, Controls	.75	7,920

Storage

Sensors	.25	2,640
Data Logger	<u>.50</u>	<u>5,280</u>

Total	42.50	448,800
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Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial heat application.

The open-loop aspect of the bean blanching operation with hot starch-laden water being expelled, points up some heat reclamation possibilities. The proposed solar system, as sized for the pilot application, would deliver an average of approximately 50% of the 1-shift heat load for a pair of bean blanchers. If an additional 50% of the required heat load could be recovered from the waste stream, this pair of blanchers would be virtually energy-independent for 1 shift per day. Further, if more than 50% recovery could be achieved, the solar system could supply additional blanchers.

SYSTEM SCHEMATIC

Figure 1

Industrial
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FOURTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
~~SITE~~ SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

January 31, 1980

Submitted by:

Orin L. Murray
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

Application:	Milk Dehydration at 350°F
Collector Type:	Line Concentrator
Field Size:	13,440 Ft ²

MID-AMERICA DAIRYMEN, INC.
El Dorado Springs, Missouri 64744

Solar Industrial Process Heat for Milk Drying: A Feasibility
Study at Mid-America Dairymen, Inc.

Firm Background

Mid-America Dairymen, Inc. is a dairy processing cooperative comprised of 35 processing plants in 14 states:

Arkansas	Kansas	Oklahoma
Colorado	Minnesota	South Dakota
Idaho	Missouri	Texas
Illinois	Nebraska	Wisconsin
Iowa	North Dakota	

The cooperative was organized into its present form in 1968. In all, it employs approximately 3000 people and processes over 2 billion gallons of liquid milk per year into various dairy products. It is divided into four (4) regional divisions, headquartered in the following cities:

Northern Division	St. Paul, Minnesota
Southern Division	Springfield, Missouri
Eastern Division	St. Louis, Missouri
Western Division	Omaha, Nebraska

The El Dorado Springs plant is in the Southern Division of Mid-America Dairymen. It is a modern plant and it recently received an addition that constitutes the process selected for feasibility evaluation of solar heat support. A high-capacity dehydrator, one of only two in the country, was put into service at the El Dorado Springs plant in August of 1979. It is one of the most advanced dehydrators in the industry and is designed to produce up to 4,000 pounds of finished product per hour.

Site Description

El Dorado Springs, Missouri is located approximately 100 miles southeast of Kansas City at a latitude of $37^{\circ} 20'N$. It has a mean daily horizontal solar insolation of 1440 BTU/square foot and a mean ambient temperature of $56^{\circ}F$. The Mid-America Dairymen plant on Highway 54 produces both liquid and dehydrated milk products. At this site, the solar collectors (line concentrating type) for the selected application would be mounted on a plot of ground of approximately four (4) acres directly adjacent to the plant, on the north side (rear) of the plant.

A collector field size of approximately 13,500 square feet would supply up to approximately 40% of the maximum process rate demand, with the remainder being supplied by the existing conventional means. A feasible collector field layout would consist of 16 rows of 6 collectors each, based on a collector (reflector) aperture area of 140 square feet and resulting in a total field size of 13,440 square feet. The exact placement of the field would be based on shadow avoidance from the nearby water tower.

Process Description

The process selected as a feasible solar application at this site is milk dehydration. The El Dorado Springs plant uses a new high-temperature dryer that is reported to be one of the most modern in the world. It uses heat transfer oil (Therminol 66) at a high temperature, $550^{\circ}F$, to heat an incoming air stream to $350^{\circ}F$ into which the liquid milk is injected for dehydration. The oil supplies the heat to the air via a liquid/air heat exchanger in a large inlet air duct. The oil is now heated by gas burners.

The conceived solar application would simply create an additional heat source for the Therminol 66 fluid, which would also

comprise the heat transfer medium for the solar system, without the need for an interface heat exchanger. The solar system would simply tee into the existing Therminol loop, using the existing burner controls to complete the satisfaction of the heat demand.

Process Energy Profile

The milk dehydration process is targeted for a 3-shift operation, running 5 days per week when the plant reaches full operational capability. The running heat load for the dehydrator is approximately 6 million BTU/hr. The process is shut down for 2 days per week. Heat loads during these two days are presently not sufficiently defined to warrant direct support from the solar system; however, heat storage could be effectively applied.

Solar System Design

The solar system would be designed to supply heat for milk dehydration 5 days per week. For the two off-days each week, there will exist some heat load for limited process support and clean-up. This will be supplied by the plant steam system, which generates 160 psig (370°F) steam. A substantial feedwater pre-heat load exists, which could be well-served by hot water storage. A 20,000 gallon hot water storage tank could absorb all of the week-end solar output and provide hot water for boiler supply on the week-end and for Monday morning start-up.

A schematic diagram of the conceived solar system is shown in Figure 1. In regular process support operation, 5 days per week, the heat transfer fluid (Therminol 66) would be pumped through the solar collector array at a maximum rate of 180 gpm and would rise in temperature from an inlet of 490°F to an outlet of 550°F. This

heated fluid would then join the main process loop (also Therminol 66) just upstream of the existing gas burners. The burners would top-off the heat supply to the stream and it would progress to the dryers where the heat would be given up to the incoming air stream, heating it up to 350°F. The process loop total flow rate is 450 gpm.

In heat storage operation on week-ends, the solar fluid would be circulated through coils in the 20,000 gallon hot water storage tank.

A line concentrating type of solar collector is recommended for this application because of the relatively high temperature levels associated with the process. An additional feature of this type of collector that will be useful in this application is the ability of the collector to "stow" itself in the event of insufficient insolation or loop overheat. There are several such collector designs available. The one considered for this feasibility work-up has a reflector size of 7 feet x 20 feet, creating an aperture area of 140 square feet per collector.

Performance Estimation

The system performance is estimated from two aspects, maximum clear day output and average weather output. A collector rotation axis in the east-west direction has been assumed. Based on these conditions, the performance for an aperture area of 13,440 square feet is estimated to be:

Maximum Clear Day Contribution = 13.7 million BTU's per day

Average Annual Contribution = 3.1 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a

13,440 square foot solar system of the characteristics described above, with associated mechanical components, instrumentation/control functions and a 20,000 gallon insulated water storage tank, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Pads	4.00	53,760
Collectors	29.00	389,760
Piping, Insulation	5.00	67,200
<u>Mechanical</u>		
Pumps, Controls	1.00	13,440
<u>Storage</u>		
20,000 Gallon Insulated tank	2.50	33,600
<u>Instrumentation</u>		
Sensors	.25	3,360
Data Logger	<u>.50</u>	<u>6,720</u>
total	42.25	567,840

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial heat application.

The elevated temperature of the application discussed here removes it from the realm of waste heat. Therefore, solar is considered to be a completely viable substitute for fossil fuel in this application.

SYSTEM SCHEMATIC

Figure 1

Industrial
Solar
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FIFTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

January 31, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

ARMOUR FOOD COMPANY
St. Joseph, Missouri

Application:	Hog Scalding at 140°F
Collector Type:	Flat Plate
Field Size:	10,750 Ft ²

ARMOUR FOOD COMPANY
St. Joseph, Missouri 64504Solar Industrial Process Heat for Hog Scalding: A Feasibility
Study at Armour Food CompanyFirm Background

Armour Food Company was founded by Phillip D. Armour in 1867. The corporate headquarters of the organization is located in Phoenix, Arizona. Armour has 31 major producing facilities in 17 states. Additionally, it has 40 distribution centers located throughout the country. In all, the company employs between 14,000 and 15,000 people.

The St. Joseph plant is a pork slaughtering operation. The original plant was erected in the early 1900's, but was replaced by the present modern plant in 1972. It employs from 350 to 400 people and processes an average of 575 hogs (approximately 130,000 pounds) per hour, one shift per day, 5 days per week.

Site Description

St. Joseph, Missouri is located approximately 50 miles northwest of Kansas City, at a latitude of 39° 30'N. The average annual daily horizontal solar insolation for the area is 1405 BTU/square foot, with a mean ambient temperature of 52°F. The Armour plant has a total roof area of approximately 140,000 square feet, with an unobstructed area of 70,000 square feet on the south side which would be feasible for collector mounting.

A collector field size of just under 11,000 square feet, sized

on the basis of 1-shift heat utilization with no daily storage could be accommodated directly over the process area. A feasible collector field layout would consist of 24 rows of 16 flat plate collectors each, based on a collector aperture area of 28 square feet and resulting in a total field size 10,750 square feet.

Process Description

The process identified as a feasible pilot application of solar energy at this site is hog scalding. The purpose of the scalding operation is to facilitate hair removal from the carcass. The scalding tank is a large U-shaped open trough filled with hot water through which the hog carcasses are transported on a conveyor chain. The water in the scalding tank is maintained at 140°F by direct injection of 90 psig (330°F) steam at several points. The operating heat load is approximately 2 million BTU/hr.

To eliminate temperature gradients in the tank, the water is continuously circulated by pumping from the discharge end to the load end. The solar support would be accomplished by intercepting this circulated water and running it through a heat exchanger interfacing with the solar loop.

Process Energy Profile

The hog scalding operation has a running load of 2 million BTU/hr for approximately 10 hours per day, 5 days per week. Sensible heat storage over the week-end in a 15,000 gallon water tank (new) would supply useful heat for the high start-up load on Monday morning.

Solar System Design

The design of the solar system would be simple and reliable for this application. The system would be sized to supply slightly less than the running process load and, hence, would require no week-day storage. The resulting collector field size of 10,750 square feet should supply a maximum of 90% of the running process load rate, leaving the existing steam controls intact to supplement this heat input for load satisfaction. Week-end heat storage in a 15,000 gallon water tank could be used directly for initial scald tank filling on Monday morning and indirectly for load heat supply through the heat exchanger until active solar input is available.

A conceptual schematic of the system is shown in Figure 1. In active operation, the solar fluid (e.g. 50% water/propylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 120-160°F to an outlet of 140-180°F. The fluid would then progress to the scald tank area where it would transfer its heat to the scald tank via a shell-tube heat exchanger. The solar fluid would then progress back to the collector field to repeat the cycle. The scald tank water would simply be returned to the tank in the normal recirculation cycle. Indirect heat from storage (via the solar loop coils) would be used whenever the storage is above 140°F and the collector output is below 140°F.

For this application, a flat-plate type of solar collector is recommended because of the relatively low process temperature and the ability of the flat plate to operate well under diffuse as well as direct radiation. No single design of collector will be recommended here, although a double glazed selective surface absorber would probably operate most efficiently under the environmental and load conditions.

Performance Estimation

The system performance is estimated from two aspects, maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 40° and a mean collector efficiency of 35%. Under these conditions, the performance for an aperture area 10,750 square feet is estimated to be:

Maximum Clear Day Contribution = 9.5 million BTU's per day

Average Annual Contribution = 2.4 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 10,750 square foot solar system of the characteristics described above, with associated mechanical components, a 15,000 gallon insulated storage tank and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.00	75,250
Collectors	22.00	236,500
Piping, Insulation	3.00	32,250
<u>Mechanical</u>		
Solar Heat Exchanger	1.00	10,750
Pumps, Controls	.75	8,062
<u>Storage</u>		
15,000 Gallon Insulated Tank	2.50	26,875
<u>Instrumentation</u>		
Sensors	.25	2,688
Data Logger	.50	5,375
Total	37.00	397,750

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

At Armour Foods, many energy conservation measures have been adopted to offset the high process heat load. Refrigeration waste heat is a big source here. At the St. Joseph plant, waste heat from the refrigeration system is heating process water which is used at the rate of 250 gpm for various preparation and cleaning processes. The hog scalding operation has received close scrutiny from the corporate energy management staff and is deemed to be a valid candidate for solar displacement of fossil fuel.

