PN-ABA-417

isn-57196

29 APR 1986

APPLICATION REVIEW FOR FIELD TEST NUMBER 3

POULTRY PROCESSING (INDUSTRIAL PROCESS HEAT)

GENERAL POULTRY COMPANY

HELIOPOLIS, EGYPT

APRIL, 1986

FINAL

RENEWABLE ENERGY RESOURCES

FIELD TESTING '86

APPLICTION REVIEW FOR FIELD TEST NUMBER 3
SUBTASK 3.3.1, GENERAL POULTRY COMPANY
AT HELIOPOLIS, EGYPT

APRIL 1986

DRAFT FINAL

PREPARED FOR

EGYPTIAN ELECTRICITY AUTHORITY

CAIRO, EGYPT

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

USAID MISSION: CAIRO, EGYPT

SUBMITTED TO

LOUIS BERGER INTERNATIONAL, INC.

WASHINGTON, D.C.

(CONTRACT AID 263-0123C-00-4069-00

LOCKWOOD GREENE PROJECT NUMBER 84208.02

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FOREWORD

APPLICATION REVIEW

The Egyptian Electricity Authority(EEA), The United States Agency for International Development (USAID/Cairo), and a group of U.S. consultants form a team responsible for conducting field test demonstration projects for eleven renewable energy applications in Egypt. These demonstration projects include the use of photovoltaic, wind, and solar thermal systems for water pumping, ice making, desalination, industrial process heat, and grid-connected electricity generation. The specific objectives of the four-year program are: (1) to demonstrate the viability of renewable energy technologies in Egypt, (2) to comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy planning and decision making, and (3) to establish the infrastructure necessary to ensure that renewable energy technologies, which have proven successful, are available for widespread use in Egypt.

Each of the field tests contains seven generic tasks: Technology Review, Application Review, Conceptual Design, Preparation of a Statement-of-Work for a Tender Document, Proposal Evaluation, Supervision of Hardware Installation, and Performance Evaluation. Five of the eleven potential field test demonstration projects are Solar Thermal Industrial Process (IPH) Heat Applications. The Application Review for one of these five field tests, General Poultry Company, is presented in this document.

The proposed field test site is located in Heliopolis, near Cairo. The system consists of a solar IPH system (designed to fill and maintain the scalder tanks' hot water level), steam flash tank, and a steam condensate return system. Each is designed to operate independently.

This Application Review is the key document on which a decision to proceed further with this particular field test will be based. The review summarizes an evaluation of the proposed field test location, user requirements, solar resource assessment, and the technology of solar thermal industrial process heat in combination with a flash steam system and condensate return system to meet the load levels required for processing poultry.

A preliminary engineering cost estimate was completed as part of this Application Review in support of Task 2.1. This cost estimate is presented in Appendix -A- of this document.

This document is subtask 3.3.1 of the field test requirements under Contract AID 263-123C-00-4069-00, Task Area 3. The recommendations made in this document are based on the technical merit of the application. The results from Task 2.1, Market/Economic Assessment, address other factors that may impact the potential for widespread implementation of Solar Thermal Industrial Process Heat Systems in Egypt. Task 2.1 results are provided in a separate document.

Finally, general background technical information on Solar Thermal is being provided in the Solar Thermal Reference Notebook (TRN) under Task 2.2.4. Section 5.0 of this Application Review contains a summary of the TRN information relevant to this specific field test.

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1.0 EXECUTIVE SUMMARY

1.1 Criteria for the Field Test Evaluation

The proposed field test for a Solar Thermal Industrial Process Heat System is one of the original eleven field tests under the Renewable Energy Field Testing (REFT) Project. The principal objective of this field test project is to provide the Egyptian Electricity Authority (EEA) with practical working experience using Solar Thermal Industrial Process Heat for the poultry processing industry. This experience includes system design, operation, maintenance, repair, and evaluation of Solar Thermal Industrial Process Heating Systems for the purpose of assessing and implementing similar projects throughout Egypt.

There are a number of key factors that provide the context for the Application Review and support the evaluation of the desirability to proceed with a particular field test. The first factor is the degree to which the field test contributes to the objectives of the overall REFT Project. The Project has broad objectives to investigate selected renewable energy options:

1. Comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy planning and decision-making for technologies and applications;

2. Develop and sustain an Egyptian renewable energy infrastructure through establishment of data bases, information systems, and organizations that effectively serve both the public and private sectors;

3. Design, realize, and evaluate the performance of a series of field tests which utilize commercially available technologies in applications having potential for widespread use in Egypt;

4. Complete formal managerial and technical training, both on-the-job and specialized, and an intensive information disseminaton program.

An assessment of the contribution of this specific field test to the REFT Project objectives must consider the criteria necessary for a successful demonstration of any Solar Thermal Industrial Process Heat system. These criteria are listed below, although not necessarily in order of importance.

1. Current and future user needs
2. A viable solar resource
3. Proven, reliable, and commercially available systems
4. Site characteristics and infrastructure for installation
5. Capability for successful operation and maintenance of the systems
6. Potential for widespread use in Egypt

The application of a Solar Thermal Industrial Process Heating System for General Poultry will serve as a demonstration of the capability of the combined technology of Solar Thermal Industrial Process Heat, Flash Steam Technology, and Condensate Return Systems to reliably supply significant amounts of energy. As in the General Poultry Application Review, other Solar IPH candidates should evaluate all waste heat sources' potential prior to assessing a solar thermal system. It is important that this field test be designed to distinguish between the performance of Solar Thermal Industrial Process Heat, Flash Steam Technology, and Condensate Return Systems, so that each can be evaluated for other applications. This field test will also provide valuable data on the performance of Solar Thermal in comparison to Flash Steam and Condensate Return Systems under similar levels of maintenance and operational support.

The following paragraphs summarize the findings of various studies and analyses addressing these criteria. Detailed discussions of each are provided in the respective sections of the document or in additional published documents as referenced.

1.2 Current and Future User Requirements

Three site visits were made by representatives from Lockwood Greene Engineers, Incorporated and EEA to collect information relevant to the poultry proccessing industry's energy consumption, solar resource, relevant institutional factors, and market and economic data.

The General Poultry company is a facility near Cairo, Egypt, that currently processes 50,000 chickens per day. Another processing line is under construction which will process an additional 50,000 chickens per day.

The facility includes a slaughter area, scalding tank, rendering removal (feathers, organs, heads, feet, etc.) area, rendering cooker area, cleaning area, and packaging area.

Hot water for scalding is presently provided by steam from boilers now fired with fuel oil.

The renderings are placed in cookers where moisture is evaporated, using high pressure steam from oil fired boilers. The remaining cooked solid product is used as chicken feed on the participating farms.

1.3 The General Poultry Company's Energy Resources

Three energy sources were identified:

1. Solar thermal industrial process heat to provide the scalders with fill water and make-up water at 60°C (140°F).

2. High pressure condensate from the rendering cookers that can be flashed to a lower pressure allowing the creation of low pressure steam and condensate.

3. Steam condensate that is presently going to the drain system.

1.4 Preliminary Conceptual Design

1. The heat load on the scalder is created by evaporation losses, radiation losses, and cold make-up water additions which are created as birds leave the scalder carrying hot water entrained in their feathers. The entrained water must then be replaced.

2. Once the renderings are removed from the bird, the renderings are placed in cookers. Five rendering cookers using high pressure steam reduce the renderings to solids. The cookers' high pressure steam condensate will be flashed to low pressure steam and condensate.

   The low pressure steam will be used to maintain the scalder's temperature and the condensate will be returned to the boilers.

3. All existing low pressure condensate will be returned to the boilers, thus minimizing cold water make-up requirement and improving boiler efficiency.

1.5 Conclusions and Recommendations

Based on this Application Review, the following conclusions and recommendations are provided.

Conclusions

1. The design, operation, maintenance, and repair experience with Solar Thermal Systems that will be obtained through this field test will form a strong technical base for the design and application of other similar renewable energy applications.

2. Data from this field test can be shared with the public and private sectors through the REIS System (Rsearch Energy Information System).

3. The General Poultry facility is an acceptable application for demonstrating the use of Solar Thermal Industrial Process Heat because there is an existing and growing demand for processed poultry.

4. General Poultry employs engineers and technicians that can be trained to operate and maintain this solar system.

5. The solar resource is exceptional and the processing plant provides a balance between Solar Thermal, Flash Steam, and a Condensate Return System.

6. The sizing of the systems is based on average hourly demands due to demand fluctuations during the day.

7. A modular design using prover, reliable, and commercially available systems is considered to minimize initial cost and so that future additional capacity can be added.

8. The most economically feasible and most reliable choice, on a long term basis, is a flat plate collector array with corresponding storage tank and delivery system.

Recommendations

1. Install a steam flash tank, where high pressure condensate from the rendering cookers is reduced to a lower pressure creating low pressure steam and condensate. The low pressure steam will be used in the scalders and low pressure condensate returned to the boilers.

2. Return all steam condensate to the boilers.

3. Install a 4,000 square foot (370 square meter) solar array with storage tank, controls and piping to provide the scalders hot water.

2.0 OBJECTIVES AND BACKGROUND

2.1 Objectives

The primary objectives of this field test are to provide EEA with practical working experience using Solar Thermal Industrial Process Heat and to provide system design and operational training for Egyptian engineers for the purpose of assessing and implementing similar projects throughout Egypt. This field test will evaluate the viability of Solar Thermal Industrial Process Heat, with Steam Flash Tank Technology and Steam Condensate Return Systems, for the poultry processing industry.

The application of Solar IPH, Flash Tank, and Condensate Return Systems for poultry processing at Heliopolis will serve as a demonstration of the capability of the combined technology of Industrial Process Heat to reliably supply significant amounts of energy at other poultry processing facilities. It is important that this field test be designed to distinguish between the performance of the Solar IPH and the performance of the Flash Tank and Condensate Return Systems so that each can be evaluated for other applications.

2.2 Background

General Poultry is a large poultry processing plant, packing 50,000 chickens per day. An ongoing expansion will increase production to 100,000 chickens per day. The process plant includes an unloading area, slaughter area, scalding process, rendering removal (feathers, organs, heads, feet, etc.) area, rendering cooker area, cleaning area, and packaging areas.

Each day 5 mTONS (11,025 lbs) of dead birds are also processed in the rendering cookers in addition to waste parts from the production line.

The cookers use high pressure steam to evaporate the moisture in renderings. The moisture is condensed in a series of vent condensers. The solids are returned to the poultry farm and used as feed. The rendering cookers' steam is from one oil-fired boiler operating at 8 bar (116 psig).

Each morning the scalders are filled with cold water and the temperature increased to 60°C (140°F) using low pressure steam in a closed coil. The steam condensate is not returned to the boilers' feed tanks. Scalder make-up water is required due to evaporation and water entrained in the chicken feathers as the chickens leave the scalder.

Boilers supplying steam to the rendering cookers and the scalders are assumed to operate at 75% efficiency (Note: No boiler or stack data is available).

No steam condensate is returned to the boilers; therefore boiler feed is 100% make-up. The make-up water is not preheated.

3.0 ASSESSMENT OF USER REQUIREMENTS

3.1 Existing Poultry Processing Evaluation

Technical data below summarizes the process information received from EEA and General Poultry. The actual data is shown in Appendix -B-. Numbers in parentheses to extreme left are applicable stream numbers, referenced from Appendix -C-.

Average production: 6,000 birds/hr/line = 50,000 birds/day/line

Annual plant operating time: 330 days

Average scalder operating time: 8 hr/day

(10c) Estimated scalder make-up water: 27.2 m^3 = 3,400 Kg/hr (7,482 lb/hr)

(1) Bird temperature before entering the scalder: 36°C (96.8°F)

(2') Bird temperature exiting the scalder: 46°C (114.8°F)

Average bird weight before entering the scalder: 1,016 gms (2.24 lbs.)

Average bird weight after the scalder: 1,276 gms (2.81 lbs.)

(2") Average water removal/bird: 260 gm/bird = 3,247 Kg/hr (7,144 lb/hr)

Average rendering operating cooker time: 11 hr/day

(3) Bird temperature before entering the cookers: 46°C (114.8°F)

(4') Moisture in renderings: 3,375 Kg/hr (7,442 lb/hr)

(4'+4") Condenser loading: 3,844 Kg/hr (8,476 lb/hr)

(3) Mass flow to cookers: 4,500 Kg/day (9,923 lb/hr)

3.2 Application of Specific Energy Sources

High Pressure Steam Condensate

When hot condensate or boiler water, under pressure, is released to a lower pressure, part of it is re-evaporated, becoming what is known as flash steam. The heat content of flash is identical to that of live steam at the same pressure, although this valuable heat is wasted when allowed to escape. With proper sizing and installation of a flash recovery system, the latent heat content of flash steam may be used for space heating; heating or preheating water, oil and other liquids; and low pressure process heating.

In some cases, the flash will have to be supplemented by live make-up steam at reduced pressure. The actual amount of flash steam formed varies according to pressure conditions. The greater the difference between initial pressure and pressure on the discharge side, the greater the amount of flash that will be generated.

To determine the exact amount, as a percentage, flash steam formed under certain conditions, use the following formula:

$$\% \text{ flash steam} = \frac{SH-SL}{H} \times 100$$

Where

SH = sensible heat in the condensate at the higher pressure before discharge, btu/lb

SL = sensible heat in the condensate at the lower pressure to which discharge takes place, btu/lb

H = latent heat in the steam at the lower pressure to which the condensate has been discharged, btu/lb

Flash Tank Construction

The flash tank can usually be conveniently constructed from a piece of large diameter piping wiht the bottom ends welded or bolted in positon. The tank should be mounted vertically. A steam outlet is required at the top and a condensate outlet at the bottom. The condensate inlet connection should be six to eight inches above the condensate outlet.

The important dimension is the inside diameter. This should be such that the upward velocity of flash to the outlet is low enough to insure that the amount of water carried over with the flash steam, is small. If the upward velocity is kept low, the height of the tank is not important, but good practice is to use a height of two to three feet.

It has not been found that a steam velocity of about 10 feet per second inside the flash tank will give good separation of steam and water. On this basis, proper inside diameters for various quantities of flash steam can be calculated.

Flash Steam Installation

Condensate return lines contain both flash steam and condensate. To recover the flash steam, the return header runs to a flash tank, where the condensate is drained, and steam is then piped from the flash tank to points of use. Since a flash tank causes back pressure on the steam traps discharging into the tank, these traps should be selected to ensure their capability to work against back pressure and have sufficient capacity at the available differential pressures.

Condensate lines should be sloped toward the flash tank and where more than one line feeds into a flash tank, each line should be fitted with a swing check valve. Then, any line not in use, will be isolated from the others and will not be fed in reverse with resultant wasted flash steam. If the trap is operating at low pressure, gravity drainage to the condensate return receiver should be provided.

Generally the loation chosen for the flash tank should meet the requirement for maximum quantity of flash steam and minimum length of pipe.

Condensate lines, to the flash tank, and the low pressure steam lines should be insulated to prevent waste of energy through radiation.

Low pressure equipment using flash steam should be individually trapped and discharged to a vented flash tank. See Exhibit 3-2.

The high pressure condensate from the rendering cookers should be flashed to low pressure steam. The low pressure steam will be used to maintain the scalder water temperature and pre-heat the boiler feed water. The low pressure steam will not be available to heat the scalder fill water, as the rendering cookers' operational day starts several hours after the scalder's operational day begins.

Steam Condensate Return System(s)

The condensate return system performs the basic function of a steam trap. The receiver operates at atmospheric pressure therefore, the condensate will flow by gravity into the condensate receiver. When the receiver condensate level reaches a set high level, the pump will start and discharge the condensate at saturation temperature.

When multiple small loads at varying steam pressures are used and a separate closed return system cannot be justified for each load, they may be combined as shown in Exhibit 3-1.

The various steam using equipment is connected through steam traps into a flash tank operating at a pressure below the minimum pressure of any connected load. A check valve is installed after each trap to prevent a backflow through the trap when a piece of equipment is not operating.

The flash tank, operating at a pressure less than any piece of connected equipment, develops low pressure steam that may be used for heating loads requiring low pressure steam. The condensate from the flash tank is then drained into a closed return system to return the condensate at saturation temperature.

Equipment with modulating temperature controllers cannot be combined in this manner as the pressure may drop below the flash tank pressure and condensate will not flow through the trap.

This arrangement is ideal for multi-roll drum type dryers, steam cookers, and autoclaves.

Traps must be sized for pressure differential between the equipment and the pressurized flash tank.

The arrangement shown in Exhibit 3-1 also permits handling of return temperatures at 250°F limiting the flash tank pressure to 15 PSIG maximum.

When multi-loads are to be combined on a system using modulating temperature controllers, they must be connected through a vented flash tank. The 212°F condensate from the vented flash tank can be pumped without the need for additional cooling.