SYSTEM SCHEMATIC

Figure 1

**Industrial
Solar
Associates**

2155 SOMERSET DR.
FLORISSANT, MO. 63033
PHONE (314) 921-5029

SIXTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

February 18, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

HALLMARK SELECT PRODUCTS
Leavenworth, Kansas

Application:	Ink Drying at 125°F
Collector Type:	Evacuated Tube
Field Size:	5,363 Ft ²

HALLMARK CARDS, INC.
450 Eisenhower Road
Leavenworth, Kansas 66048

Solar Industrial Process Heat for Ink Drying: A Feasibility
Study at Hallmark Cards, Inc.

Firm Background

Hallmark Cards started as a small greeting card organization in 1915. It has since grown to the world's leading creator and publisher of social expression products. Presently, the company produces more than 40,000 products in 17 products lines, including:

Greeting Cards
Gift Wrap
Ribbon and Yarn Tie
Writing Paper
Writing Instruments
Candles
Playing Cards
Home Decorations
Party Goods
Keepsake and Photo Albums

Calendars
Bath Products
Jigsaw Puzzles
Gift Books
Children's Books
Candy
Jewelry
Collectable Gifts
Picture Frames

The corporate headquarters of Hallmark are in Kansas City, Missouri. The company has 6 production centers (5 in Kansas and 1 in Missouri), 2 distribution centers and 9 divisions and subsidiaries.

The production plant chosen for this study is a Specialty Products plant in Leavenworth, Kansas. The plant is engaged primarily in printing of gift wrap. The energy-consciousness of the corporation and of the plant is high, making a pilot solar application potentially feasible at this site.

Site Description

Leavenworth, Kansas is located approximately 30 miles northwest of Kansas City, at a latitude of $39^{\circ} 12'N$. The average annual daily horizontal solar insolation for the area is 1375 BTU/square foot, with a mean annual ambient temperature of $56^{\circ}F$. The Specialty Products plant of Hallmark is a modern well-constructed building that is presently undergoing a significant expansion. When completed, the total roof area will exceed 270,000 square feet. There is an unobstructed area of approximately 12,000 square feet available on the existing building, near the selected process, which would be suitable for collector mounting in a pilot application. A new warehouse roof area exceeding 120,000 square feet would represent a favorable future expansion potential.

A collector field size of 5,363 square feet, sized on the basis of efficient roof area utilization near the selected process, is feasible for a pilot application. An effective collector field layout would consist of 15 rows of 13 collectors each, based on a single collector aperture area of 27.5 square feet.

Process Description

The process selected for potential pilot solar application at this site is ink drying. The gift wrap produced at this plant has multi-color patterns printed on it with solvent-based inks. This is done in 6 presses. Following the printing operation, the ink is dried with warm ($125^{\circ}F$) air, heated by steam coils in 31 dryers. Air is continuously replaced in these dryers by drawing in fresh outside air and exhausting warm ($100^{\circ}F$) solvent-laden air at a rate of 3000 cfm per dryer. Both solvent and heat recovery from this exhaust air is effectively accomplished. The heat

recovery brings the incoming air up to approximately 60°F in winter and 100°F in summer. The steam for final heating of the air is supplied at 50 psig (300°F).

The specific solar application would be to supply all or part of the makeup air heat load for 2 press lines. The heat load is estimated to range from 710,000 BTU/hr in summer to 1,840,000 BTU/hr in winter. The solar heat would be supplied by liquid-to-air heat exchangers in 2 inlet ducts (1 for each group of dryers) upstream of the existing steam coils.

Process Energy Profile

The total ink drying heat load for 6 press lines varies from an estimated 2,130,000 BTU/hr (summer) to 5,520,000 BTU/hr (winter) for a minimum of 1 shift per day, 5 days per week.

Solar System Design

The solar system would be designed to supply heat to the makeup air during the normal day-time production hours. Since the plant operates a minimum of 5 days per week, a 2-day storage capability should be provided for effective utilization of solar generated heat. This could feasibly be accomplished by storing the heat in pre-softened water, up to 200°F, in an 8,500 gallon storage tank. The hot soft water would then be available for boiler feed-water supply at Monday morning start-up.

The method of heat exchange to the dryer makeup air would be via a liquid/air heat exchange coil in each inlet air duct. This coil would be upstream of the existing steam coil so that any necessary supplementation to the heat could be made by the conventional method.

A schematic diagram of the conceived system is shown in Figure 1. In operation, the solar fluid (50% water/ethylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 100-200°F to an outlet of 120-225°F. The fluid would then progress to the dryer air intakes where it would transfer its heat to the incoming makeup air. The solar fluid would then progress back to the collector field to repeat the cycle. The heated air would proceed past the existing steam coils where it would receive any heat required to bring it up to 125°F.

An evacuated-tube type of solar collector is recommended for this application because of the medium to high output temperature required for liquid/air heat exchange and the ability of this type of collector to collect diffuse as well as direct radiation.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 40° and a mean collection efficiency of 50%. Under these conditions, the performance for an aperture area of 5,363 square feet is estimated to be:

Maximum Clear Day Contribution = 6.6 million BTU's per day

Average Annual Contribution = 1.7 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 5,363 square foot solar system of the characteristics described above, with associated mechanical components, an 8,500 gallon

Cost Estimation (cont'd.)

<u>Collector Field</u>	<u>S/Ft²</u>	<u>Total \$</u>
Collector Supports	7.50	39,600
Collectors	27.00	142,560
Piping, Insulation	3.00	15,840
<u>Mechanical</u>		
Solar Heat Exchanger	1.00	5,280
Pumps, Controls	.73	3,960
<u>Instrumentation</u>		
Sensors	.25	1,320
Data Logger	<u>.75</u>	<u>3,960</u>
Total	40.25	212,520

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial heat application.

Refrigeration waste heat is a potential source at Armour Pharmaceutical. However, this could supply heat only up to 150°F maximum. If this option were adopted at some point in the future, the solar contribution could be extended into multi-shift operation with the addition of a small (6,000 gal.) storage tank.

SYSTEM SCHEMATIC

Figure 1

Industrial
Solar
Associates

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FLORISSANT, MO. 63033
PHONE (314) 921-5029

SEVENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
~~SEE~~ SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

February 18, 1980

Submitted by:

Orin L. Murray
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

VULCAN MATERIALS COMPANY
Wichita, Kansas

Application:	Process Steam at 350°F
Collector Type:	Line Concentrator
Field Size:	10,080 Ft ²

VULCAN MATERIALS COMPANY
P.O. Box 12283
Wichita, Kansas 67277

Solar Industrial Process Heat for Process Steam Production:
A Feasibility Study at the Vulcan Materials Company.

Firm Background

The Vulcan Materials Company started in 1910 as the Birmingham Slag Company. Steady growth and acquisitions have elevated it to the largest corporation headquartered in the state of Alabama. With a work force of 6,000 men and women, Vulcan's annual sales of over \$650 million rank it with the top 400 public corporations of America.

Vulcan is a multi-industry company organized by product line and geography into 8 independent divisions. The domestic divisions operate 104 facilities in 12 states. The company also operates a division in the Eastern Province of Saudi Arabia, which provides construction materials for that country's massive modernization and industrialization projects.

The Vulcan plant in Wichita is in the Chemicals Division of the company and employs 650 people. The plant produces a diversified line of chlorinated hydrocarbons, industrial and agricultural chemicals. The Wichita plant was purchased by Vulcan in 1957 and has experienced substantial growth since that time. In 1977, the site's second chloromethanes plant was put into operation. At maximum rates, the new facility, dubbed Chloromethanes II, can produce up to 274 tons per day of methylene chloride, chloroform

and carbon tetachloride.

The Wichita plant's operations are very energy intensive and many energy conservation measures have been adopted. The interest in alternate energy source development is significant. This, together with the 24 hour-7 day operation of the plant, makes it an attractive candidate for a pilot solar application.

Site Description

Wichita, Kansas is located in south central Kansas at a latitude of 37° 45'N. The average annual daily horizontal solar insolation for the area is 1520 BTU/ square foot, with a mean ambient temperature of 57°F. The plant is composed of a number of individual buildings and structures. The complex is situated on one-half section of land (320 acres), with approximately 40% existing as open land to the north of the plant. Directly adjacent and to the north of the Chloromethanes II plant, the process to receive the solar-generated steam, there exists a large flat expanse of land which would be well suited for a solar collector field.

A collector field size of 10,080 square feet, sized on the basis of an efficient field layout near the selected process, could easily be accommodated on the adjacent ground space. A feasible collector field layout would consist of 12 rows of 6 collectors each, based on a single collector (line concentrator) aperture area of 140 square feet.

Process Description

The process selected for potential pilot solar application at this site is process steam production for use in the

Chloromethanes II plant. The existing steam supply to these processes is 150 psig (350°F), consumed at the rate of 55,000 pounds per hour. Several aspects of the specific processes in the Chloromethanes II plant are proprietary and need not be described here.

The solar application would simply comprise a supplemental source for the process steam, which would be introduced into the main steam header feeding the various Chloromethanes II processes.

Process Energy Profile

The total heat demand for process steam by the Chloromethanes II plant is 55,000,000 BTU/hr, 24 hours per day, 7 days per week.

Solar System Design

The solar system would be designed to convert all of the heat collected into process steam at 150 psig (350°F). Since the demand for steam in the application is around the clock, no storage would be required. The solar loop would be designed to be self-sufficient and would only interface with the existing steam system when it is producing steam of the required quality.

A schematic diagram of the conceived system is shown in Figure 1. In operation, the solar fluid (Exxon HT-43 or equivalent), would be pumped at a controlled flow rate through the solar collector array and would rise in temperature from an inlet of 375°F to an outlet of 450°F. The flow through the collector field would be modulated to produce the required outlet temperature. After being heated, the solar fluid would progress to the solar steam generator where it would generate 150 psig (350°F) steam. The steam would simply be allowed to free flow discharge into the main steam line

feeding the process, as governed by the solar-generated steam pressure.

Components shown in the schematic include an expansion tank with nitrogen ullage for oxidation protection, a water conditioning (softening) subsystem, a boiler feedwater pre-heater to prevent tube thermal shock and associated pumps and controls. A boiler blow-down subsystem would also be provided for scheduled boiler maintenance.

A tracking line concentrating type of solar collector is recommended for this application, because of the relatively high output temperature requirement and the favorable direct component of the solar radiation distribution in this location. There are several such collector designs available. The one considered for this study has a reflector size of 7 feet x 20 feet, creating an aperture area of 140 square feet per collector.

Performance Estimation

The system performance is estimated from two aspects, maximum clear day performance and average weather performance. A collector rotation axis in the east-west direction has been assumed. Based on these conditions, the performance for an aperture area of 10,080 square feet is estimated to be:

Maximum Clear Day Contribution = 11.0 million BTU's per day

Average Annual Contribution = 2.7 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 10,080 square foot solar system of the characteristics described

above, with associated mechanical components and instrumentation/ control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Pads	4.00	40,320
Collectors	29.00	292,320
Piping, Insulation	5.00	50,400
<u>Mechanical</u>		
Solar Boiler	1.50	15,120
Preheater, Pumps, Controls	1.00	10,080
<u>Instrumentation</u>		
Sensors	.25	2,520
Data Logger	<u>.50</u>	<u>5,040</u>
Total	41.25	415,800

Energy Conservation as as Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

Vulcan Materials, being one of the most energy-intensive plants reviewed in this study, is very conservation-minded. There is no apparent energy conservation source that can supply, or significantly reduce the heat load discussed for solar application at this site.

Figure 1

Industrial
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PHONE (314) 921-5029

EIGHTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

February 18, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

FORD MOTOR COMPANY
Saline, Michigan

Application:	Parts Drying at 160°F
Collector Type:	Evacuated Tube
Field Size:	7,013 Ft ²

FORD MOTOR COMPANY
Saline Plastics and Instrument Plant
Saline, Michigan 48176

Solar Industrial Process Heat for Plated Parts Drying: A
Feasibility Study at Ford Motor Company

Firm Background

The Ford Motor Company needs no introduction. The Saline, Michigan plant of Ford Motor manufactures plastic decorative auto parts including instrument panels, instrument clusters, radiator grilles, headlamp housings, exterior lamp lenses; and functional parts such as accelerator pedals, battery brackets, and air conditioning ducts.