Low pressure condensate from the scalder and flash tank should be returned to the boiler feed tank. The boiler(s)' feed water temperature will be increased, as 100% of the boiler steam will be returned as condensate.

This will require the combining of all steam systems.

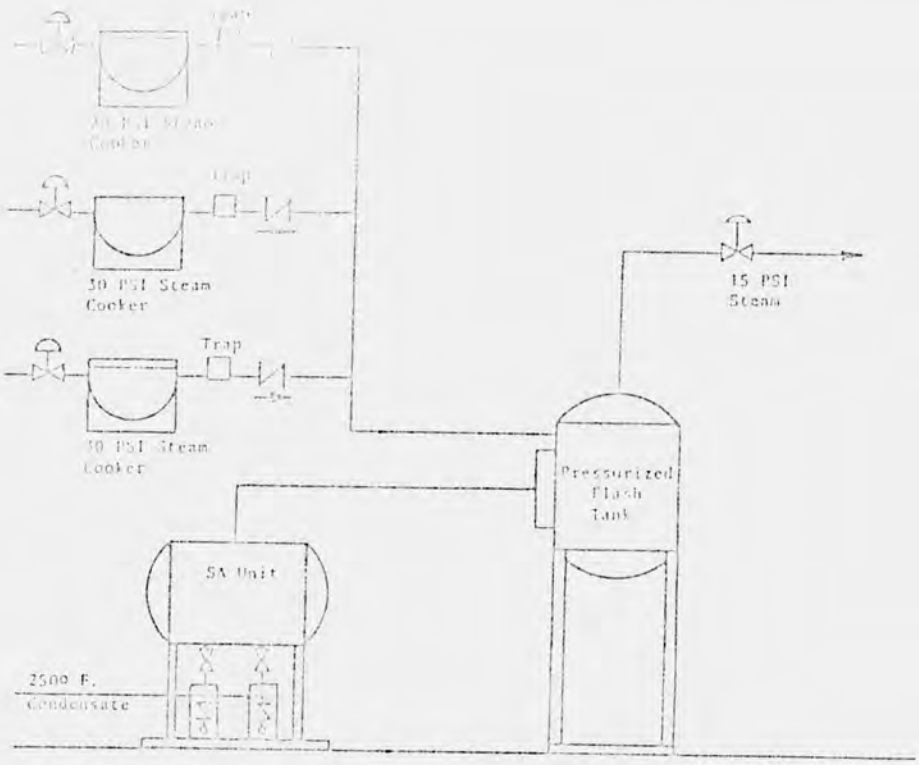


EXHIBIT 3-1
Multiple Loads Combined Into A Pressurized Flash Tank

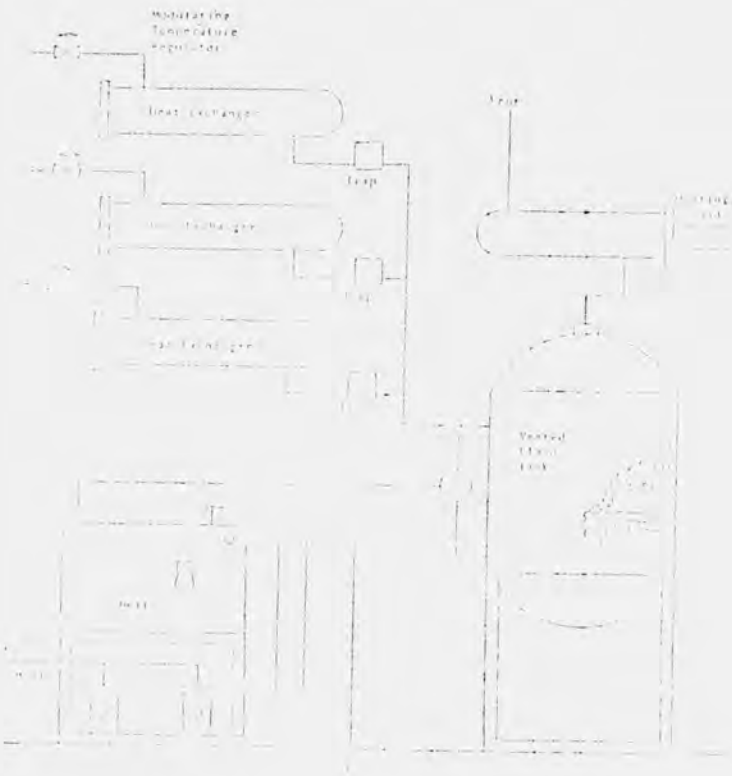


EXHIBIT 3-2
Multiple Loads Combined Into A Vented Flash Tank

3.3 Existing Poultry Processing Energy Demand

Exhibit 3-3, existing poultry process block diagram, details energy streams evaluated in this Applicaton Review. Appendix C tabulates the mass flow, operating temperature, operating pressure, enthalpy, and resulting energy demand.

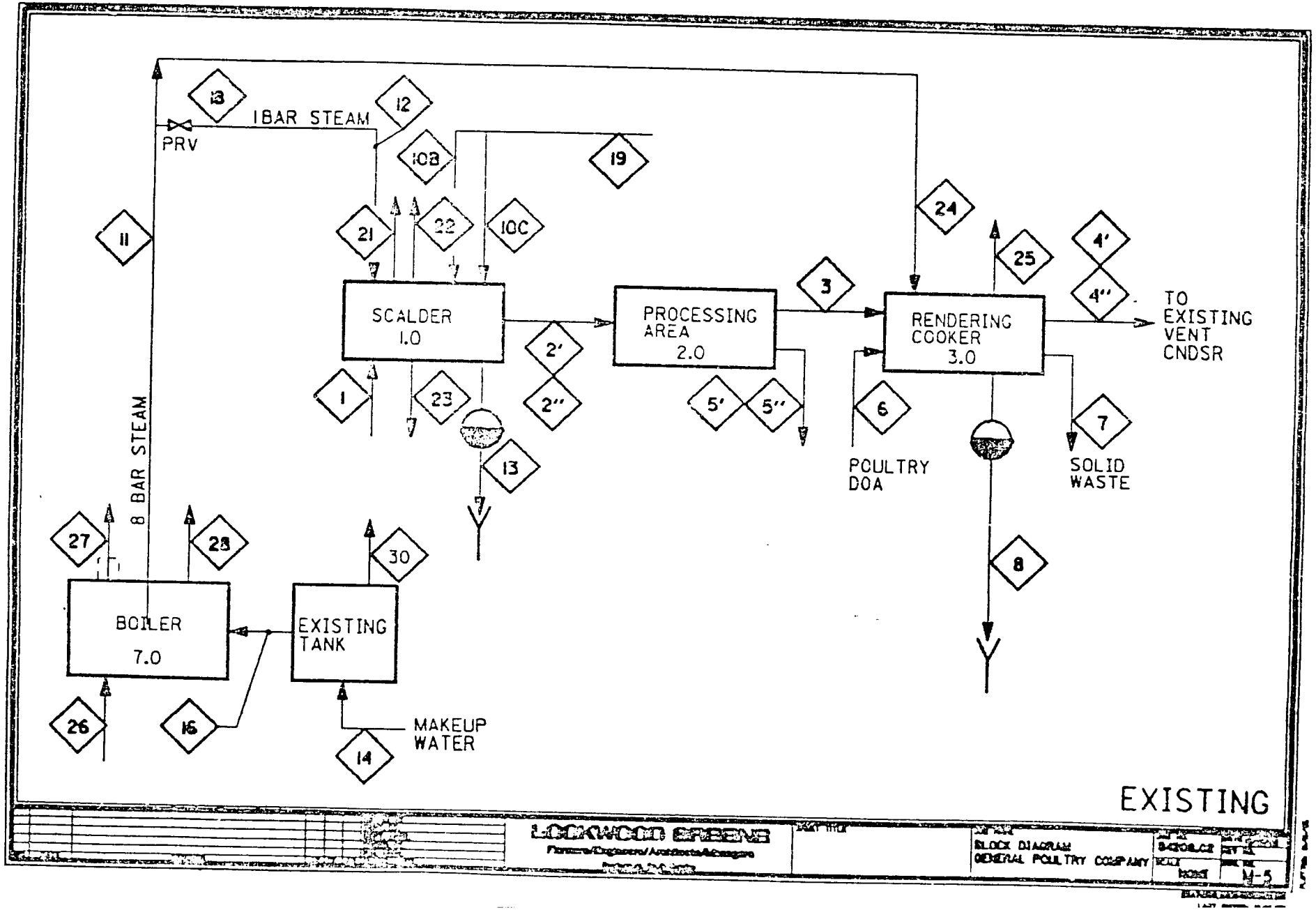


EXHIBIT 3-3

EXISTING POULTRY PROCESS BLOCK DIAGRAM

The following calculations summarize the energy demand (dQ), for the Scalders and Rendering Cookers.

Scalder Streams

(1)	Birds in	=	2,063.9	MBtu/hr
(2)	Birds out	=	-2,635.4	MBtu/hr
(2")	H_2O W/bird	=	-771.6	MBtu/hr
(21)	Evaporative losses	=	-36.5	MBtu/hr
(22)	Radiation losses	=	-122.6	MBtu/hr
(10B)	Fill water	=	+286.7	MBtu/hr
(10C)	Make-up water	=	+299.3	MBtu/hr
(23)	Fill water out	=	-773.9	MBtu/hr
	dQ1.0 (scalder)	=	-1,690.1	MBtu/hr (1.78×10^6 KJ/hr.)

Rendering Cookers Streams

(3)	Renderings in	=	658.9	MBtu/hr
(4')	Vapor out	=	-8,558.2	MBtu/hr
(4")	DOA vapor out	=	-1,188.6	MBtu/hr
(6)	DOA poultry	=	41.9	MBtu/hr
(7)	Renderings out	=	-711.9	MBtu/hr
(25)	Radiation losses	=	-975.8	MBtu/hr
dQ3.0	(rendering cookers)		-10,733.7	MBtu/hr (11.3×10^6 KJ)/hr)

3.4 Existing Poultry Processing Fuel Consumption

The following calculations summarize the fuel consumption (BBL/yr) for the Scalders and Rendering cookers' energy demand.

Scalder

dQ1.0 (scalder) = -1,690.1 MBtu/hr

Steam h_s = 1,193 Btu/lb

Condensate h_c = 219 Btu/lb

M_{STM} = $Q_s \div (h_c - h_s)$

(12) M_{STM} = -1,690.1 ÷ (219-1,193)

(12) M_{STM} = 787.3 Kg/hr (1,736 lb/hr)

Q_{STM} = $M_{STM} * h_s$

= 1,736 lb/hr * 1,193 Btu/lb

(12) Q_{STM} in = 2.18×10^6 KJ/hr (2,071 MBtu/hr)

Rendering Cookers

dQ3.0 (rendering cookers)= -10,733 MBtu/hr

Steam h_s = 1,193 Btu/hr

Condensate H_c = 319 Btu/hr

M_{STM} = $Q_s \div (h_c - h_s)$

= -10,733.8 ÷ (319 - 1,193)

(24) M_{STM} = 5,577 Kg/hr (12,297 lb/hr)

Q_{STM} = M_{STM} * h_s

= 12,297 lb/hr * 1,193 Btu/lb

(24) Q_{STM} = 15.5×10^6 KJ/hr (14,670 MBtu/hr)

4.0 ASSESSMENT OF SOLAR RESOURCES

4.1 General Insolation Profiles

Based on the insolation and ambient temperature data supplied by EEA, an optimum tilt of the solar array has been determined. Using FCHART-4R, the daily insolation normal to a tilted surface was calculated for tilt angles of 15, 20, 25, 30, 35, 40, 45 and 50 degrees ove the year. Exibit 4-1 is a graph of the insolation valves.

The system-specific condition which affects the choice of tilt angle for the array should maximize total insolation over the entire year to achieve maximum output from the solar output.

A tradeoff exists with a fixed tilt array. A 15 degree tilted array results in the highest insolation during the period May through August. A 50 degree tilt maximizes the insolation in December but significanty reduces the insolation during the summer.

One way of improving efficiency is by using a manually adjustable array. This approaches maximizing performance from a non-tracking, quasi-fixed solar array. A seasonally adjusted tilt can maximize insolation in December and throughout the year. By adjusting the tilt in September and in March improvement over a fixed array in total yearly insolation is obtained.

An adjustable tilt structure could be used to maximize the performance of the array and to provide EEA the opportunity to evaluate different operating conditions. The seasonal tilt adjustment would not be practical for the array at General Poultry since most U.S. manufacturers of Flat Plate Collectors do not offer such an option for large arrays.

4.2 Specific Solar Profiles

Insolation data were calculated based on Solar Radiation Data Supplied by EEA.

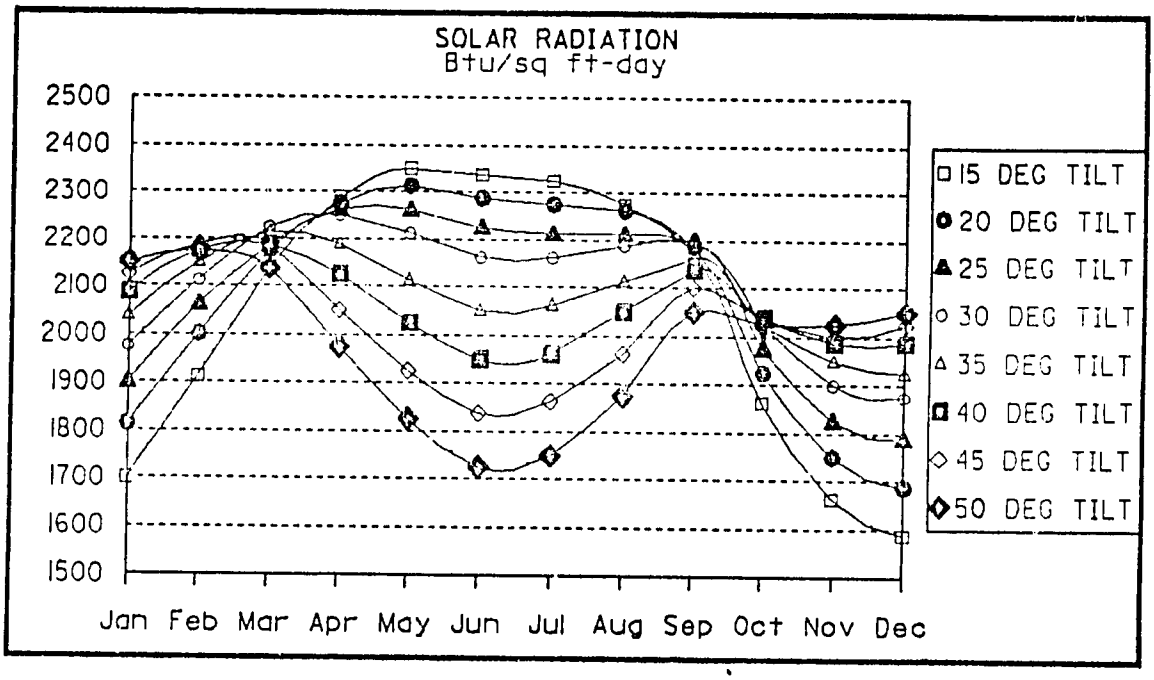


Exhibit 4-1

Insolation vs Array Tilt Angle

Cairo, Egypt

4.3 Specific Tilt Angle Evaluation

At General Poultry there are two site-specific system conditions which affect the choice of tilt angle. First, the tilt angle should provide for the maximum obtainable insolation. Secondly, the array tilt should also minimize dust collection on the collector surface.

The theoretically best collector tilt angle for year-around solar collection is approximately equal to the local latitude, in this case 30°. EEA has conducted tests which prove that the loss of optical efficiency due to dust build-up on the collector glazing is less at a tilt angle of 45° than at 30°. Quantative analysis shows that the decrease in solar collection at 30° vs 45° tilt angle is approximately equal to the increase in optical efficiency at 45° vs 30° tilt angle; therefore the actual solar collection is relatively constant between tilt angles of 30° and 45°.

Water quantities and process temperatures are constant year around; however, inlet water temperature varies with the time of year. Therefore, a higher thermal load coincides with a lower inlet water temperature during the winter.

Since larger tilt angles favor winter collection, use of a 45° tilt angle can reduce the peak auxiliary fuel use.

5.0 TECHNOLOGY REVIEW SUMMARY

General background technical information is being provided in the Technology Reference Notebook on equipment components related to Solar Thermal Industrial Process Heat Systems. The Technology Review for this field test, a separate document, reviews the specific equipment technologies. A summary discussion of the components most critical to the design and operation of the Solar Thermal Industrial Process Heat System is provided here.

5.1 Design Objectives

For a potential solar thermal application, an extensive technology data base of applicable project analysis methods and a listing of current manufacturers with available equipment descriptions are required. This information and the engineering expertise to understand the strengths and weaknesses of various designs, materials, components, and system alternatives are the tools needed for an effective understanding of solar technology.