The Saline plant was established in 1966. From an initial size of 740,000 square feet with 1,260 employees, the plant has expanded to the present 1,528,000 square feet with approximately 3,000 employees. In a continuing effort to provide both economy and durability, the plastic content of Ford vehicles has increased from 5 pounds per car, in 1964 to an average of 170 pounds per car today. These products consume approximately 60 million pounds of plastic raw materials annually at Saline.

The bright plastic trim components such as the radiator grilles manufactured at Saline are chrome plated in the plant. Process heat is required in both the plating and the post-plating drying processes. The selected process for this feasibility study involves the drying operation.

Site Description

Saline, Michigan is located approximately 50 miles southwest of Detroit, at a latitude of $42^{\circ} 20'N$. The average annual daily horizontal solar insolation for the area is 1180 BTU/square foot, with a mean annual ambient temperature of $50^{\circ}F$. The plant is of modern construction with just over 1.5 million square feet of roof area. However, much of the roof is interrupted with vents from the various processes within the plant. There is a relatively clean area of 56,000 square feet available on the southwest corner of the plant complex which would be suitable for collector mounting.

A collector field size of 7,013 square feet, sized on the basis of immediate roof area availability, is feasible for a pilot application at this site. An efficient collector field layout would consist of 17 rows of 15 collectors each, based on a collector aperture area of 7.5 square feet.

Process Description

The process which appears most feasible for a pilot solar application at this site is makeup air preheat for one of the two existing dry-off ovens. The ovens dry the plated parts before packaging. The ovens are operated at $160^{\circ}F$ and have a continuous replacement of air from an air intake on the top of each oven. The air input to each oven is 15,000 cfm from inside the plant. The air is presently heated by a gas-fired coil in the air intake. The heat load is approximately 1.3 million BTU/hr per oven.

The solar system would supply heat to this incoming air via a liquid/air heat exchange coil upstream of the existing gas heater.

Process Energy Profile

The total dry-off oven heat load is 2,600,000 BTU/hr (1,300,000 per oven), 24 hours per day, 7 days per week.

Solar System Design

The solar system would be designed to interface with one dry-off oven, in the air-intake just upstream of the existing gas-fired heater. Sizing the collector field to supply less than the total makeup air heat load would make for efficient utilization of all heat collected with no requirement for storage. The resulting collector field size of 7,013 square feet would perform well under these conditions. The existing heat controls in the oven would remain undisturbed.

A schematic diagram of the conceived system is shown in Figure 1. In operation the solar fluid (50% water/ethylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 100-200°F to an outlet of 120-225°F. The fluid would then move to the oven intake heat exchanger where it would heat the intake air up to a maximum temperature of 150°F before returning to the collectors to repeat the cycle. The intake air would proceed to the existing gas heater for the top-off heat addition to 160°F.

An evacuated-tube type of solar collector is recommended for this application because of the medium-to-high temperature range of the process and the high approach required for air heating. For this application and location, a tube spacing of 50% with shaped reflectors would prove most efficient.

Performance Estimation

The system performance is estimated for two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 43° and a mean collection efficiency of 50%. Under these conditions, the performance for an aperture area of 7,013 square feet is estimated to be:

Maximum Clear Day Contribution = 7.3×10^6 BTU's per day

Average Annual Contribution = 1.9×10^9 BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 7,013 square foot solar system of the characteristics described above, with associated mechanical components and instrumentation/control functions and based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.50	52,597
Collectors	27.00	189,351
Piping, Insulation	3.00	21,039
<u>Mechanical</u>		
Solar Heat Coil	1.00	7,013
Pumps, Controls	.75	5,260
<u>Instrumentation</u>		
Sensors	.25	1,753
Data Logger	.75	5,260
Total	40.25	282,273

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

For the particular application discussed at this site, recovery of the dry-off oven exhaust heat as a means of preheating the intake air appears to be a worthy option. However, this heat is reducing the building heating load in winter months and would probably represent a savings only in the summer months. A reduction of the oven heat load by 50% would mean that the proposed solar system could supply both existing ovens, rather than only one.

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

For the particular application discussed at this site, recovery of the dry-off oven exhaust heat as a means of preheating the intake air appears to be a worthy option. However, this heat is reducing the building heating load in winter months and would probably represent a savings only in the summer months. A reduction of the oven heat load by 50% would mean that the proposed solar system could supply both existing ovens, rather than only one.

SYSTEM SCHEMATIC

Figure 1

Industrial
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NINTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

February 18, 1980

Submitted by:
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

FIRESTONE TIRE & RUBBER CO.
Decatur, Illinois

Application:	Process Hot Water at 380°F
Collector Type:	Line Concentrator
Field Size:	10,080 Ft ²

FIRESTONE TIRE & RUBBER COMPANY
Decatur, Illinois 62525

Solar Industrial Process Heat for Process Hot Water: A Feasibility Study at the Firestone Tire & Rubber Company

Firm Background

The Firestone Company is a large and familiar organization. The company was started in Chicago, Illinois in 1896 under the name of the "Firestone Rubber Tire Company". Four years later, the company moved to Akron, Ohio, its present headquarters, and was incorporated as the Firestone Tire & Rubber Company. Today, it ranks as the 38th largest corporation in the United States.

The Firestone tire plant in Decatur, Illinois was constructed by the federal government during World War II as an engine plant. The facility was transferred to the U.S. Army Signal Corps in 1946. It was used for storage, distribution and light manufacturing until it was vacated and purchased by Firestone in 1962. Passenger tires, small truck tires and tire tread stock for retreading tires are produced at the Decatur plant, which employs approximately 2,230 people.

Energy-consciousness runs high at Firestone, with total corporate consumption amounting to 65 trillion BTUs per year. This total has been reduced by 20.16 percent since 1972.

Site Description

Decatur, Illinois is located in central Illinois at a latitude of 40° N. The average annual daily horizontal solar insolation for

the area is 1340 BTU/square foot, with a mean ambient temperature of 55°F. The Firestone plant there is well constructed with a large flat roof, although some sections are interrupted with vents. There is a suitable unobstructed area of 35,000 square feet near the process which would make a favorable mounting location for the solar collectors.

A collector field size of 10,080 square feet, sized on the basis of efficient roof area utilization near the selected process, is recommended for this application. A feasible collector field layout would consist of 9 rows of 8 collectors (line concentrators) each, based on a collector aperture of 140 square feet.

Process Description

The process selected for case study feasibility work-up at this site is pressurized hot process water production at 380°F. The hot water supplies a multitude of processes within the plant, all associated with tire manufacturing. The water is under 185 psig pressure and is circulated throughout various process areas. The water is heated in steam heat exchangers at a load demand of approximately 10,000 pounds of steam per hour.

The solar contribution to the load would be accomplished by providing a separate solar heat exchanger on the return side of the existing steam heat exchangers, thus providing higher return temperatures of the water and reducing steam demand.

Process Energy Profile

The hot process water production load is approximately 10,000,000 BTU/hr, 24 hours per day, normally 5 days per week.

Solar System Design

The solar system would be designed to interface with the existing pressurized hot water system in such a way as to not disturb the established reliability of the conventional heating system. The interface would be established upstream of the existing steam heat exchangers that supply the required heat to maintain the pressurized water loop at 380°F.

On week days, only partial satisfaction of the load would be provided by the solar system, relying upon the conventional system to complete the demand. On week-ends, solar generated heat would be stored in a 15,000 gallon tank (new) of soft water that would serve as the initial boiler feedwater source at start-up on Monday morning.

A conceptual schematic of the system is shown in Figure 1. In operation, the solar fluid (Exxon HT-43 or equivalent), would be pumped at a controlled rate through the solar collector array and would rise in temperature from an inlet of 400°F to an outlet of 480°F. The flow through the collector field would be modulated to produce the required outlet temperature. The solar fluid would then progress to the pressurized water heat exchanger where it would transfer its heat to the process water loop which is maintained at 185 psig. After leaving the solar heat exchanger, the process water would travel to the existing steam heat exchanger where its temperature would be topped off at 380°F.

A tracking line concentrating type of solar collector is recommended for this application, because of the relatively high temperature levels associated with the process. There are several such collector designs available. The one considered for this feasibility

study documentation has a reflector size of 7 feet x 20 feet, creating an aperture area of 140 square feet per collector.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day output and average weather output. A collector rotation axis in the east-west direction has been assumed. Based on these conditions, the performance for an aperture area of 10,080 square feet is estimated as follows:

Maximum Clear Day Contribution = 10.8 million BTU's per day

Average Annual Contribution = 2.3 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 10,080 square foot solar system of the characteristics described above, with associated mechanical components, instrumentation/control functions and a 15,000 gallon above ground insulated water storage tank, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Pads	5.50	55,440
Collectors	29.00	292,320
Piping, Insulation	3.50	35,280

Mechanical

Solar Heat Exchanger	1.25	12,600
Pumps, Controls	.75	7,560

Storage

20,000 Gallon Insulated Tank	2.50	25,200
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Cost Estimation (con't)

Instrumentation

Sensors	.25	2,520
Data Logger	<u>.50</u>	<u>5,040</u>
Total	43.25	435,960

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

The proprietary nature of many of the processes served by the heat application discussed above prohibits an indepth evaluation of conservation potentials. However, Firestone is obviously quite energy-minded and it would be improbable that an energy conservation source exists that could supply, or significantly reduce the heat demand of the discussed application.

SYSTEM SCHEMATIC

Figure 1

Industrial
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TENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

February 18, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

WESTERN FOOD PRODUCTS CO.
South Hutchinson, Kansas

Application:	Process Steam at 330°F
Collector Type:	Line Concentrator
Field Size:	11,200 Ft ²

WESTERN FOOD PRODUCTS COMPANY
South Hutchinson, Kansas 67501Solar Industrial Process Heat for Cooking Steam Production:
A Feasibility Study at Western Food Products CompanyFirm Background

Western Food Products Company started operation in 1904 as a small pickle works. Today, the company consists of three processing plants in the following locations:

LaJunta, Colorado
Fort Collins, Colorado
South Hutchinson, Kansas

The current product lines of the company include barbeque sauce, salad dressings, vinegar, pickles, tomato juice, catsup, syrup and a variety of fruit preserves. In all, the company employs up to approximately 650 people and has its own fleet of trucks that distribute products in 12 states.

The corporate headquarters of Western Foods are in South Hutchinson, Kansas. Here, they also process the largest variety of products running from preserves to barbeque sauce. It is a relatively modern plant that seems to be well suited for a possible solar industrial process heat application.

Site Description

Hutchinson, Kansas is located in central Kansas approximately 40 miles northwest of Wichita at a latitude of 38° N. It has a mean daily horizontal solar insolation of 1520 BTU/square foot, with

a mean ambient temperature of 57°F. The Western Food Products plant consists of four buildings which total over 130,000 square feet of roof area. The main process building comprises 92,000 square feet. The total land area, including buildings amounts to approximately 17 acres.

A solar collector field size of 11,200 square feet, sized on the basis of reasonable load contribution for a pilot application, could easily be accommodated on the main process building. A feasible collector field layout would consist of 20 rows of 4 collectors each, based on a collector (line concentrator) aperture area of 140 square feet per collector.

Process Description

The process selected at this site as being most feasible for a pilot solar application is simply the production of steam for use in the various cooking processes. The steam is produced in two gas fired boilers at 90 psig (330°F) and is consumed at approximately 6700 pounds per hour. Some of the process steam is throttled down to lower pressure for use in the individual cooking processes.