In addition, specific solar configurations that may apply to the identified field test projects are assessed with regard to manufacturers/hardware performance characteristics, reliability, flexibility, availability, and cost.

5.2 Application and Selection Considerations

In designing a solar energy system, the fundamental objective is to provide an efficient, reliable system within the construction time frame and estabished budget. In order to accomplish this objective, the most economically favorable solar application should be selected. The system design must be appropriate for the specific application.

The intensity of solar radiation is an obvious factor in the cost - and success - of the use of solar energy. Weather station insolation measurements provide historical data from which expected available energy quantities may be estimated.

Ambient dry bulb temperature ranges for the Cairo, Egypt, environment affect the performance of a solar system in several ways:

1. High ambient temperatures reduce the thermal losses associated with collectors, piping, and storage during operation and overnight, increasing system efficiency.

2. High ambient temperatures in winter permit the use of water as tne heat transfer fluid without freeze protection.

Ambient wet bulb temperature ranges for the Cairo, Egypt, environment are low. The resulting relative humidity is low, with a design point estimate of 35%. Consequently, several items must be considered when selecting equipment and materials:

1. Lubricants and packed bearing designs for rotating equipment should be selected to prevent evaporation, or drying, of the lubricant or packing, as well as preventing dust penetration.

2. Air collection systems must incorporate grounding techniques to control static buildup on components composed of materials having plastics or plasticized coatings, or any other material conducive to a static charge buildup.

Atmospheric pollutants can, and do, affect the life and performance of solar collection systems. Smoke and smog will reduce the solar insolation intensity, thus reducing the energy level available from the solar collection system to the process.

Chlorides from seawater and salt-laden sands can corrode aluminum material. Other corrosives from nearby process operations can precipitate on collector surfaces and alter the intensity of solar radiation received.

In the Egyptian environment, dust-laden winds and storms can result in dust accumulation on the collector surfaces, in pump housings and couplings, and in valve actuators. Coatings may be eroded and pumps may tend to overheat.

A materials and environmental test program is recommended to establish the frequency of maintenance required to wash down the collector surfaces to ensure optimum system performance. The wash down cycle will, of course, have to occur at night. The labor and resource (water) cost impact should be established.

5.3 Process Characteristics

General

The efficiency of a solar system decreases as operating temperature increases. Larger solar collector arrays are required, with resulting increased costs.

The objective is to adapt the industrial process to accept heat from a solar system operating as close as possible to a required process temperature.

Storing solar heat as hot water at temperatures less than 95°C (203°F) seems to be cost-effective. The volume of thermal storage that will be required to expand the fraction of process heat beyond that supplied instantaneously (during sunshine hours) is determined from the process operation schedule.

Process control modifications must also be considered, but flexibility must be maintained in order to allow full utilization of each alternate energy system (solar, boiler, etc.) when needed.

Industrial Process Hot Water System Configurations

For the most part, the form in which the energy is to be used determines the nature and configuration of the components that will make up an IPH solar system. Since industrial process energy requirements are primarily met by hot air, hot water, and steam systems, representative configurations of these three groups are presented in this section. Each system description should be general enough to permit the system designer to identify major components and their functions easily. Simple schematics of the systems are provided to facilitate this understanding.

Hot Water Systems

Solar systems to service industrial processes that require hot water can be configured as shown in Exhibits 5-1 (showing a direct hot water system) and 5-2 (showing an indirect hot water system). In the direct system, process water is the working fluid in the solar collectors. The indirect system has two separate fluid loops and usually employs an anti-freeze solution of a heat transfer oil in the collector loop.

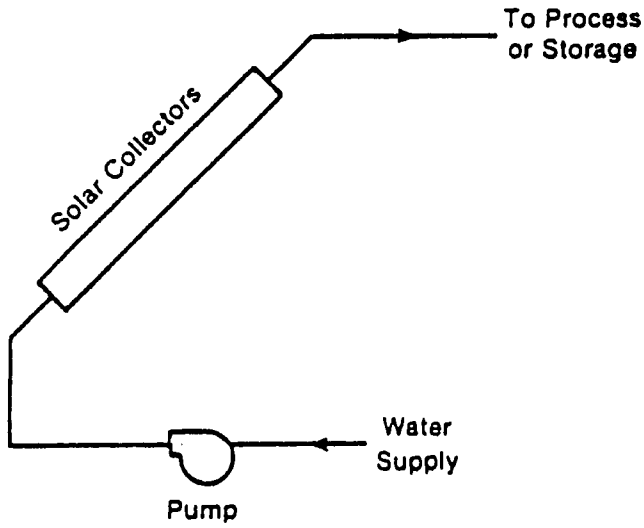


Exhibit 5-1

A Direct Solar Hot Water System

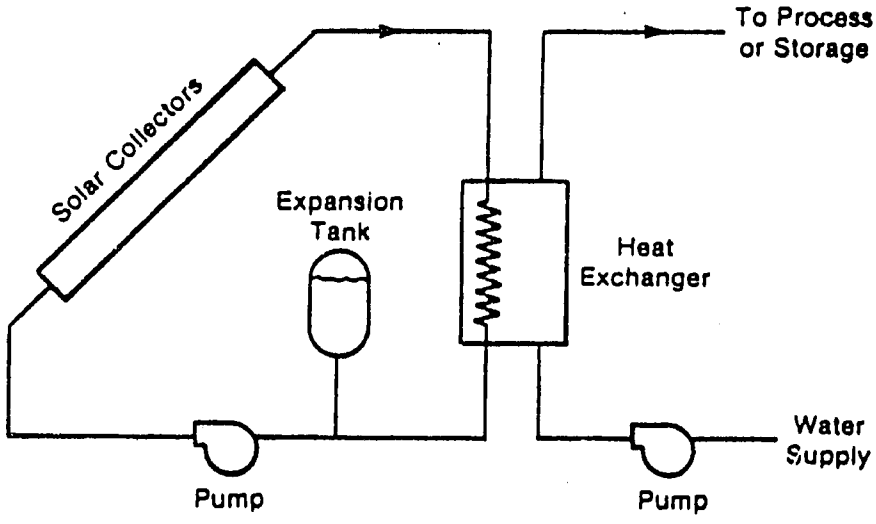


Exhibit 5-2

An Indirect Solar Hot Water System

When water is the heat transfer fluid, freeze protection is accomplished by draining the water (either through a drain or back to the solar tank) or, in mild climates, by circulating warm water periodically during the night when the system temperature approaches freezing.

Liquid collectors are designed to use water in direct systems. Liquid collectors are also used in indirect hot water systems. Theoretically, air collectors could be used in conjunction with an air-to-water heat exchanger, but the poor heat transfer and the increased power needed to transport the air make this option a poor choice. Liquid-based flat-plate collectors, evacuated-tube collectors, and parabolic troughs are all more appropriate.

A check valve is needed in the collection loop for indirect and drain-back direct systems to prevent thermosiphoning (reverse flow caused by natural convection within the fluid) when the pump is not operating. An expansion tank must also be attached to the working fluid to allow fluid expansion as it is heated. Isolation valves, drains, and filters must be installed as in other piping systems.

5.4 Component Identification

Solar Collectors

Basically, solar collectors are heat exchangers that transfer the radiant energy of incident solar radiation to the sensible heat of a working fluid--liquid or air. Many different types of solar collectors can supply energy to IPH systems. In this section, several of these types of collectors are described.

A number of different kinds of solar collectors have been proposed for solar industrial process heat systems, partly because of the wide range of process temperatures found in industry. However, the major types of collectors used thus far in industrial heat field tests are flat plates, evacuated tubes, and parabolic troughs. These three kinds of collectors, and potential or suggested improvements, are described in the following paragraphs.

Flat plates are the most commonly used solar collectors. They can supply hot air or hot water at temperatures up to about 90°C (200°F), although operating temperatures above about 70°C (160°F) diminish the relative efficiency of the system. The advantages of these collectors include the lack of moving parts, durability, and capability of collecting both direct and diffuse radiation.

One way to reduce heat losses is with a vacuum between the glazing and the absorber surface. However, because a vacuum would cause a typical flat-plate collector to collapse, this technique is used in conjunction with a tubular design. Vacuums on the order of 10^{-4} torr eliminate both convection and conduction losses. Because evacuated-tube collectors lose less heat to the environment than flat-plate collectors, they can operate at higher temperatures--up to about 175°C (350°F). Like flat plates, they can collect both direct and diffuse solar radiation and do not require tracking. However, because evacuated tubes can operate at lower insolation levels than flat plates, they can collect more energy on cloudy days. And because of the vacuum, the evacuated tube design is much less susceptible to wind-induced losses than other types of collectors. Another advantage is that the selected surface is contained in a vacuum, which ensures greater stability and a longer life for the coating.

Parabolic troughs are the best-developed line-focus concentrating collectors and have been used in several IPH field tests. Parabolic troughs can operate at temperatures up to 300°C (570°F), as the result of optical concentration effected by the parabolic-shaped concentrator. Optical concentration reduces the absorber surface area relative to the collector aperture area and thereby significantly reduces thermal losses. However, this optical concentration requires the collector to rotate to follow the apparent motion of the sun. And because only direct solar radiation is concentrated by the parabolic concentrator, the diffuse component is lost. That loss can be made up by a tracking collector, as it intercepts extra direct solar radiation. One noteworthy advantage of parabolic trough collectors is the low pressure drop associated with these systems as fluid passes through a single, straight absorber tube. Also, overnight thermal losses are minimal because of the small amount of fluid in the parabolic trough's receiver.

Storage

In conventional IPH applications, fuel consumption (oil, gas, electricity) is adjusted to match the load. The supply of solar energy, however, cannot be regulated. To reduce the mismatch between solar supply and process demand, storage systems are often deemed appropriate.

Four possible configurations for hot water storage are shown in Exhibits 5-3, 5-4, 5-5, and 5-6. These exhibits illustrate direct systems that incorporate process water passing through the collector array. (Freeze protection occurs by means of drain-back or recirculation). In any of them, however, a heat exchanger could be placed between the collectors and the storage tank, creating a separate collector loop containing a nonfreezing fluid.

Pumps

Temperatures, pressures, and the kind of heat transfer fluid used in an IPH system, as well as pump materials, drivers, couplings, and seals, all affect the choice of an appropriate pump. Although using relatively small pipes throughout the solar field may minimize piping costs, this could result in high head losses which could, in turn, necessitate a bigger, more expensive pump. Thus both capital and operating pump costs should be an integral part of the piping design process.

Piping

Three basic types of collector field layouts are employed in solar IPH systems. These layouts--direct return, reverse return, and center feed--are shown schematically in Exhibit 5-6. In each case, the hot outlet piping is shorter than the supply piping, to minimize thermal losses. There are advantages and disadvantages to each of these configurations.

The direct-return piping configuration is the simplest, and probably most exensively used of the three. Its main disadvantage is that there is a much greater pressure differential across the collector row nearest the field inlet than across the last colector row, so that balancing valves must be used to maintain equal flows through each row. These valves are responsible for most of the pressure drop in the beginning of the array; thus, their contributon to the total head loss in the system is significant. The reverse-return configuration has an inherently better balanced flow; balancing valves may still be required, but they add much less head loss to the system than they would in a direct-return configuration. The extra length of supply piping is a disadvantage in the reverse-return array because of additional heat loss, although this depends greatly on the supply field temperature. Adding length to the pipes also results in higher piping, insulation, and fluid inventory costs.

The center-feed configuration is gaining favor with some IPH system designers. As with the direct-return design, balancing valves contribute a significant portion of the head loss; but the design minimizes the amount of piping needed by eliminating a pipe that runs the length of the collector row. Also, direct access to each collector row is possible.

Along with the array configuration, the optimum array flow rate and the number of collectors to be connected in series and in parallel must also be determined. Determining the optimum collector flow rate involves a trade-off between collector and heat exchanger performance and parasitic energy requirements.

Insulation and Heat Losses

Collecting thermal energy with a solar system involves considerable expense; therefore, as much of that energy as possible should be retained by insulating the system piping. Optimum insulation is achieved with an appropriate insulating material at a thickness that provides the lowest total costs in materials, installation, maintenance, and lost energy.