Rather than design a system for individual process support, which may be somewhat sporadic in demand, it is judged to be most feasible at this site to supply the main process medium. Under these circumstances, there would more likely always be a positive demand for more heat than could be generated by the pilot solar system during production hours.

Solar System Design

The solar system would be designed to supply heat for process steam generation 5 days per week and for storage during 2 days per week.

The week-end heat could feasibly be stored in 20,000 gallons of soft water which could be used directly for boiler feedwater on Monday morning start-up of the boiler. A collector field size of 11,200 square feet would perform well under such conditions. The solar-produced steam during the week days would be produced in a dedicated solar boiler and be fed into the existing steam supply header just downstream of the conventional boiler.

A schematic diagram of the conceived system is shown in Figure 1. In regular production operation, the solar fluid (Therminol 66 or equivalent) would be pumped through the solar collector array at a controlled flow rate and would rise in temperature from an inlet of 350°F to an outlet of 430°F. The flow through the collector field would be modulated to produce the required outlet temperature. After being heated, the solar fluid would progress to the solar steam generator where it would generate 90 psig (330°F) steam. The steam would simply be allowed to discharge into the main steam line feeding the processes, as governed by the solar generated steam pressure.

Components shown in the schematic include an expansion tank with nitrogen ullage for oxidation protection, a water conditioning (softening) subsystem, a boiler feedwater pre-heater to prevent tube thermal shock and associated pumps and controls. A boiler blow-down subsystem would also be provided for scheduled boiler maintenance.

A tracking line concentrating type of solar collector is recommended for this application, because of the relatively high output temperature requirement and the favorable direct component of the solar radiation distribution at this location. There are several such collector designs available. The one considered for this study

has a reflector size of 7 feet x 20 feet, creating an aperture area of 140 square feet per collector.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day output and average weather output. A collector rotation axis in the east-west direction has been assumed. Based on these conditions, the performance for an aperture area of 11,200 square feet is estimated to be:

Maximum Clear Day Contribution = 12.6 million BTU's per day
Average Annual Contribution = 3.0 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing an 11,200 square foot solar system of the characteristics described above, with associated mechanical components, a 20,000 gallon above ground insulated water storage tank and all necessary instrumentation/control functions based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Pads	5.50	61,600
Collectors	29.00	324,800
Piping, Insulation	3.50	39,200
<u>Mechanical</u>		
Solar Boiler	1.50	16,800
Preheater, Pumps, Controls	1.00	11,200
<u>Storage</u>		
20,000 Gallon Insulated Tank	2.50	28,000
<u>Instrumentation</u>		
Sensors	.25	2,800
Data Logger	.50	5,600
Total	43.75	490,000

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

Refrigeration is an obvious source of waste heat in food processing plants such as Western Foods. However, mechanical refrigeration waste heat can, at best, only supply heat up to approximately 150°F. While this might be used to reduce individual process demands or for boiler feedwater heating, it would not materially affect the portion of the heat load that is addressed by the solar application discussed here.

Figure 1

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ELEVENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

February 18, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

MARSCO MANUFACTURING CO.
Chicago, Illinois

Application:	Glass Rinsing at 140°F
Collector Type:	Flat Plate
Field Size:	2,240 Ft ²

MARSCO MANUFACTURING COMPANY
Chicago, Illinois 60608Solar Industrial Process Heat for Glass Rinsing: A Feasibility
Study at the Marsco Manufacturing CompanyFirm Background

Marsco Manufacturing Company was started in 1946 and is a supplier of high quality glass parts to the range and microwave oven segments of the appliance industry. One of its products is a proprietary transparent infrared reflecting coating molecularly bonded to the glass to conserve energy in ranges. The company has a deep committment to energy saving.

Marsco is located in a lower middle income neighborhood in Chicago employing up to 200 employees of primarily minority background. The company processes approximately six million square feet of glass per year.

An increased quantity of hot water from a renewable source such as solar would benefit the company's operations by improving glass washing and drying capabilities, giving it faster thruput and decreasing rejects.

Site Description

Chicago, Illinois is located on the southwestern tip of Lake Michigan at a latitude of $41^{\circ} 30'$ N. The average annual daily horizontal solar insolation for the area is 1010 BTU/square foot, with a mean annual ambient temperature of 51°F .

The Marsco plant is in an urban setting, situated directly on a busy north-south thoroughfare in south Chicago. The plant consists of two separate buildings, separated by a side street. The buildings are older brick structures and well constructed. The process lines are now separated, but will soon be centralized in one building. This building has a high, flat section of approximately 5,000 square feet in area with an unobstructed exposure to the south. It would be well suited for mounting a small collector field sized to match the process needs.

A collector field of 2,240 square feet, sized on the basis of process load requirements, could efficiently be accommodated within the immediately available space. A feasible collector field layout would consist of 4 rows of 20 collectors each, based on an aperture area of 28 square feet per collector.

Process Description

The only process heat application that could feasibly be supplied by solar energy at this site is water heating for glass rinsing. Washing is done with hot water at 140°F and an equal rinse temperature capability is desired. There are three production lines and each line has a detergent wash and a rinse cycle. The wash water is heated by steam from a gas fired boiler. This heat supply appears to be adequate. However, the existing rinse water heat supply, 2 electric water heaters, are inadequate to supply the desired rinse water temperature at current and anticipated production rates. A hot rinse is needed to facilitate drying, minimizing water spotting and reducing rejects.

The total heat capability needed for effective hot rinsing is estimated at 2 million BTU's per day, roughly twice the existing capability. This added load could effectively be supplied by the proposed

collector field size.

Process Energy Profile

The normal plant production schedule is 1 shift per day, 5 days per week. The total glass rinsing heat load of 2 million BTU's per day results in an average demand load of 250,000 BTU/hr.

Solar System Design

The design of a solar system for this application would be very simple. The solar system would simply heat service water which would be stored in an existing 8,000 gallon tank. The tank has been used for gasoline storage which is not needed in present-day operations. Insulation of the tank would be all that would be required for retrofit.

A conceptual schematic of the system is shown in Figure 1. In operation, the solar fluid (e.g. 50% water/ethylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 70-150°F to an outlet of 90-170°F. The fluid would then progress to the process area where it would transfer its heat to incoming service water via a shell-tube heat exchanger. The solar fluid would then progress back to the collector field to repeat the cycle. The heated service water would go into the storage tank for use by the rinsers. Enroute to the rinsers, this water would pass through the existing electric water heaters for any top-off required to bring it up to 140°F.

For this application, a flat-plate type of solar collector is recommended because of the relatively low process temperature and the ability of the flat plate to operate well under diffuse as well as direct radiation. No single design of collector will be recommended here, although a double glazed flat black absorber would probably be

most cost effective under the given environmental and load conditions.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 42° and a mean collector efficiency of 35%. Under these conditions, the performance for an aperture area of 2,240 square feet is estimated as follows:

Maximum Clear Day Contribution = 2.0 million BTU's per day

Average Annual Contribution = 0.4 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 2,240 square foot solar system of the characteristics described above, with associated mechanical components, necessary instrumentation/control functions and insulation for the existing storage tank, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.00	15,680
Collectors	22.00	49,280
Piping, Insulation	3.00	6,720
<u>Mechanical</u>		
Solar Heat Exchanger	1.50	3,360
Pumps, Controls	.75	1,680
<u>Storage</u>		
Paint, Insulate Existing 8,000 Gallon Tank	.50	1,120
<u>Instrumentation</u>		
Sensors	.25	560
Data Logger	.75	1,680
Total	35.75	80,080

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

For the particular application discussed at this site, solar would be supplying a capability that does not now exist. The remainder of the existing process heat is used for wash water heating which is recirculated. No form of heat reclamation is conceived that could supply the capability discussed for this application.

SYSTEM SCHEMATIC

Figure 1

**Industrial
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Associates**

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TWELFTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

February 18, 1980

Submitted by:

Orin L. Murray
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

**BORDEN FOODS
CHEESE DIVISION
Plymouth, Wisconsin**

Application:	Boiler Feedwater to 210°F
Collector Type:	Evacuated Tube
Field Size:	4,043 Ft ²

BORDEN FOODS
Cheese Division
Plymouth, Wisconsin 53073

Solar Industrial Process Heat for Boiler Feedwater Heating: A
Feasibility Study at Borden Foods

Firm Background

The Borden Company, originally operating under the name "Gail Borden Jr. and Company", became Borden, Inc. in 1968. Today, the company is organized into four operating divisions: Foods, Dairy and Services, Chemical and International. Borden was the first to sell milk in bottles, to offer homogenized milk, and to develop Vitamin D fortified milk.

In addition to the familiar dairy and cheese products, Borden's product lines include:

Elmers Glue-All	Formaldehyde
Cracker Jack	RealLemon Lemon Juice
Bama Jams and Jellies	Instant Drinks
Flavor Bases for Yogurts	

Borden products are marketed throughout the world and the company has plants in France, England, Germany, Spain, Denmark, Canada, Brazil, Mexico, Panama, Argentina, Australia, Malaysia, Japan and the Phillipines

The Plymouth, Wisconsin plant produces cheese. The 1979 production totaled 230,000,000 pounds of cheese. The plant employs approximately 600 people. The present plant was initially constructed in 1958 and expanded in 1963 and 1979. The buildings are well constructed and total approximately 300,000 square feet of working and storage area.

Site Description

Plymouth, Wisconsin is located approximately 50 miles north of Milwaukee at a latitude of $43^{\circ} 15'N$. The average annual daily horizontal solar insolation for the area is 1200 BTU/square foot, with a mean annual ambient temperature of $48^{\circ}F$.

The Borden plant faces south and has a relatively unobstructed roof area on the main process building of approximately 56,000 square feet. On the southwest corner of the building adjacent to the power plant, there is a low structure of approximately 9500 square feet of clean roof area.

A solar collector field size of 4,043 square feet, sized on the basis of reasonable load support and single-level roof area utilization, could be efficiently accommodated on the low portion of the building. A feasible collector field layout would consist of 6 rows of 25 collectors each, based on an aperture area of 27.5 square feet per collector.

Process Description

The process selected for support in this feasibility study is boiler feedwater heating. All process heat in this plant comes from steam at 110 psig ($345^{\circ}F$). Total consumption amounts to approximately 7,600 pounds per hour. Almost all of this steam is used in direct injection cooking applications. As a result, only approximately 5% of the condensate is returned. This generates a fairly large boiler feedwater heat load, which could be effectively supplemented by solar energy.

Although it is presently not done for performance and economics reasons, the remainder of the boiler feedwater heating load on the low end, up to approximately $150^{\circ}F$, could be accomplished by refrigeration

heat recovery. Adoption of this option at some point in the future would still leave enough load for the selected solar system size to support. The load breakdown for feedwater heating is as follows:

Below 150°F = 576,000 BTU/hr

Above 150°F = 432,000 BTU/hr

Process Energy Profile

The total boiler feedwater heating load of 1,008,000 BTU/hr exists for a normal cycle of 24 hours per day, 6 days per week.

Solar System Design

The solar system would be designed to initially supply feedwater heating on the low-end (up to 150°F), with the capability of moving to the high-end (150-212°F), if the low-end heat were to be supplied from another source in the future, such as refrigeration waste heat. Since the normal heat demand cycle is 6 days per week, a small (7,000 gallon) above ground heat storage tank would prove cost effective for the storage of hot, soft water that could be input directly into the boiler.

A schematic of the conceived system is shown in Figure 1. In initial low-end operation, the solar fluid (e.g. 50% water/ethylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 70-160°F to an outlet of 90-185°F. The fluid would progress to the boiler room where it would transfer its heat via a shell-tube heat exchanger to cold, soft water which would go into the water storage tank at from 70 to 150°F. This water tank would constitute the regular boiler feed source. The solar fluid, having given up its heat to the feedwater,

would progress back to the collector field to repeat the cycle. In possible future high-end operation, the above temperatures would all be raised by approximately 60°F.

An evacuated-tube type of solar collector is recommended for this application because of the high sensible range temperature potential of the application and the ability of this type of collector to operate well under diffuse as well as direct insolation conditions. For this application, a tube spacing of 50% with shaped reflectors would prove most efficient.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 44° and a mean collection efficiency of 50%. Under these conditions, the performance for an aperture area of 4,043 square feet is estimated to be:

Maximum Clear Day Contribution	5.1 million BTU's per day
Average Weather Contribution	1.1 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 4,043 square foot solar system of the characteristics described above, with associated mechanical components, a 7,000 gallon above-ground storage tank and instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.50	30,323
Collectors	27.00	109,161
Piping, Insulation	3.00	12,129

Cost Estimation (con't)

Mechanical

Solar Heat Exchanger	1.00	4,043
Pumps, Controls	.75	3,032

Storage

7,000 Gallon Insulated Tank	2.75	11,118
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Instrumentation

Sensors	.25	1,011
Data Logger	<u>.75</u>	<u>3,032</u>

Total	43.00	173,849
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Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

As mentioned above, the amount of refrigeration performed at this plant represents a quantity of waste heat that might become a feasible alternate heat source. It is presently not favored because the existing refrigeration system is made to condense at a low temperature range (85-95°F) with the waste heat being carried away in discharge water. Raising the condensation temperature would bring about a reduction in the system efficiency and additional refrigeration equipment would have to be added to handle the existing load. Nevertheless, this might become a viable alternate at some point in the future, at which time the solar system could simply assume the high end of the feedwater heating load (above 150°F), rather than the low end (below 150°F).

SYSTEM SCHEMATIC

Figure 1

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THIRTEENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

March 3, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

AMERICAN CRYSTAL SUGAR CO.
Moorhead, Minnesota

Application:	Waste Water Treatment at 95°F
Collector Type:	Flat Plate
Field Size:	13,440 Ft ²

AMERICAN CRYSTAL SUGAR COMPANY
Moorhead, Minnesota 56561

Solar Industrial Process Heat for Waste Water Treatment: A
Feasibility Study at American Crystal Sugar Company

Firm Background

American Crystal Sugar Company is a Minnesota agricultural cooperative corporation owned by its member-growers. The company processes beet sugar, beet pulp and molasses. The corporation is headquartered in Moorhead, Minnesota.

American Crystal Sugar was formed in 1924 when the American Beet Sugar Company, then headquartered in New York, purchased the Minnesota Sugar Company and the Northern Sugar Company, both sugar beet processing companies operating in the Red River Valley in Minnesota.

The company was purchased by its growers in 1973. Today, the company consisting of 6 operating plants (3 in Minnesota, 2 in North Dakota and 1 in California), is one of the country's leading suppliers of sugar. In 1978, a record 5.9 million tons of sugar beets were harvested by the company, with a sugar content of nearly 1 million tons of sugar.

The Moorhead, Minnesota plant was constructed in 1948. Under normal conditions, the plant can process 5,000 tons of beets daily. An innovation at the Moorhead plant is the production of high grade fertilizer as a bi-product of the process water treatment procedure involving an ion exchange technique.

Site Description

Moorhead, Minnesota is located on the western border of Minnesota at a latitude of 46° 46' N. The average annual daily horizontal solar insolation for the area is 1300 BTU/square foot, with a mean ambient temperature of 41°F. The American Crystal Sugar plant in Moorhead is a large complex, occupying a total of approximately 400 acres, including water treatment lagoons. The plant is situated on the northern edge of the city.

Immediately adjacent to the process to be supported, there is a ground area exceeding 100,000 square feet that would be well suited for locating a solar collector field. A collector field size of 13,440 square feet, sized on the basis of reasonable process load support for a pilot system, could easily be installed at this site. A feasible collector field layout would consist of 40 rows of 12 collectors each, based on an aperture area of 28 square feet per collector.

Process Description

The process selected for solar feasibility evaluation is an unique one involving low grade heat waste water treatment. The plant uses an Anamet system employing anerobic and aerobic techniques for Biological Oxygen Demand (BOD) reduction of process water. The water is processed at the rate of 6.7 million gallons per week.

The Anamet system is designed to operate continuously, 24 hours per day, 7 days per week. The processing of sugar beets starts in September and goes without shut down for 180 to 220 days. The process water is stored in 100+ million gallon lagoons.

The water in the lagoons cannot be released to the river (Red River of the North which flows into Canada) until the BOD meets all state, federal and international (IJC) requirements. The Anamet system provides the required treatment, but the water should be heated to approximately 95°F from 40-72°F before entering the Anamet tank, for maximum system efficiency. The water is presently heated with steam via a heat exchanger at the rate of 695 gpm. Solar energy could provide an effective alternate source for this low grade energy on a year-round basis.

Process Energy Profile

The energy profile for the process waste water treatment covers a range of from 8 million (summer) to 19 million (winter) BTU/hr, 24 hours per day, 7 days per week.

Solar System Design

The solar system design for this application would be very simple. A minimum of components and controls would be required in the solar loop since the pilot system would logically be designed to supply less than the minimum (summer) heat demand. The interface between the existing system and the solar loop would be upstream of the existing steam heat exchanger. This would maintain all control functions within the existing system and the present steam heat exchanger would serve as the top-off heat source for the process.

Future expansion potential for solar-generated heat would be expected to place the greater reliance on solar heat, especially during the summer when beet processing is not going on. At such

time, the necessary controls could easily be added to the solar loop.

A conceptual schematic of the pilot system is shown in Figure 1. In operation, the solar fluid (50% water/ethylene glycol), would be pumped through the solar collector array and would rise in temperature from an inlet of 100°F to an outlet of 120°F. The solar fluid would progress to the process water solar heat exchanger where it would give up its heat to the process water before returning to the collector field to repeat the cycle. After receiving the solar heat, the process water would move to the steam heat exchanger to pick up any additional heat required to bring its temperature up to 95°F.

A flat-plate type of solar collector is recommended for this application because of the low process temperature requirement and the favorable performance characteristics of the flat plate collector under diffuse as well as direct insolation conditions. No one particular design of collector will be recommended here; however, the ambient temperature extremes prevalent at this location would probably render a double glazed, flat black absorber most cost effective.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day output and average weather output. Both analyses assume a collector tilt angle of 47° and a mean collection efficiency of 40%. Under these conditions, the performance for an aperture area of 13,440 square feet is estimated to be:

Maximum Clear Day Contribution = 13.6 million BTU's per day

Average Annual Contribution = 3.1 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 13,440 square foot solar system of the characteristics described above, with associated mechanical components and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	6.00	80,640
Collectors	22.00	295,680
Piping, Insulation	3.00	40,320
<u>Mechanical</u>		
Solar Heat Exchanger	1.00	13,440
Pumps, Controls	.50	6,720
<u>Instrumentation</u>		
Sensors	.25	3,360
Data Logger	.50	6,720
Total	33.25	446,880

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process heat application.

The identified solar application at American Crystal Sugar is for low grade heat of the level that would usually lend itself well to a conservation source. However, it is unceasing in demand and extends beyond the cycle of the regular processing reason. There is literally no heat to conserve for this process during the off-season which lasts up to 6 months per year. For such an application, solar is not only a feasible source, but one which is a true alternate to fossil fuel.

Flat Plate Collectors (13,440 Ft²)

Exp. Tank

240gpm

Solar Ht. Exch.

Existing Steam Ht. Exch.

695gpm

From Lagoon or Process

To Anamet Tank

-6-

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FOURTEENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

March 3, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

DICKSON FOREST PRODUCTS, INC.
Sturgis, South Dakota

Application: Lumber Kilning
to 140°F

Collector Type: Flat Plate

Field Size: 3,640 Ft²

DICKSON FOREST PRODUCTS, INC.
Sturgis, South Dakota 57785

Solar Industrial Process Heat for Lumber Kilning: A Feasibility Study at Dickson Forest Products

Firm Background

Dickson Forest Products in Sturgis, South Dakota is a subsidiary of Mosinee Paper Company, headquartered in Mosinee, Wisconsin. The Sturgis sawmill and chip plant primarily processes ponderosa pine, from initial sawing operations through kiln-drying.

The sawmill was originally started by J.A. Dickson in 1942. It has since been destroyed by fire and rebuilt three times. With each reconstruction, the mill was improved and new capacity added, with the last improvement amounting to a 25 percent increase in capacity.

The mill presently employs approximately 50 persons, working a regular schedule of 1 shift, 5 days per week. Production capacities are from 40 to 50 thousand board feet per day. Shipments of lumber go to wholesalers and lumber brokers in the midwestern states while the chips and pulpwood go to the parent paper mill in Mosinee, Wisconsin.

Site Description

Sturgis, South Dakota is near the western border of the state, approximately 30 miles northwest of Rapid City, at a

latitude of $44^{\circ} 10'N$. The annual average daily horizontal solar insolation for the area is 1455 BTU/square foot, with a mean ambient temperature of $47^{\circ}F$. The Dickson Forest Products mill is situated on approximately 17.7 acres of flat and level terrain. There is an unobstructed southern exposure of one face of the kiln and the adjacent ground, which would make for a novel but efficient method of mounting the solar collectors.

A collector field size of 3,640 square feet, sized on the basis of reasonable process support and immediate space availability, could be installed using the vertical south face of the kiln as the back support for a 5 row planar array, with a ground mounted array of 5 rows to the south of the kiln. Each row would contain 13 collectors, with an aperture area of 28 square feet per collector.

Process Description

The selected process for solar feasibility at Dickson Forest Products is lumber kilning. Specifically, the application would be to preheat the incoming fresh air to the kiln which is drawn in to replace the moisture-laden air which is expelled. This air exchange is handled by 8 vents on the roof of the kiln, which alternate in halves of 4 to inhale fresh air and exhale moist air at the rate of approximately 10,000 cfm. Internal ductwork and baffles provide the air distribution and flow direction. The heat source for the kiln is direct-fired gas burners. The internal set point temperature of the kiln is $170^{\circ}F$. The kiln operates around the clock, 7 days a week with each charge of lumber remaining in the kiln for 48 hours. Kiln temperatures are maintained at all times.

The specific solar contribution to this application would be

to preheat the incoming air up to a maximum of 140°F, reducing the load requirement on the burners. In this manner, the existing burner controls would retain their function at all times and the solar system controls could be greatly simplified. The solar interface would be made in the internal ductwork of the kiln via a liquid/air heat exchange coil for heating the incoming air.

Process Energy Profile

The total burner heat load of the kiln is 1,500,000 BTU/hr, of which an average of 1,000,000 BTU/hr is estimated to be attributed to makeup air heating. This load runs 24 hours per day, 7 days per week.

Solar System Design

The solar system would be designed to supply only part of the air heating load, up to a maximum of 140°F. The remaining load would be supplied by the existing gas-fired burners, retaining high reliability and eliminating redundant controls. Since internal kiln temperatures are maintained at all times, with lumber exchange times reduced to an absolute minimum, there would be a continuous demand for the solar-generated heat and no storage would be required.

A conceptual schematic of the system is shown in Figure 1. In operation, the solar fluid (50% water/ethylene glycol), would be pumped through the solar collector array and would rise in temperature from an inlet of 70-150°F to an outlet of 90-170°F. The fluid would then move to the inlet air heat exchange coil where it would transfer its heat to the incoming air before

returning to the collectors to repeat the cycle. The incoming air would simply be distributed within the kiln as is presently being performed, with the gas burners supplying any additional heat required to maintain the set point temperature of 170°F.