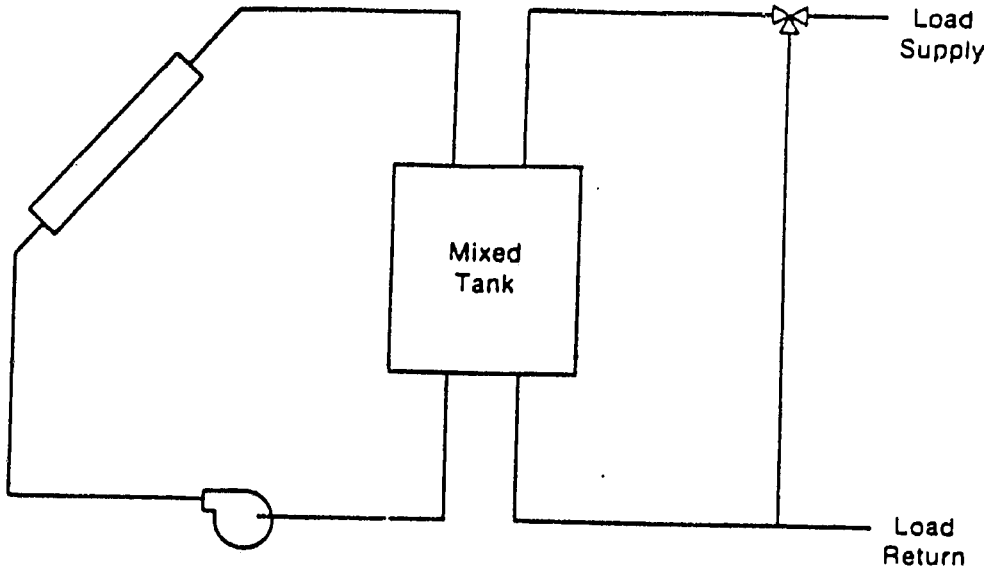


Exhibit 5-3

Four Pipe Storage Configuration

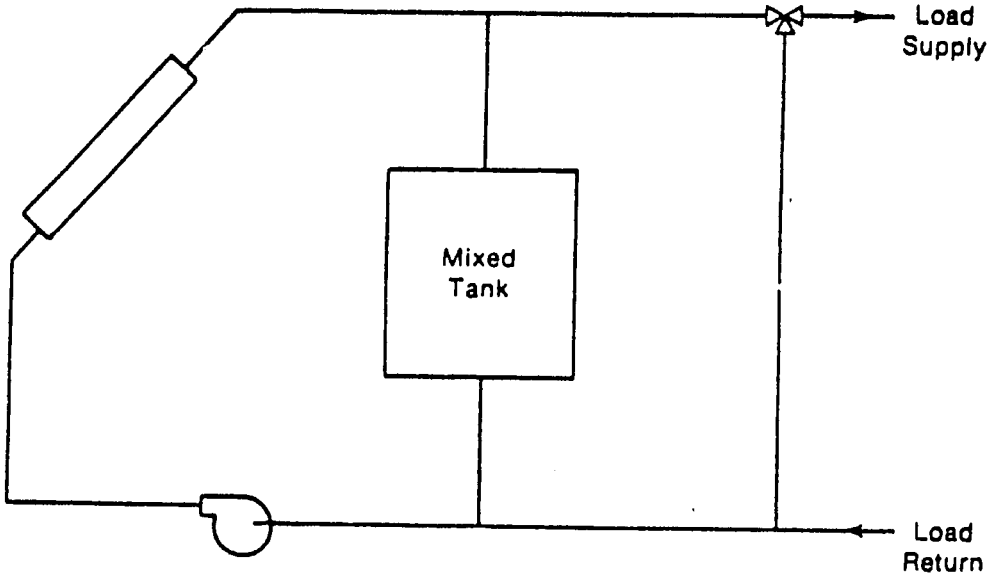


Exhibit 5-4

Two Pipe Storage Configuration

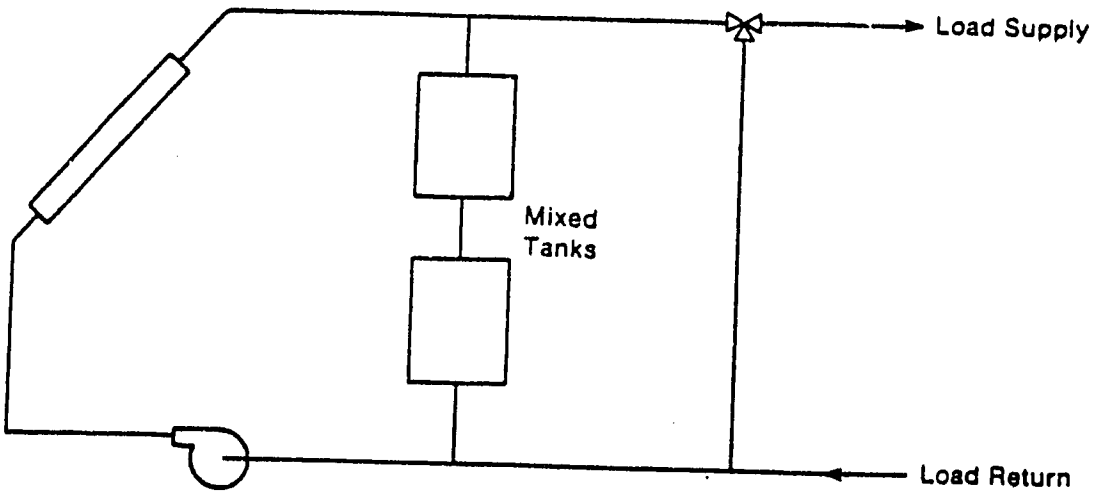


Exhibit 5-5

Multiple Tank Storage Configuration for Achieving Stratification

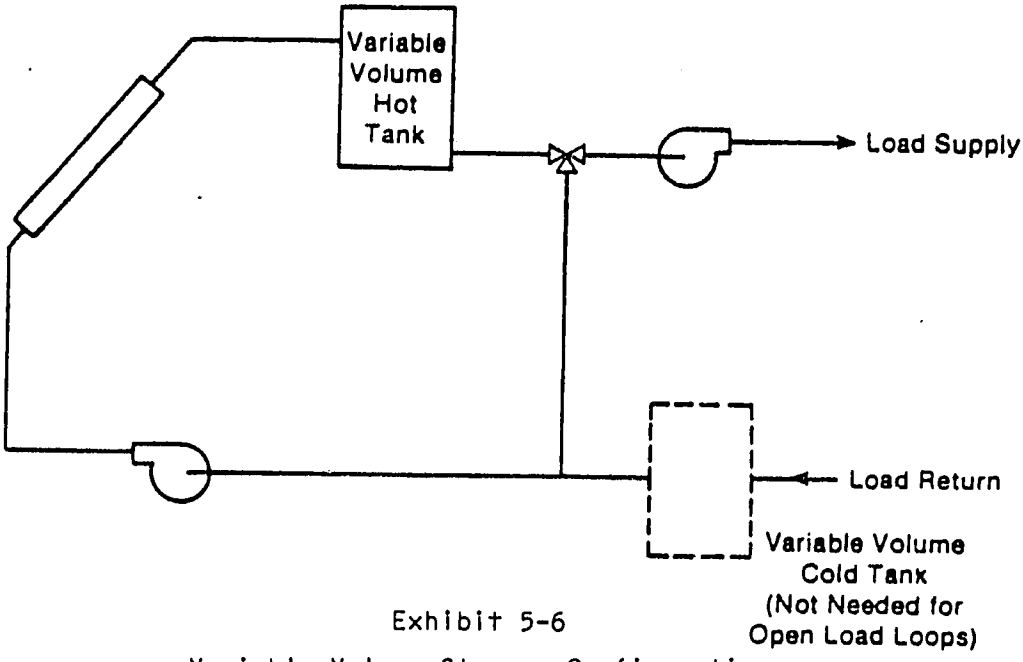


Exhibit 5-6

Variable Volume Storage Configuration

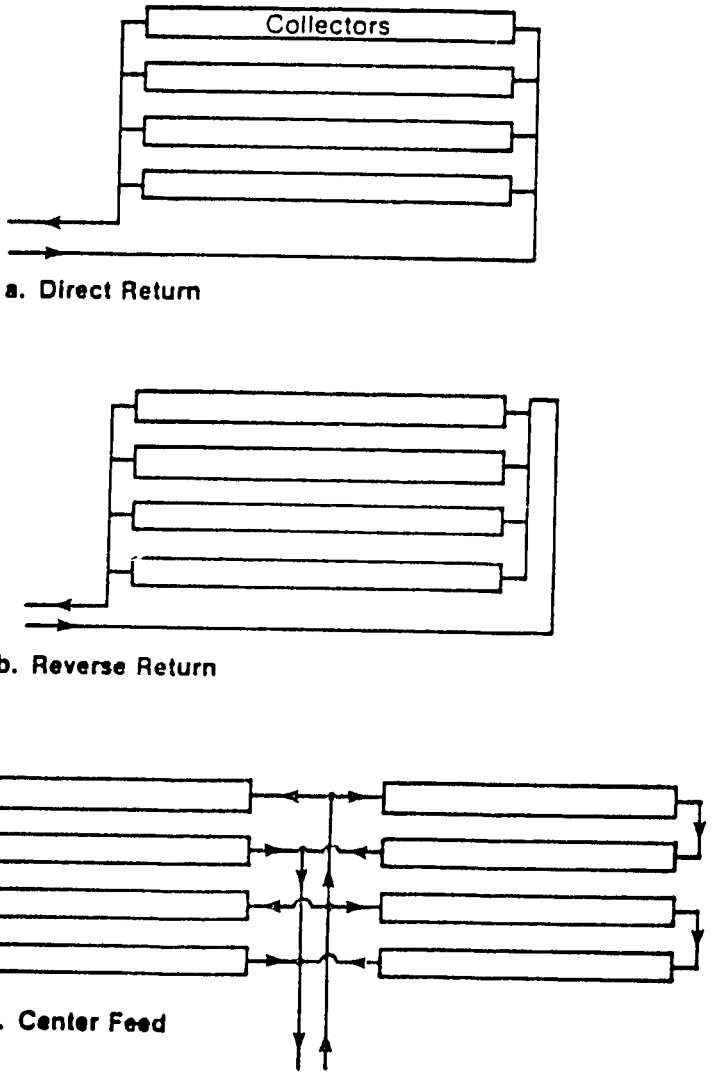


Exhibit 5-7

Sollar Collector Field Layouts

Heat Exchangers

Often, process fluid should not pass directly through the collector field; thus, many solar applications require heat exchangers. A closed-loop solar system allows the use of nonfreezing collector fluids that are less corrosive and less prone to scaling than the process fluid. Possible contamination of the process fluid is another factor to take into account in selecting a closed-loop system. However, incorporating a heat exchanger in a solar system introduces cost penalties associated with that exchanger and with auxiliary piping; the performance of the solar system is reduced by virtue of the increased operating temperature of the collector system working fluid. Another penalty is the result of the greater pumping power needed because of the increase in system pressure drop and the need for an additional pump. Thus, the objective in designing an exchanger for a solar IPH application is to size the exchanger so that performance and pumping power penalties and heat exchanger costs are minimized.

Control Definition

Controls and Logic play an important role in solar IPH systems. Control fundamentals address such items as controllers, control loops, measurement dynamics, noise, and control valve characteristics. The special control problems of solar energy systems begin with normal operating modes, and include start-up/shutdown, freezing/stagnation, emergency conditions, operator training, and checkout.

The controller is the part of the control loop that implements corrective action as the process variable deviates from a desired set point. The control modes that characterize the corrective action include on-off, proportional, integral (reset), and derivative (rate). There are no adjustments to "on-off" control systems (unless a deadband is included), and the controller output changes full-scale as the

process variable crosses the set point. The corrective action implemented with proportional control is normally a linear function of the error signal.

Integral cnotrol (reset) is usually combined with proportional control. It forces the controller output to change in accordance with the time integral function of the error signal and can reduce steady-state error. It also repeats initial proportional output response as long as the error signal persists.

Derivative control is combined with proportional control to change the controller output in accordance with the rate of change of error signal. This action ceases when the error signal stops changing.

Common Control Loops

The common types of control loops are flow, pressure, and temperature. Some rule of thumb are as follows:

Flow Loops: Proportional plus reset controllers are used almost exclusively. The process typically is very fast and noisy, and the flow measurement is usually nonlinear (square).

Pressure Loops: For a liquid, the process is fast and noisy with most of the lags in the control system, and the measurement is nonlinear (square). For a gas, the process is simple: linear with no dead time and no noise. For vapor pressure control, equal percentage valves and proportional-reset-derivative controllers are employed. This process is slow compared with other pressure processes.

Level Loops: High-gain or proportional-plus-reset controllers are used for precise control; low gain proportional-plus-reset controllers for averaging control. Valve characteristics are important.

Temperature Loops: Temperature control loops can vary greatly i. complexity. Almost all the temperature control problems in solar applications are heat transfer problems characterized by long time constants and slow reaction rates. Distance-velocity lag (also known as dead time) is common. The measurement lag can pose a serious problem, especially if the thermal system is protected with a well.

Nonlinearities also cause complications in the temperature loops. Heat transfer proceses have parameters that vary with flow, so that time constants and distance-velocity lag vary with load or operating point. Imperfect mixing is a good example of hidden dead time.

Controlling temperature by mixing hot and cold stream is more of a blending problem that a heat exchange problem. Good mixing and fast temperature measurement are the keys to simplifying the control job. Proportional-plus-reset controllers should be used.

6.0 PRELIMINARY CONCEPTUAL DESIGN

6.1 Design Approach

The system configuration is developed on the loads identified, the equipment technology under consideration, and the design purpose (i.e., development, demonstration, training, lowest cost option). An iterative process is conducted to determine a preferred design; specifically for this field test, a mix between solar thermal, flash steam, and a condensate return system.

The solar thermal conceptual design is based on an average hourly load equal to the scalder's total daily energy demand. In this case, the design is based on an eight hour operation to maximize capacity. This results in a constant hourly load, which may not be the case in actual practice. A cyclic load, as typified by filling the scalders each morning and then increasing the water temperature, would require a larger capacity hot water storage system, but would not affect array sizing because array sizing is performed on an energy per day basis. When flash steam quantities cannot maintain the scalder temperature, steam from the boilers can be used. Conversely, when the scalder make-up water requirement decreases, the accumulation rate of solar-heated water will increase in the storage tank.

6.2 Operating Concept

The operating concept behind the solar thermal, flash tank and condensate return systems is to operate each energy system at its highest efficiency while producing the lowest levelized energy cost. This means minimizing the solar array and storage capacity and optimizing the flash steam, while maximizing the operation of the condensate return system. This operating direction should reduce annual fuel consumption and minimize maintenance cost.

Exhibit 6-1 is a block diagram of the operation of a solar thermal, flash tank, and condensate return system in conjunction with the poultry process. In general, the solar thermal system fills the scalders each morning and maintains the scalder's daily operating level. The stream from the flash tank maintains the scalder water temperature and pre-heats the boiler feed water. The condensate return system recycles the low pressure condensate from the flash tank and scalder to the boiler feed water tank.

6.3 Performance Modeling

A computerized simulation model has been developed to acomplish a dynamic heat balance of the process total energy requirements in order to establish a design basis for waste energy recovery and solar array utilization schemes.

Process material flow, temperature changes, and enthalpy changes during the production cycle are determined from field data and information supplied by EEAPMT and General Poultry personnel.

Total energy flows are then determined at the various stations of interest in order to establish base operating conditions in the heating media stream.

Fuel consumption values may then be deterined by summation of each station requiring additional heat for maintaining the desired production station temperature.

The net fuel savings can then be determined by comparing the calculated fuel consumption for the base model (existing conditions) to the expected fuel consumption of the proposed configuration.

Simulation model results are valid in a relative context only such as comparison of existing versus proposed configurations. It is not appropriate to expect the calculated fuel consumption values to compare with actual plant consumption values because of changes in actual production rates and procedures.

Components and Related Energy Supply Streams are detailed in Appendix -C-.

Energy consumed by the scalder and rendering cookers are dQ1.0 = 1,690,258 Btu/hr and dQ7.0 = 10,733,777 Btu/hr, respectively. The estimated fuel consumption for the boilers is 21,575,134 Btu/hr or 9,687 BBL/yr.

Performance Assumptions

1. Array reference performance data for flat plate collector systems are provided in Appendix -D-.

2. Tilt angle 45°.

3. Boiler stack losses are 25%.

4. The energy content of fuel oil is 140,000 btu/gallon and 42 gals/barrel.

5. Condensate returned to the boiler feed tank is 100% and 212°F.

6. Excess steam from the flash tank can be used to preheat boiler feedwater while the rendering cookers are operating.

7. The annual energy production values are calculated based on average monthly array efficiency and insolation.

6.4 System Sizing and Configuration

Solar Array Sizing Approach

The most significant design question of a Solar Thermal Industrial Process Heat System is the sizing of the solar array and storage/distribution system. The solar array and storage/distribution system size is a function of the relative cost of the solar array, storage/distribution system, and the oil-fired steam boilers. To define this relation, three different array sizing options are considered as shown in Exhibit 6-2.

The first array sizing option is Curve 1 in Exhibit 6-2 labeled "Fuel Displacement". In this sizing, solar energy serves only to displace fuel oil when the sun shines. No storage is used because, on the average, no excess energy is produced. The maximum size for a solar array in this instance is when peak array output at midday equals average energy demand at that period. If the cost of solar-produced energy equals the cost of fuel, this "solar only" sizing is justified as a fuel displacement design.

The second solar array sizing option is shown as Curve 2 and is labeled "Partial Load Supply". The solar array produces excess energy during the day which is stored in a hot water storage system and returned to the load during periods when the solar array output is less than the load. Solar energy costs, in this case, must be less than fuel oil cost.

In the third sizing level, the solar/hot water storage system is sized to supply the total daily load during the year and is shown as Curve 3 labeled "Total Daily Load Supply". As in all cases, the combined cost of the solar array and hot water storage must be equal to or less than fuel oil. Because of the relatively large hot water storage cost, solar energy costs must be significantly less than fuel oil.

Sizing of the solar array to supply the total energy demand can greatly affect financial performance of the system. If the sizing is performed based on December insolation (for assuring reliable energy supply during months with low insolation), significant amounts of solar energy will be "dumped" during the summer because of excess production. The amount of wasted energy is a function of the change in insolation from winter to summer and any seasonal load fluctuations. Designing for the average daily insolation over the year results in a smaller surplus in the summer but an energy deficit in the winter. Energy deficits would be supplied by existing boilers because the hot water storage capacity required to carry summer surplus to winter deficits would be unrealistic.

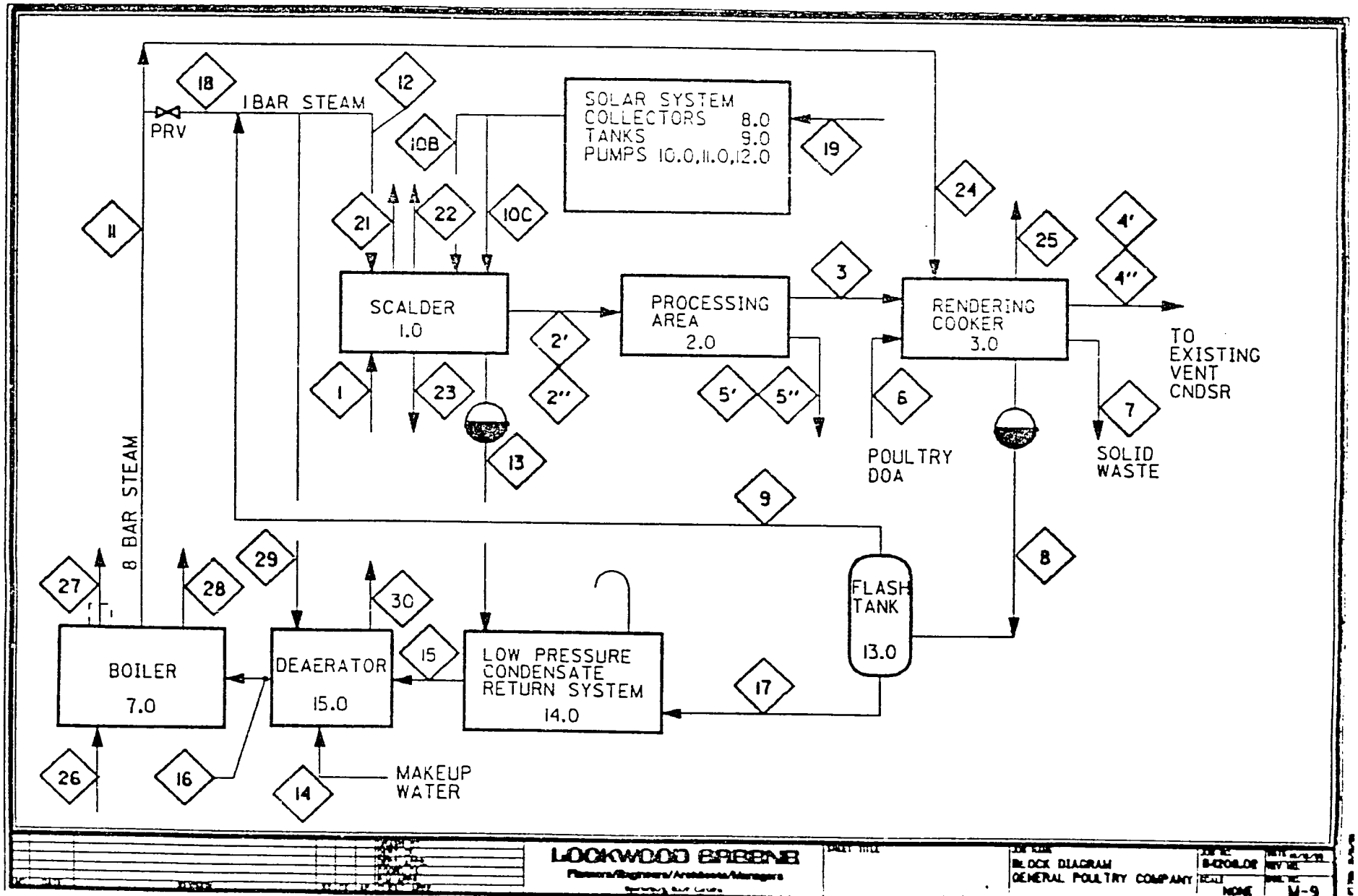


Exhibit 6-1

Solar Thermal, Flash Tank, and Condensate Return System in conjunction with the poultry process

CURVE 1:

FUEL DISPLACEMENT
-SOLAR ARRAY,NO STORAGE
-NO EXESS CAPACITY
-SOLAR THERMAL ~ 25 - 30% OF LOAD

CURVE 2:

TOTAL DAILY LOAD SUPPLY
MINIMAL HOT WATER STORAGE
$SOLAR ARRAY + $HOT WATER = $FUEL
$SOLAR ARRAY << $FUEL
$SOLAR ARRAY/STORAGE ~ 70% OF LOAD

CURVE 3:

TOTAL DAILY LOAD SUPPLY
MINIMAL HOT WATER STORAGE
$SOLAR ARRAY + $HOT WATER STORAGE = $FUE
$SOLAR ARRAY << $FUEL
$SOLAR ARRAY/$STORAGE = 25 - 70% OF LOAD

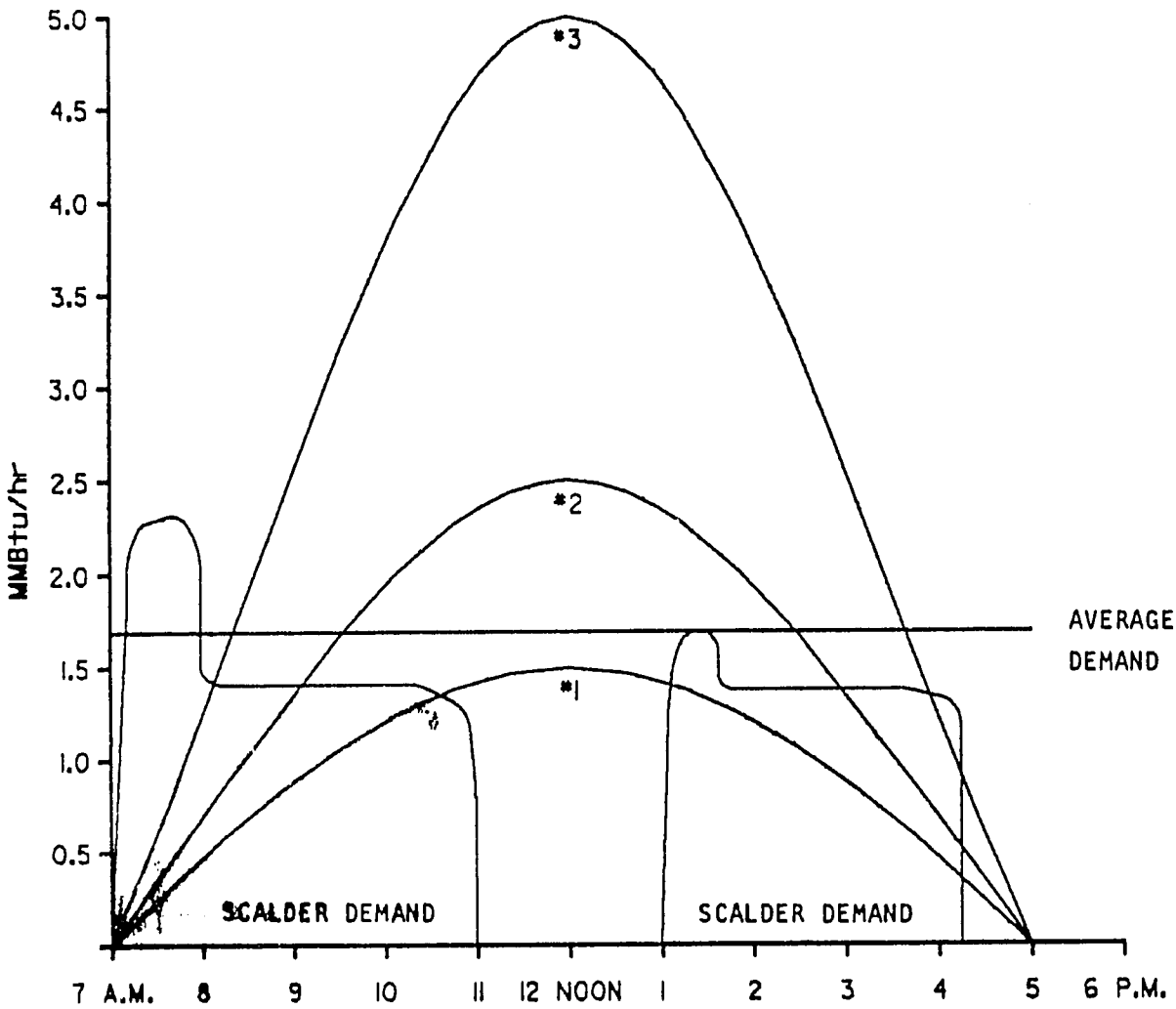


Exhibit 6-2

Array Sizing Options

The principal conclusion regarding sizing options for the solar array is that if solar energy costs (without storage) are less than total energy costs, then some hot water storage is justified, and the solar array/hot water storage system can be sized to provide an optimum percentage of the total yearly energy demand. The optimmum percentage is a function driven by the economics of the system components, primarily the solar array, hot water storage, boiler costs, and fuel costs

The discussion points out that solar array optimization and hot water sizing in hybrid energy system design constitute a complex task and are as much a function of economics as technical issues. More importantly, projected costs for solar arrays, hot water storage, and fuel oil energy are extremely important for this field test to aid in evaluating the viability of energy supply from solar array/hot water storage systems compared to conventional fuel oil-fired boiler systems.

Solar array, hot water storage, and related component sizings for this field test are based on supplying an optimum percent of the daily energy demand. This sizing provides for significant technical and financial operating experience with all major components of the solar array/hot water storage systems, and as such will form the design basis for optimizing solar array, hot water storage, and fuel oil boiler sizing on future applications.

Solar Array Sizing

The required size of a solar array to produce the average Btu/day can be estimated using the average daily insolation, average array operating efficiency over the year, the array reference efficiency, and losses associated with hot water storage. FCHART-4R shows the relationship among these factors to calculate an approximate solar size.

In the FCHART-4R calculation, energy losses from hot water storage and piping is determined and the solar array size increased to compensate for the losses.

Insolation and solar array operating efficiency values are also determined. Insolation and ambient temperature data were used and the array tilt angle set. Appendix -E- contains the results for FCHART-4R.

Lastly, solar array sizing may vary depending on the methods used to calculate the required solar array size and specific solar array configuration requirements to achieve an efficient operating system. A solar array size range of 3000 to 6000 square feet is considered reasonable. The technical and financial analysis portion of this Application Review is performed using a 4000 square foot array.

Hot Water Storage Sizing

The purpose of hot water storage in this project is to minimize the hours of boiler operation. In doing so, the hot water storage will also reduce the hours of low capacity (low efficiency) boiler operation which would otherwise be required. This is accomplished by storing solar array energy in excess of that required by the load(s) at a given point in time and returning it to supplement the boilers at required periods. The hot water storage will also serve as a demand "buffer" to reduce the problems associated with maximum boiler loading during early morning hours.

At the same time, it is desirable to minimize the amount of hot water storage because of the additional cost and inefficiency associated with hot water storage. The amount of hot water storage is determined on the basis of the minimum amount of energy required stored and the maximum boiler demand to be experienced.

Considering the hot water storage to be sized to store excess energy produced during the day, the sizing would be based on the month with the most excess energy. Results from EEA insolation data, provided in Appendix -D-, show that the month with the most excess solar array energy is June.

FCHART-4R estimated that 1,508 x 10^6 Btu/yr (0.57 x 10^6 Btu/hr) can be supplied to the scalder, i.e. 33.8% of the scalders energy consumption. Exhibit 6-3 plots Btu and storage tank temperature vs. months per year.

Flash Tank System

The flash tank system is a "waste energy recovery system". The sizing is based on the maximum quantity of waste energy available from the energy sourcce. The flash tank energy source is the high pressure steam condensate from the rendering cookers. The rendering cookers' daily operating cycle begins 2 to 3 hours after scalder operation commences, but operates 5 to 6 hours longer.

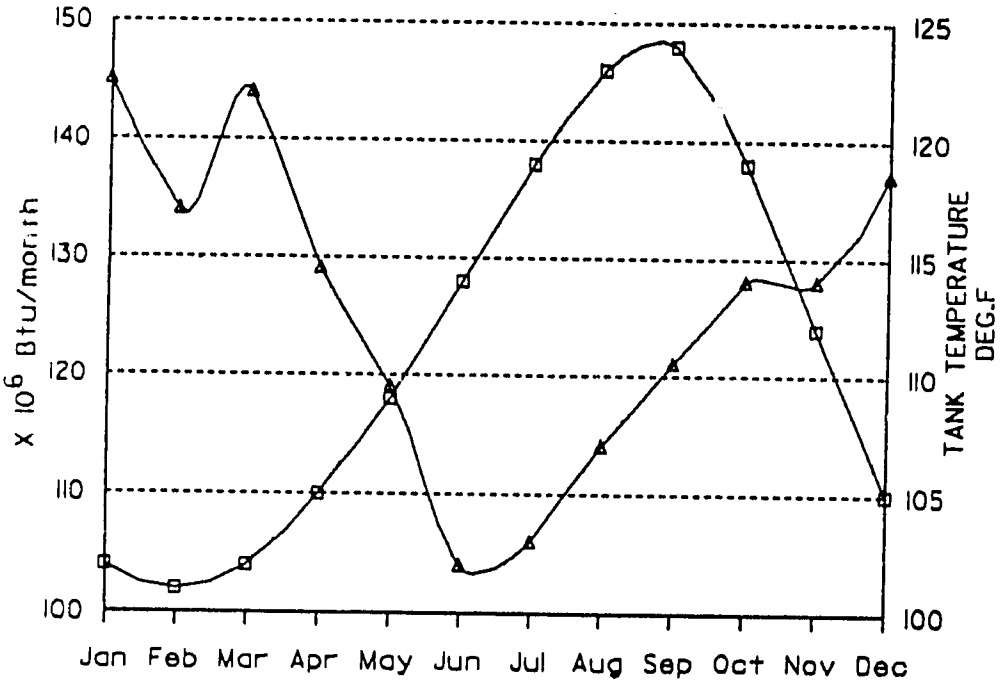
Waste energy from the rendering cookers is 3,922 x 10^3 BTUH(8). The flash tank system should recovery 8% to 12% of the waste energy as low pressure steam. The low pressure steam would be used to maintain scalder and boiler feed water temperatures.

The Steam Condensate Return System

The steam condensate return system is a "waste enegy recovery system". The sizing is based on the maximum quantity of waste energy available from the energy source. The condensate return system's sources are the flash tank and scalder's condensate. The system's peak demand will be during the rendering cooker temperature increase. During this period, the condensate from the rendering cookers and scalder will be returned to the boiler feedwater tank. The higher temperature boiler feed water will increase the boiler's overall efficiency.

Miscellaneous Equipment

Sizing for water pumps and motors, water treatment, and other small loads are not considered here because they are minimmal. As explained earlier, however, the sizing and complexity of all equipment must be determined immediately after an energy system analysis is performed to identify any aspects of high maintenance cost, which may detract from the solar array's performance evaluation during this field test.



MONTHS	Btu/month $\times 10^6$ △	DEG. F □
Jan	145	102
Feb	134	101
Mar	144	102
Apr	129	105
May	119	109
Jun	104	114
Jul	106	119
Aug	114	123
Sep	121	124
Oct	128	119
Nov	128	112
Dec	137	105

EXHIBIT 6-3

BTU, STORAGE TANK TEMPERATURE VS MONTHS/YEAR

7.0 ADDITIONAL CONSIDERATIONS

7.1 Structural Analysis

The Poultry Facility is a single story concrete rigid frame structure. The roof slab between deep roof girders. The roof girders extend approximately 3'-0" above the roof.

The solar collectors will be roof-mounted on a steel frame over the process area. The frame will span between the existing roof beams, as shown on sheets no. SK1 and SK2. The support framing will be anchored to the concrete roof beams at each bearing point. Slippage will be provided in the steel framing at existing expansion joints. An access platform will be provided between each row of collectors.

The design loads are as follows:

A. Solar Collectors = 3 psf
Framing Dead Load = 4 psf
Total = 7 psf

B. Wind Loads V = 85 mph

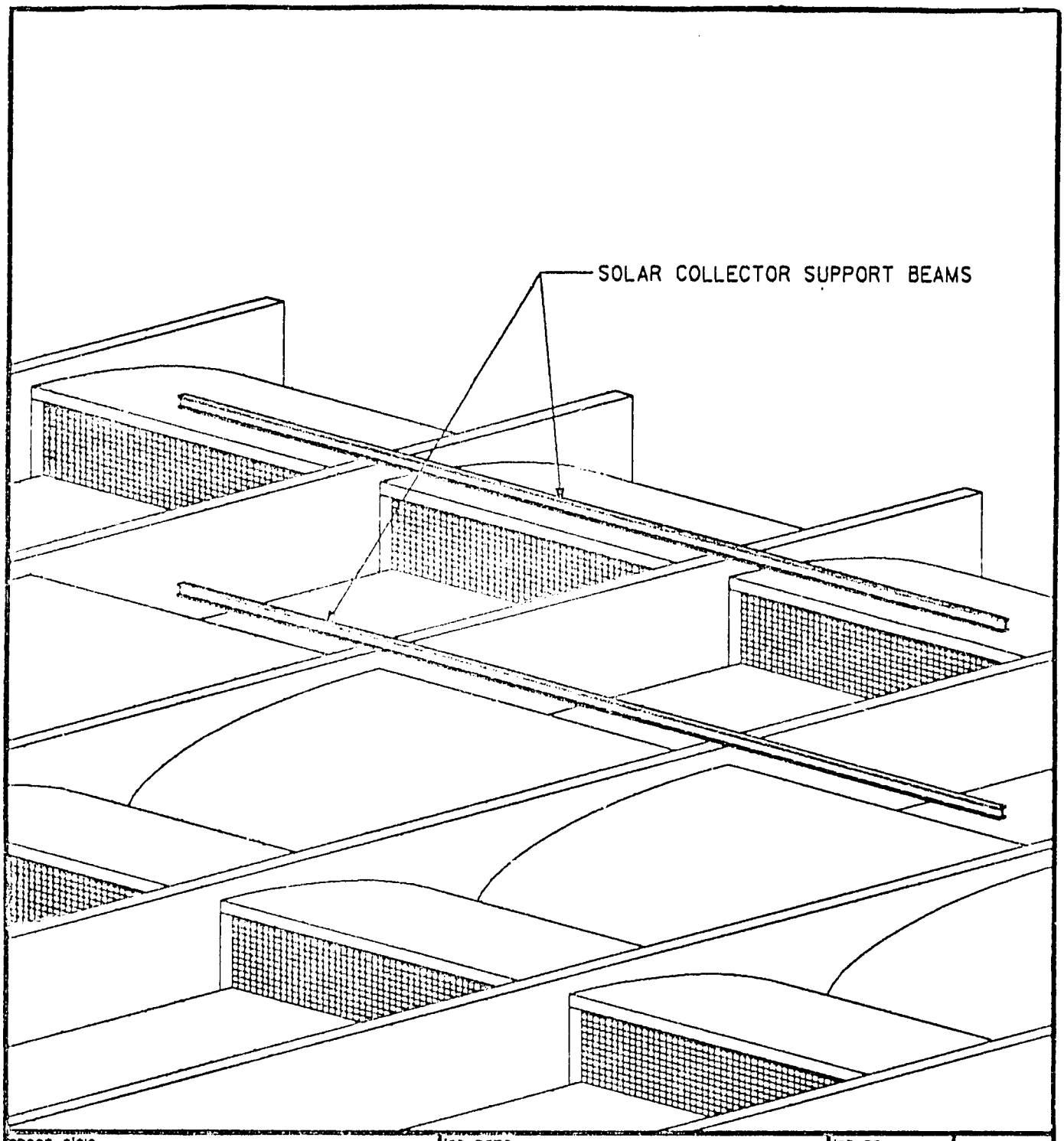
$q = 0.0256\ V^2\ cg$ V = Wind Velocity
$q = 00256\ (85)^2\ (1.0)$ q = Wind Pressure
$q = 18.5$ psf ch = Height coefficient
$ch = (h/30)^{2/7}$
ch = 1.0 below h = 30'

Wind load is based on Navy Design Manual for adjacent countries. Information was not available for Egypt. Confirmation of wind load for final design of solar units and support structure must be made.