A flat-plate type of solar collector is recommended for this application. The method of mounting depicted in the rendering of the system, using the kiln itself as the back support for a planar array, lends itself especially well to a flat-plate collector design. Also, a flat-plate collector is adequate for this low to medium temperature range, performing well under both diffuse and direct insolation conditions. For this application and climate, a double-glazed selective surface absorber design would be recommended.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 45° and assume a collector efficiency of 35%. Under these conditions, the performance for an aperture area of 3,640 square feet is estimated to be:

Maximum Clear Day Contribution = 3.2 million BTU's per day

Average Annual Contribution = 0.8 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 3,640 square foot solar system of the characteristic described above, with associated mechanical components and necessary instrumentation/control functions, based on first quarter 1980

component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Supports, Framing	6.50	23,660
Collectors	22.00	80,080
Piping, Insulation	3.00	10,920
<u>Mechanical</u>		
Solar Heat Coil	1.50	5,460
Pumps, Controls	.75	2,730
<u>Instrumentation</u>		
Sensors	.25	910
Data Logger	<u>.75</u>	<u>2,730</u>
Total	34.75	126,490

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

At Dickson Forest Products, the single kiln represents the sole process heat requirement. Since the kiln is direct-fire heated, combustion waste heat is minimal. However, heat recovery from the 170°F exhaust air from the kiln might be worth consideration. In this case, the recovered heat might supplement the daytime solar input to the point that little or no additional top-off from the burners would be required under favorable climatic conditions.

SYSTEM SCHEMATIC

Figure 1

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FIFTEENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

March 3, 1980

Submitted by:

Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

PAN-O-GOLD BAKING CO.
Holsum Bread Bakery
Fargo, North Dakota

Application: Bread Proofing
Steam at 245°F

Collector Type: Stationary Concentrator

Field Size: 2,240 Ft²

PAN-O-GOLD BAKING COMPANY
Holsum Bread Bakery
Fargo, North Dakota 58102

Solar Industrial Process Heat for Bread Proofing: A Feasibility
Study at Pan-O-Gold Baking Company

Firm Background

The Pan-O-Gold Baking Company has two plants; in Fargo, North Dakota and St. Cloud, Minnesota. The company employs a total of approximately 450 people, 200 of which make up the work force at the Fargo Holsum Bread Bakery. Together, the two bakeries process a total of 25 million pounds of flour yearly, with approximately 17.5 million pounds being attributed to the Fargo plant.

As the name implies, the Fargo bakery is engaged in the baking of Holsum Bread. The origin of the Fargo bakery dates back to the 1930's with present ownership being assumed in 1966. The bakery underwent a complete refurbishment in 1978 and today, it is obviously in very good condition. The section of roof which is considered most feasible for solar collector mounting is well constructed and completely unshaded. Management attitudes are very positive toward energy conservation and alternate source development.

Site Description

Fargo, North Dakota is located on the eastern border of North Dakota at a latitude of 46° 46'N. The average annual daily

horizontal solar insolation for the area is 1300 BTU/square foot, with a mean ambient temperature of 41°F. The Holsum Bread Bakery has a total roof area of approximately 15,000 square feet, comprised of several levels and sections. The warehouse which is on the northeast corner of the property, has a clean unobscured area of 6,400 square feet on one level. This would be the favored location of the postulated solar collector field.

A collector field size of 2,240 square feet, sized on the basis of effective load support, is feasible for a pilot application at this site. An efficient collector field layout would consist of 5 rows of 16 collectors, mounted in a 2-high stacked configuration. The resulting field size of 2,240 square feet is based on an aperture area of 28 square feet per collector.

Process Description

The process selected for pilot system solar feasibility at this site is process steam production for bread proofing. Bread proofing is performed on the loaves of dough before they are baked, to hasten the rising of the dough under controlled heat and humidity conditions. The loaf pans are placed on racks, rolled into the "proof box" and allowed to stay there for a given time. The proof box is continually being loaded from one side and unloaded from the other. The proof box is room-sized and is temperature and humidity controlled by low pressure steam at 13 psig (245°F).

The proof box is maintained at 128°F and slightly under 100% relative humidity. This is done by steam jackets lining the walls and steam injection into the air. The steam demand of the Holsum Bakery proof box, which holds 25 racks of bread, is 280 pounds per hour or 280,000 BTU/hr.

The specific solar application for this process would be to produce steam at 13 psig and input it to the steam supply header feeding the proof box.

Process Energy Profile

The total proof box heat load is 280,000 BTU/hr, 24 hours per day, 5 days per week.

Solar System Design

The solar system would be designed to produce steam at 13 psig during normal production hours and to store energy in the form of boiler feedwater at all other times. The solar loop would be self-sufficient as far as mechanical components, and would interface with the existing steam system only when it is producing steam of the required quality. In this manner, all existing proof box controls would remain untouched and the operation would not be affected. On week-ends and other non-production hours, the solar-generated heat would be stored in a 4,000 gallon tank (new) of conditioned water which could be used directly as boiler feedwater.

A conceptual schematic of the system is shown in Figure 1. In operation, the solar fluid (Therminol 66 or equivalent), would be pumped at a controlled flow rate through the solar collector array and would rise in temperature from an inlet of 250°F to an outlet of 300°F. After being heated, the solar fluid would progress to the solar steam boiler where it would generate 13 psig (245°F) steam. The steam from the solar boiler would be allowed to discharge into the main steam line feeding the proof box, as

governed by the solar-generated steam pressure.

Components shown in the schematic include an expansion tank with nitrogen ullage for oxidation protection, a water conditioning (softening) subsystem, a boiler feedwater pre-heater to prevent tube thermal shock and associated pumps and controls. A boiler blow-down subsystem would also be provided for scheduled boiler maintenance.

A stationary concentrating type of solar collector is recommended for this application, because of the mid-range temperature capability of this type of collector and its simple operational and mounting characteristics. There are several such collector designs available. The one considered for this study is completely enclosed and glazed, with an aperture area of 28 square feet per panel. The overall plane dimensions of each collector are 104 x 47.5 inches, with the long dimension installed in the east-west direction. A 2-high butt-joined mounting arrangement is recommended for this application, creating a plane 104 x 95 inches, facing south and tilted at 47° from the horizontal.

Performance Estimation

The system performance is estimated from two aspects, maximum clear day performance and average weather performance. Based on an average collector temperature of 275°F and a tilt angle of 47° , the performance for a total aperture area of 2,240 square feet is estimated to be:

Maximum Clear Day Contribution = 2.1 million BTU's per day

Average Annual Contribution = 0.4 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 2,240 square foot solar system of the characteristics described above, with associated mechanical components, a 4,000 gallon above ground insulated storage tank and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.00	15,680
Collectors	28.00	62,720
Piping, Insulation	3.50	7,840
<u>Mechanical</u>		
Solar Boiler	2.00	4,480
Preheater, Pumps, Controls	1.50	3,360
<u>Storage</u>		
4,000 Gallon Insulated Tank	3.00	6,720
<u>Instrumentation</u>		
Sensors	.25	560
Data Logger	.75	1,680
Total	46.00	103,040

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

The production of process steam such as discussed in this application is difficult, if not impossible, to achieve with waste heat. Certainly, no known source exists at this site. Therefore, solar substitution is considered to be a viable alternative to fossil fuel in this application.

Figure 1

Industrial
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SIXTEENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
~~SITE~~ SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

March 3, 1980

Submitted by: Orin L. Murray
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

CRYSTAL TISSUE CO.
Middletown, Ohio

Application: Paper Stock
Preparation to 140°F

Collector Type: Flat Plate

Field Size: 5,040 Ft²

CRYSTAL TISSUE COMPANY
Middletown, Ohio 45042Solar Industrial Process Heat for Paper Stock Preparation:
A Feasibility Study at Crystal Tissue CompanyFirm Background

The Crystal Tissue Company produces a wide variety of grades and types of tissue including wrapping, decorative and absorbent tissues and craft paper. The company was founded in 1894 as the Crystal Paper Company and was renamed the Crystal Tissue Company in 1920. The single plant in Middletown, Ohio supports sales offices in 6 locations; Baltimore, Dallas, Elgin Illinois, Los Angeles, Middletown and New York, as well as more than 2,000 dealers and distributors throughout the world.

Crystal Tissue's plant covers approximately 35 acres located south of Middletown. The total production of the plant amounts to 50+ million pounds of tissue per year. The plant operates on a normal work schedule of 3 shifts per day, 6 days per week.

Since paper production is an energy-intensive operation, conservation and alternate source development are topics of keen interest at Crystal Tissue.

Site Description

Middletown, Ohio is located approximately 40 miles north of Cincinnati at a latitude of 39° 30'N with a mean daily solar radiation level of 1280 BTU/square feet and a mean ambient temperature

of 57°F. The Crystal Tissue plant consists of a number of buildings with the largest energy users situated on the eastern side of the complex near the boiler plant.

A collector field size of 5,040 square feet, sized on the basis of reasonable load interfacing and immediate space availability, could be accommodated near the selected process. A feasible collector field layout would consist of 9 rows of 20 collectors each, based on a collector aperture area of 28 square feet.

Process Description

The process identified as a feasible solar application at this site is "white water" heating to 140°F. The re-cycled white water (process water) is used in stock preparation at 150°F. The water is presently heated by direct 30 psig steam injection in the stock preparation vat. The solar application would be to supply heat to the process water while it is stored in one of the two existing 20,000 gallon tanks. The process water enters these tanks at 70-80°F.

The white water is drawn for use at the rate of 250,000 gallons per day, on cycles of 30 minutes out of each hour. The solar system would not be designed to address the transient load, but would continuously store all available heat in either of the two existing storage tanks.

Process Energy Profile

The plant operates 3 shifts, 6 days per week. The average running stock preparation heat load during plant operation is

4.2 million BTU/hr. However, energy storage at a rate of 3 million BTU/hr can be utilized 7 days per week.

Solar System Design

The solar system would be designed to continuously supply heat to the process water in the storage tanks. This would provide an even load for the solar system that could efficiently utilize all of the heat produced by a 5,040 square foot system. The existing steam coils in the stock preparation vats would remain unchanged and would serve as a top-off heat source to bring the water in the vats up to 150°F.

A schematic diagram of the conceived system is shown in Figure 1. In operation, the heat transfer fluid (50% water/ethylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 70-150°F to an outlet of 90-170°F. The fluid would progress to the white water storage tank area where it would transfer its heat to the process water via a shell-tube heat exchanger. The solar fluid would then progress back to the collector field to repeat the cycle. The process water would simply be pumped out of either of the two storage tanks, circulated through the solar heat exchanger, and returned back to the storage tank for supply to the stock preparation vats.

A flat-plate type of solar collector is recommended for this application, because of the low temperature of the process and the ability of the flat plate to effectively utilize diffuse as well as direct radiation. There are many such collector designs available. Based on local climatic conditions of the site and the

operational temperature requirements of the collector, a double-glazed flat black absorber would probably be most cost-effective.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day performance and average weather performance. Both analyses assume a tilt angle of 40° and an average collection efficiency of 35%. Under these conditions, the performance for an aperture area of 5,040 square feet is estimated to be:

Maximum Clear Day Contribution = 4.5 million BTU's per day

Average Annual Contribution = 1.0 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 5,040 square foot solar system of the characteristics described above, with associated mechanical components and instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.00	35,280
Collectors	22.00	110,880
Piping, Insulation	3.00	15,120
<u>Mechanical</u>		
Solar Heat Exchanger	1.25	6,300
Pumps, Controls	.75	3,780
<u>Instrumentation</u>		
Sensors	.25	1,260
Data Logger	.75	3,780
Total	35.00	176,400

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

The solar application identified at Crystal Tissue is one which will work to eliminate energy spikes, which usually are accompanied by significant losses. Hence, the use of a steady source such as solar in conjunction with a large existing storage capacity serves as an effective energy conservation measure in itself. There is no apparent waste heat source that could serve the heat load discussed in this application.