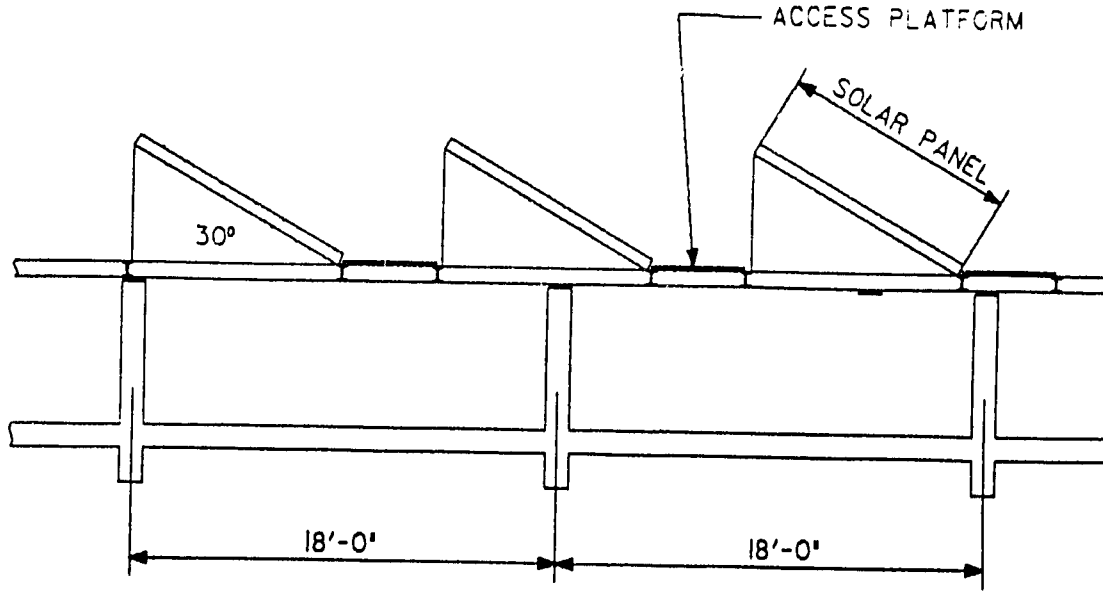
C. The access platform will be designed for 50 psf live load.

The weight of solar panels in 3 psf. The load from the support structure is approximately 4 psf. The total load of 7 psf from this equipment is negligible. Therefore, reinforcing of the existing structure will not be required.

The solar tank and heat exchangers will be located on the ground near the No. 2 boiler house.

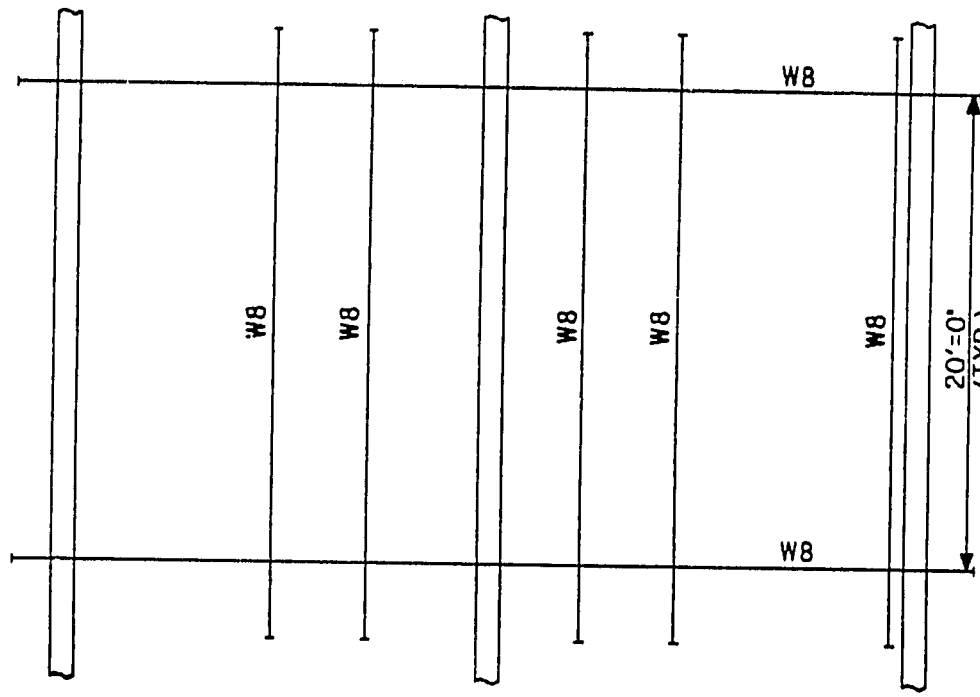


sheet title	job name	job no.	dwg. no
EXHIBIT 7-I TYPICAL SOLAR SUPPORT FRAMING	U.S. AID GENERAL POULTRY	date	



SECTION

SCALE: 1/8" = 1'-0"



PLAN

SCALE: 1/8" = 1'-0"

sheet title	job name	job no.	dwg. no
EXHIBIT 7-2 TYPICAL SOLAR SUPPORT FRAMING	U.S. AID GENERAL POULTRY	date	

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8.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are provided based on the Technology Review and Application Review.

8.1 Conclusions

1. The design, operation, maintenance, and repair experience with Solar Thermal Systems that will be obtained through this field test will form a strong technical base for the design and application of other similar renewable energy applications.

2. Data from this field test can be shared with the public and private sectors through the REIS System (Rsearch Energy Information System).

3. The General Poultry facility is an acceptable application for demonstrating the use of Solar Thermal Industrial Process Heat because there is an existing and growing demand for processed poultry.

4. General Poultry employs engineers and technicians that can be trained to operate and maintain this solar system.

5. The solar resource is exceptional and the processing plant provides a balance between Solar Thermal, Flash Steam, and a Condensate Return System.

6. The sizing of the systems is based on average hourly demands due to demand fluctuations during the day.

7. A modular design using proven, reliable, and commercially available systems is considered to minimize initial cost and so that future additional capacity can be added.

8. The most economically feasible and most reliable choice, on a long term basis, is a flat plate collector array with corresponding storage tank and delivery system.

8.2 Recommendations

A 4000 square foot solar array with storage tank, steam flash tank, and condensate return system is recommended to be field tested at General Poultry.

The 4000 square foot solar array with hot water storage and distribution system will provide EEA and the General Poultry Company with an exceptional solar resource for monitoring and evaluation.

The flash tank and condensate return system will be available for waste heat evaluation.

Appendix -A-

Preliminary Cost Estimate

Preliminary Cost Estimates

Three (3) systems are considered appropriate for cost analysis. Cost estimates are preliminary for use in the Application Review portion of this project.

A. Steam Flash Tank.

B. Condensate Return System.

C. Solar Thermal Collection System.

Current $US (mid-1985) are applied, then escalated to mid-1986, the expected construction period, at 10 percent.

For cost assessment purposes, all material and supervision will be considered imported to Egypt. Labor costs will reflect some Egyptian rate influence, although certain installation procedures will require experienced labor not currently available in Egypt.

The average annual wage for the Egyptian construction industry in 1985 is 7800 LE, or $5,778 (US). ($1.35 LE per US $)

An average labor rate in the United States for construction services applicable to this project is estimated by the R. S. Means Company to be $21.77 per hour in 1985 (crew Q4). An estimated thirty percent imported labor, with seventy percent Egyptian labor, can be used for establishing a mixed labor rate average of $9.36 per hour (US). A labor cost modifier for wages becomes $9.36/$21.77, or 0.43.[1]

Equipment and system cost estimates and percentages are established by using R. S. Means Company Cost Data, 1985, and equipment suppliers' budget pricing estimates.

The solar cost data are determined in fixed-and variable-cost increments as required by the FCHART-4R program input format. A solar collection array size of 4,000 square feet (372 m^2) is estimated for use in determining the variable cost factor.[2]

CONSTRUCTION COST ESTIMATE
A. STEAM FLASH TANK SYSTEM

DESCRIPTION	SUBTOTAL	TOTAL
TOTAL EQUIPMENT(MID-1985)	$7,500	
ESCALATION FACTOR	1.1	
TOTAL EQUIPMENT (MID-1986)		$8,250
PIPING COST @ (40% EQUIP COST)	0.40	$3,300
INSULATION COST @ (25% PIPING COST)	0.25	$825
TOTAL MATERIAL COST	$12,375	
LABOR COST (71.5% MATERIAL COST)	$8,848	
MODIFIER,LABOR MIX	0.47	
MODIFIED LABOR COST		$3,805
MATERIAL + LABOR	$16,180	
CONTRACTOR OVERHEAD AND PROFIT @ 45%		$7,281
TOTAL SYSTEM CONSTRUCTION COST		$23,461

B. CONDENSATE RETURN SYSTEM

DESCRIPTION	SUBTOTAL	TOTAL
TOTAL EQUIPMENT(MID-1985)	$21,500	
ESCALATION FACTOR	1.1	
TOTAL EQUIPMENT (MID-1986)		$23,650
PIPING COST @ (40% EQUIP COST)		$9,460
INSULATION COST @ (25% PIPING COST)		$2,365
TOTAL MATERIAL COST	$35,475	
LABOR COST (71.5% MATERIAL COST)	$25,365	
MODIFIER,LABOR MIX	0.43	
MODIFIED LABOR COST		$10,907
MATERIAL + LABOR	$46,382	
CONTRACTOR OVERHEAD AND PROFIT @ 45%		$20,872
TOTAL SYSTEM CONSTRUCTION COST		$67,254

C. SOLAR THERMAL COLLECTION SYSTEM
VARIABLE COST (MID-1986)

DESCRIPTION	SUBTOTAL	TOTAL
SOLAR COLLECTORS @ $10.00/FT2	$10	
COLLECTOR AREA 4000 FT2	4000	
COLLECTOR COST	$40,000	
SOLAR CIRCULATING PUMPS	$1,750	
SOLAR DISTRIBUTION PUMPS	$1,250	
STRUCTURAL STEEL	$15,000	
SOLAR CONTROLS	$3,000	
INSTRUMENT AIR SYSTEM/PIPING	$750	
LOW VOLTAGE CABLE	$1,500	
EXCAVATION AND FOUNDATIONS	$2,000	
ELECTRICAL	$500	
TOTAL EQUIPMENT(MID-1985)	$65,750	
ESCALATION FACTOR	1.1	
TOTAL EQUIPMENT (MID-1986)		$72,325
PIPING COST @ (40% COLLECTOR COST)	0.40	$16,000
INSULATION COST @ (25% PIPING COST)	0.25	$4,000
TOTAL MATERIAL COST	$92,325	
LABOR COST (71.5% MATERIAL COST)	$66,012	
MODIFIER,LABOR MIX	0.43	
MODIFIED LABOR COST		$28,385
MATERIAL + LABOR	$120,710	
FREIGHT,DUTY,TAXES TO EGYPT @10%	0.10	$12,071
SUBTOTAL	$132,781	
CONTRACTOR OVERHEAD AND PROFIT @ 45%	0.45	$59,752
SUBTOTAL	$192,533	
CONTINGENCY @ 15%	0.15	$28,880
TOTAL VARIABLE COST		$221,413
COST PER FT2	$55	

GENERAL POULTRY MWJPAC01

FIXED COST (MID 1986)

DESCRIPTION	SUBTOTAL	TOTAL
CONTRACTOR'S RENTAL SUPPLIES	$4,000	
CONTRACTOR'S FACILITIES	$3,000	
CONTRACTOR'S UTILITIES	$1,000	
CONTRACTOR'S MATERIAL HANDLING	$1,500	
CONTRACTOR'S CLEAN-UP	$2,000	
DISMANTLING AND MOVING	$2,000	
BOXING AND CRATING	$5,000	
U.S. TRANSPORTATION	$5,000	
SUB-TOTAL	$23,500	$23,500
CONTRACTOR'S OVERHEAD AND PROFIT @ 45%	0.45	$10,575
SUB-TOTAL	$34,075	
CONTINGENCY @ 15%	0.15	$5,111
TOTAL FIXED COST		$39,186

LGE COST BASED ON CURRENT FIELD TEST PROJECT

TOTAL VARIABLE COST	$221,413
TOTAL FIXED COST	$39,186
TOTAL SYSTEM CONSTRUCTION COST	$260,599

EEA COST DATA BASED ON FUTURE PROJECT
USING IN-COUNTRY CONTRACTOR AND EQUIPMENT

VARIABLE COST @ $28.62/FT2	$28.62	
COLLECTOR SIZE (FT2)	4000	
TOTAL VARIABLE COST		$114,480
EEA FIXED COST		$26,757
TOTAL SYSTEM CONSTRUCTION COST		$141,237

CONSTRUCTION COST SUMMARY

A. STEAM FLASH TANK SYSTEM	$23,461
B. CONDENSATE RETURN SYSTEM	$67,254
C. SOLAR THERMAL COLLECTION SYSTEM	$260,599
TOTAL CONSTRUCTION COST A,B, & C	$351,313

APPENDIX B

MEMOS AND CORRESPONDENCE

A.1 GENERAL ORGANIZATION FOR POULTRY (Letter to Dr. Anhar Hegazi from Dr. Hamed).

A.2 Review comments from Anhar Hegazy dated August 16, 1985.

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A.1 GENERAL ORGANIZATION FOR POULTRY

A Report
Concerning Solar Water Heating at the
Automatic Slaughter House at Heliopolis

Requirements of Hot Water

1 - Feather pull off (scalding) basin of 6000 chickens/hour to produce 50,000 chickens/day which will be operated at the beginning of 1984. Another basin will be established at the beginning of 1985 together with doubling production to reach 100,000 chicken/day.

A water meter is installed to measure the quantity of water passing in the main line and feeding the feather detachment basin at Khanga Slaughter House on 6, 8, 1983. To measure quantities of water needed for filling the basin and compensating water the enclosed results have been registered in the period from 8/7/1983 to 9/3/1983

Heliopolis

Basin Dimensions:	Length	Width	Depth
	6.6m	3.35m	0.85m

Side wall surface area $(5.42 \times 0.915)m^2$

Khanga Basin dimensions:	Length	Width	Depth
	5m	3.85	1.05

Quantity of water needed to fill the Basin: $13m^3$

Quantity of Compensating water $13m^3$

Ratio of water consumed for each chicken: 108-273 cm^3

The time that each chicken spent in the Basin: 1.5 min

Number of chickens inside the Basin: 207

Side walls are made of stainless steel

Temperature of water in the basin: 50°C

Temperature of a chicken before entering the basin: 36°C

The nature of a chicken after entering the basin: 46°C

A sample of chickens of different weights have been weighed before and after immersing in the basin to define the quantity of water lost with each chicken.

The weights on 8/15/1983 were as the following:

Before immersing	After immersing	Difference in Lost Water Weight (gm)
900	1.060	160
920	1,090	170
990	1.160	210
1,100	1.280	180
1,210	1,440	230

Number of chickens slaughtered: 35932

Quantity of water consumed in Compensation: 8.1 m^3

Ratio of water consumed for each chicken: 224 cm^3

Difference in water for evaporation = 224 - 210 = 14 cm^3

Weights in 17-8-1983:

Before immersing	After immersing weight (gm)	Difference in lost water
900	1100	200
1040	1240	200
1150	1400	250
1200	1400	250
1250	1500	250

Number of chickens slaughtered 32563

Mid weight (950-1000)

Water consumed for compensation: 7m^3

Ratio of water consumed for each chicken 215 cm^3

Difference in water for evaporation 225 - 210 = 15 cm^3

Atmosphere temperature around the basin

Time:	1000	1200	1000
Temperature (^oC)	28	28	29

Weights on 18, 8, 1983.

Before immersing	After immersing	Difference in lost water weight (gm)
1075	1380	305
1000	1300	200
1135	1320	185
1160	1340	180
1350	1560	220

Number of chickens slaughtered 35065

Average weight (1.160)

Water consumed for compensation 8.5 m^3

Ratio of water consumed for each chicken 242.4

Difference in water for evaporation 242.4 - 200 = 42.4

Temperature around the basin

Time	1030	1230	130
Temperature	27	31	30

Water of scalding basin and other processes is heated by vapor. There are two boilers which are operated weekly 4 tonnes/hour at pressure of 8 bars. The figure shows vapor distribution network in the slaughter house.

Quantity of heat wanted for filling and compensating water to put off the feather of 50,000 chickens/day.

Temperature of the basin: 60°C

Temperature of feeding water 20°C

Quantity of heat needed to heat the filling water of $13m^3$

= 520,000 kilocalorie

= 2,064,400 BTU

Quantity of heat needed to heat the compensating water of 13 m^3

= 520,000 kilocalorie

= 2,064,400 BTU

Waste Section: After having reconstructed (rehabilitated) this section includes 3 cookers. The vapor result is condensed before discharged as waste water, by water through closed cooling cycle. A quantity of heat amounted to (60×10^6) BTU can be obtained from this cycle.

Date/Items	Aug 7	Aug 8	Aug 9	Aug 10	Aug 11	Aug 13	Aug 14	Aug 15	Aug 16	Aug 21	Aug 22	Aug 23	Aug 24	Aug 25
No. of Slaughtered Chickens	35,844	36,514	37,090	34,817	36,788	32,774	32,565	35,932	32,563	35,065	30,140	34,580	40,395	32,803
Average Weight (kg)	1.115	1.105	1.100	1.150	1.150	1.150	1.150	1.950	1.950	1.160	1.229	1.123	0.950	1.095
Amount of Compensate Water (m^3)	7.5	10	4	6.5	9.5	6	8.5	8.1	7.3	8.5	8	9	8	8.5
Avg. Amount of Water per Each Chicken (cm^3)	209	273.9	108	187	245	183	261	225.4	224	242.4	265.4	260.3	198	259

* Average ambient temp. during measuring hours 28°C

Date/Items	Aug 27	Aug 28	Aug 29	Aug 30	Aug 31	Sept 1	Sept 3
No. of Slaughtered Chicken	30,783	37,544	45,018	39,027	21,894	17,665	24,124
Average Weight (kg)	1.05	1.100	1.100	1.105	1.100	1.05	1.200
Amount of Compensate water (m^3)	7	8	10	9	11	8	11
Average Amount of water per each chicken (cm^3)	227.4	213	222	227.7	502	452	456

* Average Ambient temperature during measuring hours 28°C

A.2 Review comments from Anhar Hegazy August 16, 1985

LOCKWOOD GREENE

Planners Engineers Architects Managers

August 16, 1985

USAID/REFT Project
SUBJECT: Reviewed Report on the Applications Review for Field Test No. 3 "General Poultry"

Mr. Tom West, Laison Project Manager
Louis Berger International, Inc.

FM: Anhar Hegazi, I.P.H. Task Leader

In reference to Mr. R. Spongberg's letter dated July 7, 1985 concerning the submittal of the a/m Report for review. The report was reviewed and views were exchanged with LGE during my stay at Spartanburg. This was helpful to enhance the direct discussion and common understanding. Also, some reflections which I received from Mr. Eric Peterson at Cairo have been discussed and highly considered. LGE is now reprocessing the report to incorporate the required chapters. The main comments and modifications required for the report are as follows:

Since the report was made available to Dr. Ezzat Abd El Hamid, the Director of General Poultry Plants, collected data were refined considering the extension plans of the plant within 1985-1986. LGE was requested to incorporate these requirements in the project calculations to enhance the waste heat recovery opportunities.

2. Assumptions made and some of the data used for calculations were discussed and a typical schedule of plant operation was developed.

3. Since the submitted, application review has considered the use of the solar heating system only for filling scalder tank, associated with the assumption of quite short life time of the solar system, it shows very poor payback and economics of solar system versus waste heat recovery options.

   It was recommended to LGE to consider using the solar heat for the makeup water to scalder tank, which increases solar contribution, together with modifying life time of the system to 15 years to show the practical economics of the solar system. (This has almost doubled the solar contribution). This was a main reflection from Mr. Eric Peterson, to address adequate evaluation of the use of solar in this project.

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4. All heat and mass balances of the system were reconsidered to adapt the A/M changes.

5. According to the results achieved so far from the A/M consideration and calculations, some system configuration changes may be appropriate, "mainly reconsideration of the use of flash tank and makeup water preheater", which would increase the effectiveness of the proposed system.

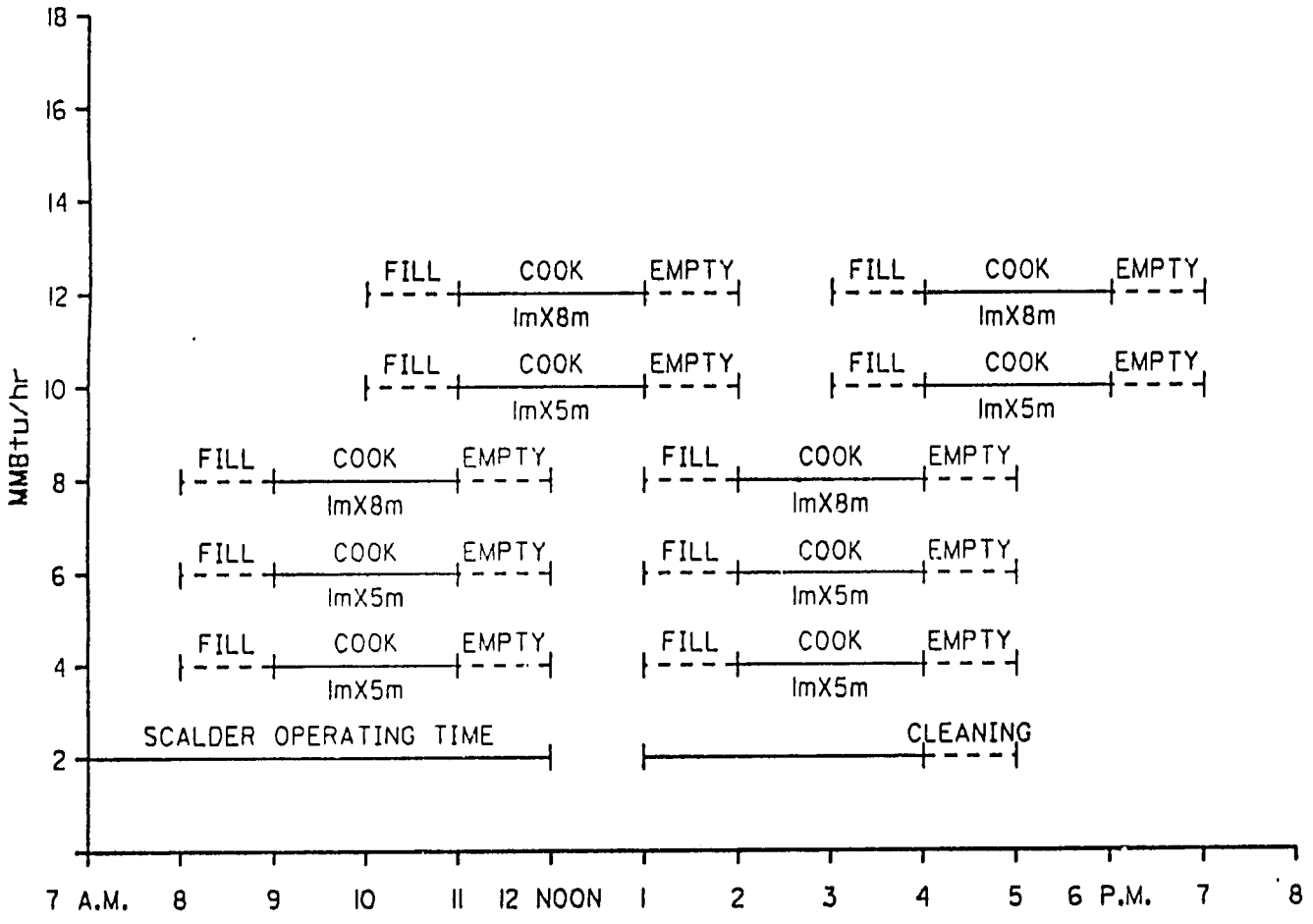
6. Final report incorporating the results of this work is expected by 8/__/85 from LGE.

Very truly yours,

Anhar Hegazi
I.P.H. Task Leader

AH:dc3c/3

cc: Mr. Mike Jones
Mr. T. El Tablawi
Mr. E. Peterson



APPENDIX-B

SCALDERS & RENDERING COOKERS SCHEDULE

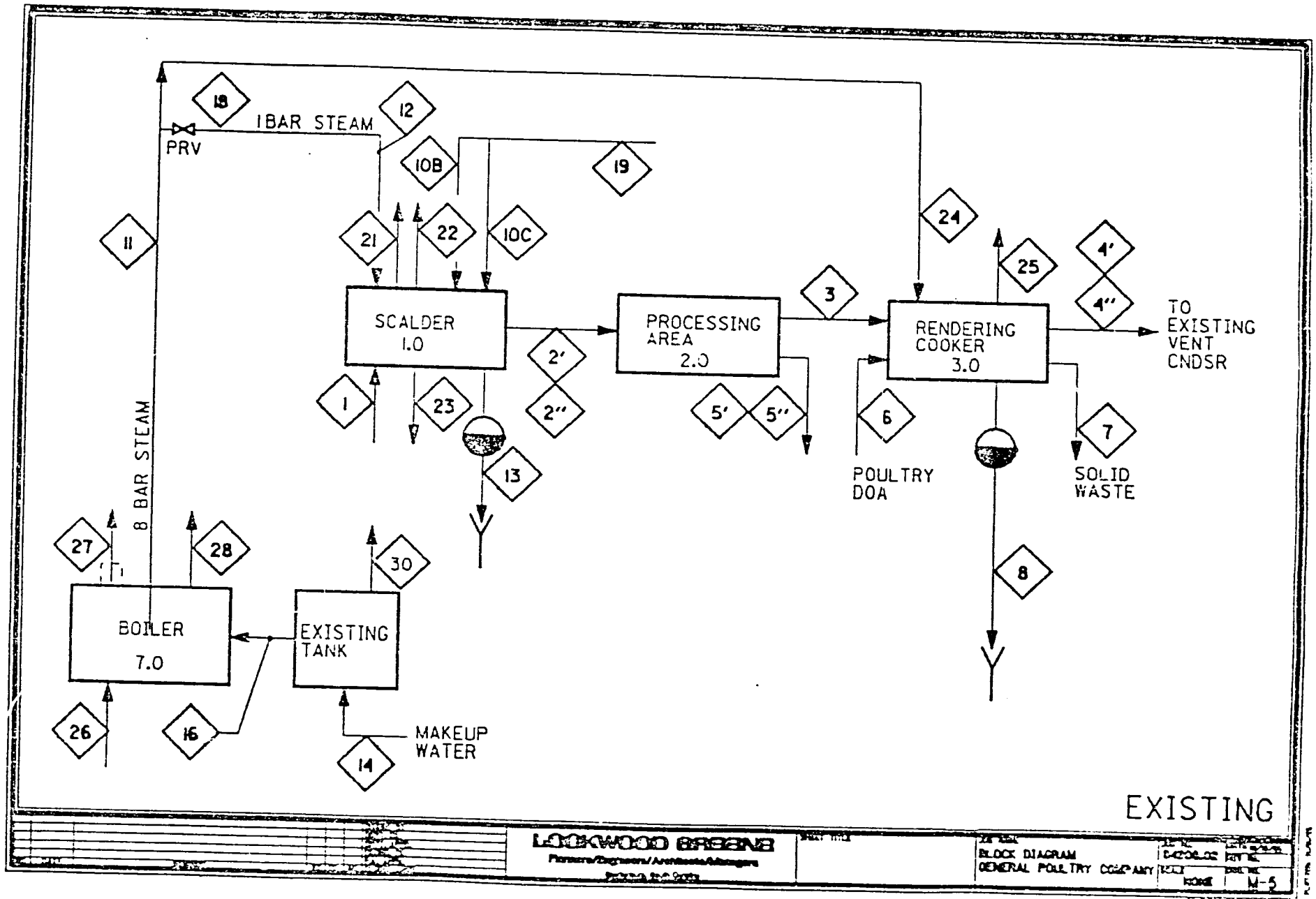
Appendix -C-

Energy Balance Calculations

C.1 General Existing Conditions Flow Sheet

C.2 Lotus Model Results

Existing Conditions (MWJPAC)



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GENERAL POULTRY MWJPAC01

EXISTING MWJPAC01 DESCRIPTION	BIRDS IN	BIRDS OUT	H2O W/ BIRD	BIRDS TO RENDER'G	H2O TO VENT COND	H2O TO VENT COND	PROCESSED BIRDS	H2O FROM BIRDS	DOA BIRDS
LOCATION	1	2'	2''	3	4'	4''	5'	5''	6
M (LB/HR)	39,690	39,690	7,144	9,923	7,442	1,034	29,768	7,144	1,378
T (DEG F)	97	115	140	115	212	212	115	140	70
PRESSURE(PSIG)									
H (BTU/LB)	52	66	108	66	1,150	1,150	66	108	30
Q (BTU/HR)	2,063,880	2,635,416	771,574	658,854	8,558,150	1,188,633	1,976,562	771,574	41,895

GENERAL POULTRY MWJPAC01

EXISTING MWJPAC01 DESCRIPTION	SOLIDS FRO COOKERS	COND COOKERS	LP STM FR F T'K	FILL H2O	MAKE-UP H2O	STM FROM BOILERS	STM TO SCALDER	COND FROM SCALDER	H2O TO MAKE-UP	LP COND TO DEAIR
LOCATION	7	8	9	10B	10C	11	12	13	14	15
M (LB/HR)	2,825	12,297	N/A	7,166	7,482	14,032	1,736	1,736	14,032	N/A
T (DEG F)	347	347	N/A	72	72	347	250	250	72	N/A
PRESSURE(PSIG)		115	N/A	ATM	NR	115	15	15	NR	N/A
H (BTU/LB)	252	319	N/A	40	40	1,193	1,193	219	40	N/A
Q (BTU/HR)	711,939	3,922,688	N/A	286,650	299,297	16,740,623	2,070,508	380,251	561,295	N/A

GENERAL POULTRY MWJPAC01

EXISTING MWJPAC01 DESCRIPTION	BOILER FEED	F. TANK COND	MAKE-UP STM TO SC	H2O TO SCALDER		SCALDER V LOSSES	SCALDER R LOSSES	SCALDER DRAIN	STM TO COOKER	LOSSES COOKER
LOCATION	16	17	18	19	20	21	22	23	24	25
M (LB/HR)	14,032	N/A	1,736	14,648	DELETED	(338)	0	(7,166)	12,297	0
T (DEG F)	72	N/A	347	72	DELETED	140	140	140	347	347
PRESSURE(PSIG)	115	N/A	15	NR	DELETED	NR	ATM	ATM	115	
H (BTU/LB)	40	N/A	1,192	40	DELETED	108	NR	108	1,193	NR
Q (BTU/HR)	561,295	N/A	2,068,252	585,937	DELETED	(36,500)	(122,630)	(773,955)	14,670,115	(975,798)

EXISTING MWJPAC01	FUEL TO	STACK	BOILER	dQ1.0	dQ3.0	dQ7.0
DESCRIPTION	BOILER	LOSSES	RAD LOSSES	BTU/HR	BTU/HR	BTU/HR
LOCATION	26	27	28			
M (LB/HR)	NR	0	0	(1,690,258)	(10,733,777)	(21,575,134)
T (DEG F)	NR	NR	NR			
PRESSURE(PSIG)	NR	NR	NR			
H (BTU/LB)	NR	NR	NR			
Q (BTU/HR)	21,575,134	(4,044,832)	(1,350,974)			

GENERAL POULTRY MWJPAC01

F-CHART	INPUT GAL/DAY	OUTPUT BTU/YR	OUTPUT BTU/DAY	OUTPUT BTU/HR	ENERGY SAVED
SCALDER CONSUMPTION @ 140 F	12,718			(1,690,258)	
SOLAR SYSTEM ENERGY SAVINGS		1,508,920,000	4,572,485	571,561	
SOLAR SYSTEM FUEL SAVINGS					-33.8%

FLASH TANK SYSTEM	MASS FLOW CONDENSATE FROM RENDERING COOKERS M8 LB/HR	ENERGY CONDENSATE FROM RENDERING COOKERS Q8 BTU/HR	CONVERSION METHODOLOGY %FLASH STM	MASS FLOW FLASH STM LB/HR	ENERGY SAVED BTU/HR
FLASH TANK SYSTEM INPUT	12,297	3,922,688			
FLASH TANK ENERGY SAVINGS			10.6%	1,301	1,229,560
FLASH TANK FUEL SAVINGS					