SYSTEM SCHEMATIC

Figure 1

Industrial
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PHONE (314) 921-5029

SEVENTEENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

March 3, 1980

Submitted by: Orin L. Murray
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

AMERICAN MOTORS CORPORATION
Kenosha, Wisconsin

Application: Car Body
Washing at 180°F

Collector Type: Evacuated Tube

Field Size: 9,680 Ft²

AMERICAN MOTORS CORPORATION
Kenosha, Wisconsin

Solar Industrial Process Heat for Car Body Washing: A Feasibility Study at American Motors

Firm Background

American Motors is a familiar organization to the American motoring public. The company is a pioneer leader in one of the nation's most highly competitive industries. Its compact Rambler cars sparked a modern revolution in the automotive industry. Today, American Motors is one of America's fifty largest industrial companies, with sales throughout the U.S. and 140 foreign countries.

The company's administrative headquarters are in Detroit, where sales, purchasing, research, experimental engineering and styling departments are also centered. Automobile manufacturing is concentrated in Wisconsin, with plants at Kenosha and Milwaukee and a proving ground near Burlington.

The company was founded in 1902 as the Thomas B. Jeffery Company of Kenosha, Wisconsin. It was purchased in 1916 by Charles W. Nash, formerly the president of General Motors. The company assumed its present corporate structure with the merger of Nash-Kelvinator and Hudson Motor Car Company in 1954.

The Kenosha plant of American Motors produces the Eagle, Concord and Spirit automobiles at the rate of 975 units per day, a 34 percent increase from last year. The plant employs 7,000 people, who work on 3-shift, 5 day work weeks. Total property area

of the Kenosha complex is 165 acres with 3,800,000 square feet of floor space.

Site Description

Kenosha, Wisconsin is located approximately 30 miles south of Milwaukee, at a latitude of 43° N. The annual average daily horizontal solar insolation for the area is 1250 BTU/square foot, with a mean annual ambient temperature of 49° F.

The American Motors plant consists of a number of individual buildings in an urban setting. One of the main process buildings (Building 40), where the potential solar application has been identified, has a total roof area of approximately 205,000 square feet. Approximately one-third of this roof, or 68,000 square feet, is unobstructed and would be well suited for solar collector mounting.

A solar collector field size of 9,680 square feet, sized on the basis of load/storage balance and efficient roof area utilization, could be well accommodated on the identified building. A feasible collector field layout would consist of 22 rows of 16 collectors each, based on an aperture area of 27.5 square feet per collector.

Process Description

The process selected for potential solar support in this feasibility study is an operation called Bonderite washing. The car bodies, before being painted, are progressively submerged in a series of tanks of graduated temperatures starting with a pre-wash bath at 180° F and finishing with a chromatic acid bath at 120° F.

The purpose of the process is to clean and slightly etch the

metal, providing a good surface for paint adherence. The tanks are heated with steam coils fed by 150 psig steam. The most substantial heat load is in the pre-wash bath at 180°F, with the successive tanks benefiting from the heat cascading effect of the hot car bodies from the previous bath. The heat load of the pre-wash bath is the one selected for potential support, estimated at 1,600,000 BTU/hr.

The solar heat input for this application would be via a shell-tube heat exchanger that would interface the solar fluid with the pre-wash solution which would be withdrawn and returned to the pre-wash tank. Since the normal work week is 5 days, thermal storage would be required for capture of weekend heat. This heat would be used at Monday morning start-up to bring the process fluid and solar loop fluid up to operating temperature quickly.

Process Energy Profile

The Bonderite washing (pre-wash) heat load of 1,600,000 BTU/hr exists for a normal cycle of 16 hours per day, 5 days per week.

Solar System Design

The design of the solar system would be based on 1-shift support of the process with no storage for a minimum of 5 days per week and enough storage capacity for 2-day weekends. This storage capacity would be provided by a 15,000 gallon insulated water tank. This hot water, stored at up to 200°F, would be used on Monday morning for initial process and solar loop warm up. The storage would also be useful during extended maintenance downtime of the line.

A schematic of the conceived system is shown in Figure 1. In active operation, the solar fluid (50% water/ethylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 180 °-200°F to an outlet of 200°-225°F. The fluid would then progress to the solar heat exchanger where it would transfer its heat to the pumped pre-wash solution before returning to the collector field to repeat the process. The heated pre-wash solution would simply return to the tank. Flow rates and maximum temperature changes for each loop would be as follows:

Solar loop: 150 gpm; $\Delta=25^{\circ}\text{F}$

Pre-wash loop: 630 gpm; $\Delta=5^{\circ}\text{F}$

An evacuated-tube type of solar collector is recommended for this application because of the high sensible-temperature range of the process. For this application and location, a tube spacing (density) of 50% with shaped reflectors would prove most efficient.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 44° and a mean collection efficiency of 50%. Under these conditions, the performance for an aperture area of 9,680 square feet is estimated to be:

Maximum Clear Day Contribution = 12.2 million BTU's per day

Average Annual Contribution = 2.7 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 9,680 square foot solar system of the characteristics described

above, with associated mechanical components, a 15,000 gallon above ground insulated storage tank and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.50	72,600
Collectors	27.00	261,360
Piping, Insulation	3.00	29,040
<u>Mechanical</u>		
Solar Heat Exchanger	1.00	9,680
Pumps, Controls	.75	7,260
<u>Storage</u>		
15,000 Gallon Insulated Tank	2.50	24,200
<u>Instrumentation</u>		
Sensors	.25	2,420
Data Logger	.50	4,840
Total	42.50	411,400

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

The identified solar application in this feasibility study is a relatively high quality heat application at 180°F. Additionally, the temperature swing of the process solution must be narrow in order to maintain good process control. Both requirements lead to a high temperature source; one that is not available in the process vicinity in the form of waste heat. Therefore, the identified solar application is apparently a viable substitute for fossil fuel.

SYSTEM SCHEMATIC

Figure 1

Industrial
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EIGHTEENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

March 3, 1980

Submitted by:

Orin L. Murray
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

C. F. INDUSTRIES, INC.
Freemont Nitrogen Complex
Freemont, Nebraska

Application: Boiler Feedwater

Collector Type: Flat Plate

Field Size: 10,640 Ft²

CF INDUSTRIES, INC.
Fremont Nitrogen Complex
Fremont, Nebraska 68025

Solar Industrial Process Heat for Boiler Feedwater Heating: A
Feasibility Study at CF Industries

Firm Background

CF Industries is North America's leading manufacturer and distributor of chemical fertilizers. It is owned by 19 regional farm supply cooperatives in the U.S. and Canada. The organization was founded in 1946 and has its headquarters in Long Grove, Illinois. Total worldwide employment is approximately 3,600.

Through its 9 manufacturing complexes, mining operations and a wide-ranging distribution network, CF Industries supplies member cooperatives with approximately 18 billion pounds of fertilizer products annually. The three basic constituents of chemical fertilizer are nitrogen, phosphate and potash.

The company operates 7 nitrogen complexes, 6 in the U.S. and 1 in Canada:

Donaldsonville, Louisiana	Chattanooga, Tennessee
Ahoskie, North Carolina	Terre Haute, Indiana
Fremont, Nebraska	Olean, New York
Medicine Hat, Alberta, Canada	

Phosphate plants are operated in 3 Florida locations:

Hardee, Florida	Mining
Bartow, Florida	Manufacturing
Plant City, Florida	Manufacturing

Although CF Industries does not share ownership in potash mining facilities, the organization holds beneficial supply contracts with major potash producers in Saskatchewan and in New Mexico. These supply contracts allow CF to maintain its role as a total plant food supply source for its member owners.

The Fremont Nitrogen Complex of CF Industries was formed in 1971 through stock acquisitions of Fel-Tex, Inc. of Fremont, Nebraska which had been operating the plant since 1965. Presently, the plant employs approximately 50 people and produces 120 tons of Anhydrous Ammonia per day, operating 24 hours per day, 7 days per week. The plant management is very progressive and energy concious.

Site Description

Fremont, Nebraska is located approximately 45 miles northwest of Omaha at a latitude of $41^{\circ} 30'N$. The annual average daily horizontal solar insolation for the area is 1405 BTU/square foot, with a mean ambient temperature of $53^{\circ}F$.

The CF Industries Nitrogen Complex is situated on one-half section (320 acres) of flat terrain north of Fremont. Directly adjacent and to the east of the process selected for pilot solar feasibility is a large unobstructed area of ground which would be well suited for a solar collector field.

A collector field size of 10,640 square feet, sized on the basis of reasonable load support for a pilot application, would fit easily on the selected ground area. A feasible collector field layout would consist of 19 rows of 20 collectors each, based on a single collector aperture area of 28 square feet.

Process Description

The process selected for potential pilot solar application at this site is boiler feedwater heating. In the manufacture of anhydrous ammonia and the related sub-products of nitrogen solutions, approximately 60,000 pounds per hour of steam is consumed. Of this amount, approximately 32,500 pounds per hour (65gpm), or 54 percent, of the feedwater is made up from a deep well located on the property. The nature of the varied heat applications in the process operations prevents a larger percentage of condensate to be returned.

The well water is supplied at a near-constant temperature of 55°F throughout the year. Because of its high oxygen content, it is processed through a deaerator where steam injection strips out much of the dissolved oxygen and supplies some preheat to the water. From there, the feedwater goes to 4 boilers, 3 of which are supplied by waste heat from flue gas.

The conceived solar interface would be just upstream of the deaerator, which would add up to 50°F of preheat to the feedwater, bringing it up to approximately 105°F, thereby increasing the effectiveness of the deaerator and reducing the steam demand for preheat. The solar system would thus supply up to approximately one-third of the total preheat load for the 65 gpm of feedwater makeup required.

Process Energy Profile

The total boiler feedwater preheat load, from 55°F to 212°F, is 5,106,580 BTU/hr, 24 hours per day, 7 days per week.

Solar System Design

The design of the solar system for this application would be extremely simple. No storage and only a minimum of controls would be required, since the process will always demand substantially more than the solar system, as sized for the pilot application, can supply. The interface will be via a shell-tube heat exchanger just upstream (in the feedwater circuit) of the existing deaerator. The temperatures are low enough that high system efficiencies can be expected.

A schematic of the conceived system is shown in Figure 1. In operation, the solar fluid (50% water/ethylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 60-110°F to an outlet of 80-130°F. The solar fluid would then progress to the interface solar heat exchanger where it would give up its heat to the incoming feedwater before returning to the collector field to repeat the cycle. After receiving the solar heat, the feedwater would progress to the deaerator to be reduced in dissolved oxygen and receive additional preheat.

A flat-plate type of solar collector is recommended for this application, because of the low selected process temperature range and the favorable performance characteristics of the flat plate collector under diffuse as well as direct insolation conditions. No particular design of collector will be recommended here; however, the average ambient and collector output temperature requirements would probably point toward a single-glazed, flat black absorber as being most cost-effective.

Performance Estimation

The system performance is estimated from two aspects; maximum

clear day output and average weather output. Both analyses assume a collector tilt angle of 42° and a mean collection efficiency of 45%. Under these conditions, the performance for an aperture area of 10,640 square feet is estimated to be:

Maximum Clear Day Contribution = 12.1 million BTU's per day

Average Annual Contribution = 3.0 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 10,640 square foot solar system of the characteristics described above, with associated mechanical components and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	6.00	,63,840
Collectors	20.00	212,800
Piping, Insulation	3.00	31,920
<u>Mechanical</u>		
Solar Heat Exchanger	1.00	10,640
Pumps, Controls	.50	5,320
<u>Instrumentation</u>		
Sensors	.25	2,660
Data Logger	.50	5,320
Total	31.25	332,500

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to

any industrial process heat application.

Waste flue gas heat is already being captured at this site for fueling 3 of the 4 steam boilers. There is no other known source of waste heat at this site that could supply the required heat addressed in this application.

SYSTEM SCHEMATIC

Figure 1

Industrial
Solar
Associates

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NINETEENTH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

March 3, 1980

Submitted by:
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

Application: Glass Washing
at 140°F

Collector Type: Evacuated Tube

Field Size: 3,300 Ft²

VIRACON, INC.
Owatonna, Minnesota 55060

Solar Industrial Process Heat for Glass Washing: A Feasibility
Study at Viracon, Inc.