CONDENSATE RETURN SYSTEM	CONDENSATE FROM RENDERING COOKERS AND SCALDERS M8 AND M13 LB/HR	CONDENSATE FROM RENDERING COOKERS AND SCALDERS Q8 AND Q13 BTU/HR	USING HIV (HI @ 212F)-(HI @ 72F)= BTU/LB	ENERGY SAVED BTU/HR M*dHIV=
M8 ENERGY SAVINGS	12,297	3,922,688	180	
M13 ENERGY SAVINGS	1,736	380,251	40	
TOTAL ENERGY SAVINGS	14,032	4,302,938	140	
TOTAL FUEL SAVINGS				1,964,532

F-CHART	ENERGY SAVED BTU/YR	FUEL SAVED BTU/YR	FUEL SAVED GAL/YR	FUEL SAVED BBL/YR	%SAVINGS	CONSTRUCTION COST
SCALDER CONSUMPTION @ 140 F						
SOLAR SYSTEM ENERGY SAVINGS	1,508,920,000					
SOLAR SYSTEM FUEL SAVINGS		2,012,144,820	14,372	342	-3.5%	$260,599

FLASH TANK SYSTEM

	ENERGY SAVED BTU/YR	FUEL SAVED BTU/YR	FUEL SAVED GAL/YR	FUEL SAVED BBL/YR	%SAVINGS	CONSTRUCTION COST
FLASH TANK SYSTEM INPUT						
FLASH TANK ENERGY SAVINGS	3,246,037,710					
FLASH TANK FUEL SAVINGS		4,328,591,287	30,919	736	-7.6%	$23,461

CONDENSATE RETURN SYSTEM

	ENERGY SAVED BTU/YR	FUEL SAVED BTU/YR	FUEL SAVED GAL/YR	FUEL SAVED BBL/YR	%SAVINGS	CONSTRUCTION COST
M8 ENERGY SAVINGS						
M13 ENERGY SAVINGS						
TOTAL ENERGY SAVINGS	5,186,365,707					
TOTAL FUEL SAVINGS		6,916,018,670	49,400	1,176	-12.1%	$67,254

	BTU/YR	GAL/YR	BBL/YR	
EXISTING BOILER F CONSUMPTION	(56,958,353,761)	(406,845)	(9,687)	
PROPOSED BOILER F CONSUMPTION	(45,713,729,432)	(312,154)	(7,432)	-23.3%

Appendix D

Insolation Data Cairo, Egypt

A Summation of the Daily Total Solar Radiation Received on Surfaces of Various Orientations in cal/cm^2

Month	Normal	H	South	North	E	W
Jan.	720	360	485	44	215	215
Feb.	752	435	440	49	250	250
March	796	523	350	56	273	273
April	830	600	226	65	275	275
May	863	650	150	106	288	288
June	864	662	115	130	295	295
July	858	650	130	116	288	288
Aug.	828	610	190	80	285	285
Sep.	790	546	293	59	270	270
Oct.	714	438	385	51	240	240
Nov.	672	361	452	45	216	216
Dec.	660	330	466	42	202	202
Annual	779	514	306	70	258	258

Provided by EEA

CAIRO, EGYPT

DAILY TOTAL SOLAR RADIATION

BTU/FT2

Month	Normal	Horiz.	South	North	East	West
JAN	2657	1328	1790	162	793	793
FEB	2775	1605	1624	181	923	923
MAR	2937	1930	1292	207	1007	1007
APR	3063	2214	834	240	1015	1015
MAY	3184	2399	554	391	1063	1063
JUN	3188	2443	424	480	1089	1089
JUL	3166	2399	480	428	1063	1063
AUG	3055	2251	701	295	1052	1052
SEP	2915	2015	1081	218	996	996
OCT	2635	1616	1421	188	886	886
NOV	2480	1332	1668	166	797	797
DEC	2435	1218	1720	155	745	745
ANNUAL	2875	1897	1130	260	952	952

Unit Conversion by LGE

Appendix E
Results from FCHART-4R

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** FCHART-4R VERSION 2.00 **
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PROJECT: General Poultry
COMMENT: Application Review-Final

DATE: 04/03/86
FILE NAME: MWJPAC

THERMAL DATA

GENERAL INFORMATION:

1	SYSTEM TYPE (1-5) 1 = DHW-1TANK 4 = DHW-PREHEAT-LOADSIDE HX 2 = DHW-2TANK 5 = CONSTANT TEMP-COLLECTOR ONLY 3 = PROCESS HEAT	2.00
2	ECONOMICS (1=YES; 2=NO, 3=ECONOMIC ONLY)	2.00
3	COLLECTOR AREA OPTIMIZATION (1=YES; 2=NO)	2.00
4	CITY NUMBER	262.00

COLLECTOR AND COLLECTOR HX:

11	COLLECTOR AREA	4000.00	SQFT
12	FR-UL PRODUCT	0.72	BTU/SQFT-HR-F
13	FR-TAU-ALPHA PRODUCT	0.76	
14	INCIDENT ANGLE MODIFIER CONSTANT	0.17	
15	COLLECTOR TILT ANGLE	45.00	DEGREES
16	COLLECTOR AZIMUTH (SOUTH=0, EAST=-90, WEST=+90)	0.00	DEGREES
17	COLLECTOR HX EFFECTIVENESS	1.00	
18	COLLECTOR LOOP FLOW RATE	14.70	LB/HR-SQFT
19	COLLECTOR-STORAGE LOOP FLOW RATE	14.70	LB/HR-SQFT
20	SPECIFIC HEAT OF COLLECTOR FLUID	1.00	BTU/LB-F
21	SPECIFIC HEAT OF SOLAR TANK FLUID	1.00	BTU/LB-F
22	UA OF COLLECTOR INLET PIPE	0.50	BTU/HR-F
23	UA OF COLLECTOR OUTLET PIPE	0.50	BTU/HR-F
24	GROUND REFLECTANCE	0.20	
25	COLLECTOR TEST FLOW RATE	33.74	LB/HR-SQFT

SOLAR STORAGE TANK:

31	SOLAR STORAGE CAPACITY	1.50	GAL/SQFT
32	SOLAR TANK HEIGHT-DIAMETER RATIO	2.00	
33	SOLAR TANK U-VALUE	0.10	BTU/HR-SQFT-F
34	SOLAR TANK ENVIRONMENT TEMPERATURE	70.00	DEG F

AUXILIARY STORAGE TANK:

41	AUX TANK OVERALL UA	0.00	BTU/HR-F
42	AUX TANK ENVIRONMENT TEMPERATURE	0.00	DEG F

DHW LOAD INFORMATION:

51	WATER HEATER USAGE	12718.00	GAL/DAY
52	WATER HEATER SET TEMPERATURE	140.00	DEG F
53	WATER SUPPLY TEMPERATURE (-1000 SETS TO GND TEMP)	-1000.00	DEG F

PROJECT: General Poultry
COMMENT: Application Review-Final

DATE: 04/03/86
FILE NAME: MWJPAC

ENVIRONMENTAL DATA AND THERMAL PERFORMANCE

ENVIRONMENTAL DATA

CAIRO , EG — LATITUDE = 30.08
TILT ANGLE = 45.00 — AZIMUTH ANGLE = 0.00

	HORIZONTAL SOLAR RAD	TILTED SOLAR RAD	AMBIENT AIR TEMPERATURE	WATER SUPPLY TEMPERATURE
	BTU/SQFT-DAY	BTU/SQFT-DAY	DEG F	DEG F
JAN	1329.	2122.	57.	58.
FEB	1606.	2180.	59.	56.
MAR	1931.	2174.	64.	58.
APR	2215.	2050.	70.	65.
MAY	2400.	1931.	77.	73.
JUN	2444.	1839.	82.	81.
JUL	2400.	1862.	82.	87.
AUG	2252.	1964.	83.	89.
SEP	2016.	2099.	79.	86.
OCT	1617.	2037.	75.	80.
NOV	1333.	2006.	67.	71.
DEC	1218.	2020.	60.	64.

THERMAL PERFORMANCE — SPECIFIED COLLECTOR AREA = 4000.00 SQFT

	SOLAR FRACTION	INCIDENT SOLAR	COLLECTOR OUTPUT	SOLAR SYS OUTPUT	TANK LOSS	LOAD	TANK TEMP	TEMP OUT
	%	*	*	*	*	*	DEG F	DEG F
JAN	53.7	263.11	146.49	145.25	1.22	270.66	102	102
FEB	53.6	244.19	134.83	133.77	1.07	249.52	101	101
MAR	53.6	269.62	145.12	143.89	1.23	268.36	102	102
APR	53.9	245.95	130.46	129.13	1.31	239.65	105	105
MAY	53.7	239.41	120.10	118.59	1.49	221.00	109	109
JUN	55.6	220.72	106.00	104.36	1.64	187.78	114	114
JUL	60.2	230.94	107.33	105.54	1.90	175.29	119	119
AUG	67.4	243.58	116.09	113.94	2.11	169.04	123	123
SEP	70.5	251.86	123.34	121.20	2.08	171.86	124	124
OCT	64.9	252.60	130.13	128.22	1.91	197.65	119	119
NOV	58.8	240.68	129.82	128.28	1.56	218.33	112	112
DEC	54.4	250.51	138.09	136.75	1.35	251.59	105	105
YR	57.6	2953.15	1527.79	1508.92	18.87	2620.75		

* UNITS = MMBTU — ANNUAL OPERATING HOURS = 2887

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E.1 FCHART-4R is a computer program that simulates the performance of several types of solar hot water and process heat systems. It is intended for use by engineers, architects, solar energy consultants, energy analysts, and others who need accurate information about the thermal and economic performance of the types of solar energy systems included. Features include optimization of collector area and a comprehensive economic analysis which was developed at the National Bureau of Standards.

E.2 Types of systems that can be simulated using FCHART-4R include liquid based active solar hot water and process heat systems. System types include systems that have either one or two storage tanks and may optionally have a collector heat exchanger.

E.3 The thermal performance report generated by FCHART-4R calculates the monthly average values for solar fraction, solar energy incident on the collectors, solar energy collected, tank losses, load, average tank temperature, and average temperature delivered from the solar storage tank. The program also calculates annual results.

E.4 The economic report generated by FCHART-4R calculates the discounted life cycle cost of the solar, auxiliary, and reference systems. Also included are the net savings, internal rate of return, discounted payback time, and annual simple and discounted cash flow for the solar energy system relative to the reference system. Economics will be addressed in a separate document; therefore, the FCHART-4R economics report will not be used.

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A. Input Data Descriptions

General Poultry Company
Heliopolis, Egypt

B. General Information

1. System Type = 2.

1.1 Two-Tank System (FCHART-4R only)

1.2 This type of system includes a collector with an optional heat exchanger, a solar storage tank, and a separate auxiliary tank. In this system, water flows between the solar storage tank and the collector, where it is heated. Makeup water is supplied to the solar tank. When there is a hot water demand, the solar tank provides its output to the auxiliary tank where the hot water load is supplied from the auxiliary tank. If the temperature from the solar tank is lower than the thermostat setting on the auxiliary tank, auxiliary energy is added to bring it to the set temperature. In our case, the auxiliary tank is the scalder.

2. Economics (Yes=1, No=2, Economic Only =3)

Enter a one (1) to perform a thermal and economic analysis, a two (2) for thermal analysis only, and three (3) for economic analysis only. If either collector area optimization (#3) or range of areas-fractions (#136) options are chosen, a one (#1) must be entered, as these options require economic data.

3. Collector Area Optimization (Yes=1, No=2)

Enter a one (#1) to perform collector area optimization or a two (#2) for the area specified in data item 11. The optimal collector area is the collector area which results in the greatest net savings over the analysis period. When optimization is selected, the economic data items must be specified.

4. City Number = 262.

CAIRO, EGYPT

LATITUDE = 30.08

	AMBIENT TEMP (DEG F)	DEGREE DAYS (DEG F-DAY)	HORIZONTAL SOLAR RAD. (BTU/SQFT-DAY)	GROUND WATER TEMP (DEG F)
JAN	57.0	148.0	1329.0	57.7
FEB	59.0	115.0	1606.0	56.0
MAR	63.5	97.0	1931.0	58.4
APR	70.0	63.0	2215.0	64.7
MAY	76.5	23.0	2400.0	72.8
JUN	81.5	1.0	2444.0	81.0
JUL	82.0	0.0	2400.0	86.7
AUG	82.5	0.0	2252.0	88.6
SEP	79.0	1.0	2016.0	86.0
OCT	74.5	22.0	1617.0	79.9
NOV	67.0	81.0	1333.0	71.4
DEC	59.5	138.0	1218.0	63.5

C. Collector and Collector HX

11. Collector Area = 4,000

Enter the total collector area. If optimization is selected, this value is ignored. (1.0 square foot is the minimum value accepted by FCHART).

12. FR-UL Product = 0.72 Btu/hr. sf. F

Enter the slope of the straight line collector efficiency curve as determined by the ASHRAE 93-77 Collector Method. (Value is for flat U.S. solar collector).

13. FR-TAU-ALPHA Product = 0.76

Enter the y-intercept of the straight line collector efficiency curve as determined by the ASHRAE 93-77 Collector Test Method. (Value is for U.S. solar collector).

14. Incident Angle Modifier Constant = 0.17

Enter the value which is experimentally determined by the ASHRAE 93-77 Collector Test Method. (Value is for U. S. solar collectors.)

15. Collector Tilt Angle = 45 degees, Base Run

Enter the number of degrees (from horizontal) that the collector is tilted.

16. Collector Azimuth Angle (South Ø, East=-9Ø, West=+9Ø)

Enter the direction of the collector relative to South, which is defined as zero. Any azimuth between -18Ø and +18Ø is acceptable.

17. Collector HX Effectiveness = 1.

Enter a value of one (1) when there is no collector heat exchanger. When there is a collector heat exchanger, enter a value between zero and one. Typical values are 0.7 with correctly sized heat exchanger and 1 for no heat exchanger.

18. Collector Loop Flow Rate = 14.70 lb/hr sq ft

The flow rate per unit of collector area between the collector array and the collector heat exchanger or tank (depending on whether there is a collector heat exchanger or not).

Fluid flow per square foot (SF) of collector area. Define as 1.0 gpm/34 SF.

8.33 lb/gal of water

The collector loop flow rate becomes

	0.029	gpm/SF
*	8.33	lb/gal
*	60	minutes/hour
	14.70	lb/hr sf

Collector-Storage Loop Flow Rate = 14.70 lb/hr

The flow rate per unit of collector area between the collector heat exchanger and the tank if there is a collector heat exchanger. If there is no heat exchanger, value is ignored.

20. Specific Heat of Collector Fluid = 1.0 Btu/lb.F

Enter the value for the specific heat of the collector fluid. The value for water is one (1) when using English units.

21. Specific Heat of Tank Fluid = 1.0 Btu/lb.F

Enter the value for the specific heat of the tank fluid. The value for water is one (1) when using English units.

22. UA of Collector Inlet Pipe = 0.5 Btu/hr.F

The overall heat loss coefficient U of the inlet pipe multiplied by the surface area A of the pipe.

23. UA of Collector Outlet Pipe = 0.5 BTU/HR.F

The overall heat loss coefficient U of the outlet pipe multiplied by the surface area A of the pipe.

24. Ground Reflectance = 0.2

Enter the reflectance of the horizontal surface in front of the collector. A value of 0.2 is typical except for conditions of snow or water surroundings, or other reflective surfaces.

25. Collector Test Flow Rate = 33.74 LB/HR.SF

The flow rate per unit of collector area through the collector during the ASHRAE 93-77 collector efficiency test. (Value is for U.S. solar collector)

D. Solar Storage Tank

31. Solar Storage Capacity = 1.5 gal/SF

Enter the tank storage capacity per unit collector area. Typical values are 1.2 to 2.0 gal/sq ft (English units).

32. Solar Tank Height - Diameter Ratio = 2.

Enter ratio of the tank height to tank diameter.

33. Solar Tank U-Value = 0.10 BTUH/SF.F

Enter the overall heat loss coefficient of the Solar Storage Tank.

34. Solar Tank Environment Temperature = 70 degrees F

Enter the temperature to which tank losses occur. 70 degrees F is the mean annual ambient temperature for Cairo, Egypt.

E. Auxiliary Storage Tank

41. Aux Tank Overall UA = 0.

Enter the overall heat loss coefficient U times surface area A of auxiliary tank. This is the tank heat loss per degree of temperature difference between tank fluid temperature and environment. Tank temperature is assumed to be equal to the hot water set temperature. The scalder is the auxiliary tank for this application. Scalder heat loss has been accounted for in the energy balance.

42. Aux Tank Environment Temperature = 0.

Enter the temperature to which tank losses occur.

F. Process Load Information

51. Water Heater Usage = 12,718 gal/day

52. Water Heater Set Temperature = 140 degrees F

Enter the desired supply temperature of heated water. This temperature is used to calculate the total water heating load.

53. Water Main Temperature = -1000.

Enter the temperature of the cold water supplied to the water heating system (DHW). If a value of -1000 is used, temperature will be set equal to monthly ground water temperature (which is in the weather data file).

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