Firm Background

Viracon, Inc. manufactures laminated auto glass products including sunroofs, windshields, rear windows and flat laminated glass. The company is a division of the Apogee Corporation. There are Viracon plants in three locations; the Owatonna complex which consists of two buildings, the Chicago and Bensenville, Illinois plants. The Owatonna plant was founded in 1970.

Total glass production of all Viracon plants totals approximately 400,000 pounds per day. Of this total, the Owatonna plant is responsible for roughly 50 percent. The Owatonna plant works on a normal production schedule of 16 hours per day, 5 days per week. The plant is situated on 14.5 acres on the northern edge of Owatonna in a modern industrial park. Together, the two Owatonna plant buildings comprise 160,000 square feet of working space.

Energy conservation is taken very seriously at Viracon. At the Owatonna plant, process heat is conserved to such a degree and the buildings are insulated to the extent that all building heat is normally supplied from process heat. Also, all building energy services such as lighting, heating and air conditioning are controlled and monitored by a microprocessor.

Site Description

Owatonna, Minnesota is located approximately 45 miles south of Minneapolis at a latitude of 44° N. The average annual daily horizontal solar insolation for the area is 1280 BTU/square foot, with a mean annual ambient temperature of 44° F.

The Viracon plant buildings are well constructed, of modern design with flat roofs. The total roof area stands at approximately 168,000 square feet. The main process building, the proposed site for the solar collector field, has a roof area of approximately 84,000 square feet, measuring 280 feet by 300 feet.

A collector field of 3,300 square feet, sized on the basis of process load requirements, could easily be accommodated on the southwest corner of the process building roof. A feasible collector field layout would consist of 10 rows of 12 collectors each, based on an aperture area of 27.5 square feet per collector.

Process Description

The process selected for solar feasibility work-up at this site is glass washing. There are 4 production lines, each with its own washer, which sprays 140° F water over the glass as it passes through the washer on a conveyor. Following the wash operation, the glass is simply air-dried at room temperature. The washer reservoirs are heated by steam injection at 135 psig (358° F). There is fresh water makeup at the rate of 24 gallons per hour for each of the 4 washers (96 gpm total), to maintain water cleanliness. The total heat load for makeup water heating and process consumption is approximately 2.2 million BTU's per day, based on a 16 hour day. The proposed collector field size of 3,300 square feet could effectively

supply this required heat.

The specific solar objective for this process would be to provide a quantity of hot water, approximately 2300 gallons per day up to 200°F, that would supply both the heat and the water makeup for all of the washers. This hot water would be stored in an insulated tank located centrally to the washers. The total storage capacity would be sized at 6,000 gallons for 2-day weekend storage capacity at higher than average solar insolation conditions. This hot water would then be available at Monday morning start-up for washer support as well as possible boiler feedwater.

Process Energy Profile

The process energy profile for glass washing is 2,200,000 BTU/day or 137,500 BTU/hr, based on the normal 16 hour work day, 5 days per week.

Solar System Design

The design of the solar system for this application would be based on energy storage at all times when the system is operational. The heat (and makeup water) would then be taken from this central storage as needed for glass washing.

A schematic of the conceived system is shown in Figure 1. In operation, the solar fluid (50% water/ethylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 70-200°F to an outlet of 90-225°F. The fluid would then progress to the storage tank where it would transfer its heat to the incoming fresh water via a shell-tube heat exchanger. The solar fluid would then progress back to the collector field to repeat the cycle. The heated water would go into the storage

tank for use by the washers.

For this application, an evacuated-tube type of solar collector is recommended because of the relatively high sensible-range storage temperature requirement. Because of the significant diffuse component in the average insolation conditions a tube spacing of 50% is recommended, with shaped reflectors behind the tubes.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 45° and a mean collector efficiency of 50%. Under these conditions, the performance for an aperture area of 3,300 square feet is estimated as follows:

Maximum Clear Day Contribution = 4.2 million BTU's per day

Average Annual Contribution = 0.9 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 3,300 square foot solar system of the characteristics described above, with associated mechanical components, a 6,000 gallon above ground insulated storage tank, and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	7.50	24,750
Collectors	27.00	89,100
Piping, Insulation	3.00	9,900

Cost Estimation (con't)

Mechanical

Solar Heat Exchanger	1.25	4,125
Pumps, Controls	.75	2,475

Storage

6,000 Gallon Insulated Tank	2.75	9,075
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Instrumentation

Sensors	.25	825
Data Logger	.75	2,475

Total	43.25	142,725
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Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

Process heat conservation at Viracon is being practiced to a fine degree, eliminating the usual need for a separate building heat source. There is no apparent energy conservation measure that can supply or significantly reduce the heat load discussed for solar application at this site.

SYSTEM SCHEMATIC

Figure 1

Industrial
Solar
Associates

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TWENTIETH CASE STUDY

Contract: MA-SC-79-MO-0008

SOLAR FEASIBILITY STUDY FOR
SITE SPECIFIC INDUSTRIAL PROCESS HEAT APPLICATIONS

March 3, 1980

Submitted by:

Orin L. Murray
Orin L. Murray, President
Industrial Solar Associates

Submitted to: MASEC CORPORATION
8140 26th Avenue South
Bloomington, MN 55420

RALSTON PURINA CO.
Soybean Processing Plant
Iowa Falls, Iowa

Application: Soybean Meal
Drying at 160°F

Collector Type: Evacuated Tube

Field Size: 10,780 Ft²

RALSTON PURINA COMPANY
Soybean Processing Plant
Iowa Falls, Iowa

Solar Industrial Process Heat for Soybean Meal Drying: A Feasibility Study at the Ralston Purina Company

Firm Background

The Ralston Purina Company was founded in 1894 as Robinson-Danforth Commission Company, St. Louis, Missouri. The corporate headquarters of the organization have remained in St. Louis. Ralston Purina is a broadly-based, protein-oriented food and feed company, building on a foundation of agricultural products and services, and expanding into other consumer industries. Its operations fall in four categories:

Grocery Products

Agricultural Products

Restaurants

Diversified Business

The company produces such food products and ingredients as cereals, poultry products, edible soy protein products, crackers, cookies, mushrooms and canned tuna. It is the world's largest producer of dry dog food and dry and soft-moist cat food, and of commercial feeds for livestock and poultry. One of the largest processors of soybeans in the United States, the company produces soybean meal and oil for sale to others.

Ralston Purina has facilities and personnel throughout the United States, in Canada, Mexico, Central and South America, Europe, Australia, Asia and Africa. Worldwide, the company employs approximately 70,000 people with approximately 61,000 in

the United States.

The Ralston Purina plant in Iowa Falls, Iowa is a soybean processing facility. It employs approximately 50 people and is a year-around, 7 day per week operation. From a continuous flow of raw soybeans, the plant produces 800 tons of soybean meal and 200 tons of soybean oil per day.

The importance of energy to the present and future operations of Ralston Purina is evidenced by corporate level energy responsibility assignment and the cooperative and progressive attitude displayed at both the corporate and local plant management levels.

Site Description

Iowa Falls, Iowa is located approximately 70 miles northeast of Des Moines, at a latitude of $42^{\circ} 20'$ N. The annual average daily horizontal solar insolation for the area is 1290 BTU/square foot, with a mean annual ambient temperature of 49°F . The Ralston Purina plant is situated on approximately 20 acres of flat terrain just south of the Iowa Falls business district. There is an unobstructed plot of newly acquired ground of 6 acres directly adjacent and to the south of the plant. This ground has been partially set aside for plant expansion, leaving an ample area for solar collector field mounting immediately adjacent to the selected process for solar feasibility.

A collector field size of 10,780 square feet, sized on the basis of reasonable load support with no storage, would be feasible for a pilot application. An efficient collector field layout would consist of 28 rows of 14 collectors each, based on a single collector aperture area of 27.5 square feet.

Process Description

The process selected for potential solar application at this site is soybean meal drying. In a continuous process, the soybeans are cracked, flaked, processed through the oil extractor, then dried for shipment. The meal enters the dryer at approximately 225°F and 18% moisture. The dryer, a rotary steam tube dryer measuring 6 feet in diameter by 50 feet long, dries the meal down to approximately 13% moisture content. The dryer rotates and tumbles the meal which is dried by contact with internal steam tubes at 366°F (150 psig) and by hot air flow at 150-160°F which is continuously being drawn through the dryer at approximately 10,500 cfm. This air is drawn in from outside the dryer building and is heated by steam coils (150 psig, 366°F) in the inlet duct.

The specific solar application would be to supply heat to the outside ambient air before it is drawn past the existing steam coils, thus reducing the load demand on the steam coil, which is designed for a load of 1,670,000 BTU/hr. A liquid-to-air heat exchanger interfacing with the solar fluid loop would be placed upstream of the existing steam coils in an extension of the existing inlet duct. The new solar heat coil would require approximately 40 square feet of frontal flow area in addition to the existing 14.5 square feet, which may require a slight increase in the existing blower motor horsepower.

Process Energy Profile

The design heat load for soybean meal drying is 1,670,000 BTU/hr, 24 hours per day, 7 days per week.

Solar System Design

The solar system would be designed to supply heat to the inlet ambient airstream to the dryer, up to a maximum rate that would just match the existing design heat load. At all other times, the existing steam coils would supplement the solar heat to bring the incoming air up to 160°F. This type of operation would require no storage and would provide maximum cost effectiveness. In order to handle the solar heat on the infrequent occasions when the dryer is inoperative, a heat-dump damper would be incorporated into the inlet duct, which would simply expel the heat to the atmosphere.

A conceptual schematic of the system is shown in Figure 1. In operation, the solar fluid (50% water/propylene glycol) would be pumped through the solar collector array and would rise in temperature from an inlet of 100-200°F to an outlet of 120-225°F. The fluid would then progress to the dryer air intake where it would transfer its heat to the incoming ambient air. From the dryer, the solar fluid would travel back to the collector field to repeat the cycle. Seasonal climatic variances and daily insolation conditions would determine the duration and amount of solar heat contribution each day, as covered in the performance estimation below.

An evacuated-tube type of solar collector is recommended for this application because of the medium to high output temperature required for effective liquid/air heat exchange and the ability of this type of collector to operate well under diffuse as well as direct insolation conditions.

Performance Estimation

The system performance is estimated from two aspects; maximum clear day performance and average weather performance. Both analyses assume a collector tilt angle of 43° and a mean collection efficiency of 50%. Under these conditions, the performance for an aperture area of 10,780 square feet is estimated to be:

Maximum Clear Day Contribution = 13.6 million BTU's per day

Average Annual Contribution = 3.1 billion BTU's per year

Cost Estimation

The estimated incremental and total costs of installing a 10,780 square foot solar system of the characteristics described above, with associated mechanical components and necessary instrumentation/control functions, based on first quarter 1980 component and labor costs are as follows:

<u>Collector Field</u>	<u>\$/Ft²</u>	<u>Total \$</u>
Collector Supports	6.00	64,680
Collectors	27.00	291,060
Piping, Insulation	3.00	32,340
<u>Mechanical</u>		
Solar Heat Coils, Ducting	1.50	16,170
Pumps, Controls	.75	8,085
<u>Instrumentation</u>		
Sensors	.25	2,695
Data Logger	.50	5,390
Total	39.00	420,420

Energy Conservation as an Alternate to Solar

Waste heat reclamation represents a potential that should be thoroughly explored before considering a solar interface to any industrial process application.

At the Iowa Falls Ralston Purina plant, energy conservation is supplying a significant part of the solvent heating in the soybean oil extraction process. For the drying operation, low grade exhaust heat recovery has been considered, but concluded to be impractical if not impossible, because of the high starch content of the effluent. Therefore, a solar source for the specified process heat application is felt to be a viable displacement of fossil energy.

SYSTEM SCHEMATIC

Figure 1