PN-AAW-663
ISN: 49151
62
30 JUN 1986

CONCEPTUAL DESIGN FOR FIELD TEST NO. 3
POULTRY PROCESSING (INDUSTRIAL PROCESS HEAT)
GENERAL POULTRY COMPANY
HELIOPOLIS, EGYPT
JUNE, 1986
FINAL

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RENEWABLE ENERGY RESOURCES

FIELD TESTING

CONCEPTUAL DESIGN FOR FIELD TEST NUMBER 3
SUBTASK 3.3.3, GENERAL POULTRY COMPANY
AT HELIOPOLIS, EGYPT

JUNE 1986

FINAL

PREPARED FOR

EGYPTIAN ELECTRICITY AUTHORITY

CAIRO, EGYPT

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U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

USAID MISSION, CAIRO, EGYPT

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SUBMITTED TO

LOUIS BERGER INTERNATIONAL, INC.

WASHINGTON, D.C.

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

LOCKWOOD GREENE PROJECT NUMBER 84208.02

000241

005104

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84208.02
R566/2.mh

FOREWORD

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.

Five of the eleven potential field test documentation projects are Solar Thermal Industrial Process Heat (IPH) energy system applications. 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. The Conceptual Design for one of these five field tests, a Solar Thermal IPH System, is presented in this document. The proposed site is the General Poultry Company near Heliopolis and will consist of a Solar Thermal IPH System, Flash Steam System, and Condensate Return System. The systems are designed to operate independently. This document is Subtask 3.3.3 of the field test requirements under Contract AID 263-123C-00-4069-00, Task Area III.

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Nomenclature U.S. Aid General Poultry

units	
atm	atmosphere
BBL	barrel of fuel oil
Btu	British Thermal Unit
ch	height coefficient
cm	centimeter
gal	gallon
gms	grams
hz	hertz
hr	hour
j	joules
K	Kilo (1,000)
Kg	Kilogram
lb	pound
M	Thousand
min	minute
mTONS	metric tons
m 2	square meters
m 3	cubic meters
°C	degree Centigrade
°F	degree Fahrenheit
psf	pounds per square foot
psi	pound per square inch
psig	pound per square inch gage
Q	heat transfer per hour
q	wind pressure
sec	second
V	wind velocity
w8	8" wide flange structural member

Conversion Factors U.S. Aid General Poultry

units	
bar	14.5 psi
BBL	42 gallons
Btu/gal Fuel Oil	140,000
cm	0.3937 in
lbs/gal	8.345
gms	454 gms/lb
hz	1 cycle/sec
j	1,054 joules/btu
Kg	2.205 lb/kilogram
mTONS	2,205 lbs/mTONS
m 2	10.72 ft 2/m 2
m 3	264.2 gallons

1.0 EXECUTIVE SUMMARY

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 a Solar Thermal Industrial Process Heating (IPH) energy system. This experience will include 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.

This document presents the conceptual design for field test number 3, a Solar Thermal Industrial Process Heat (IPH) System, Flash Steam Tank and Steam Condensate Return System. The general concept of the solar IPH system is to provide hot water for General Poultry's scalding operation. The waste heat systems, a Flash Steam Tank and a Steam Condensate Return System, will provide additional heat for maintaining the scalder's temperature and improving boiler efficiency. Implementation of these systems will reduce the overall boiler load, resulting in a fuel savings.

The General Poultry conceptual design study provides an acceptable fuel saving methodology for the poultry industry.

The Steam Flash Tank, providing 1.23 MM Btu/Hr, can be constructed from large diameter piping with the ends welded or bolted in position. 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 condensate return system providing 1.96 MM Btu/hr performs the basic function of a steam trap. The receiver will operate 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 to the boiler feed water tank.

The Solar Thermal IPH System providing 0.572 MM Btu/hr will be composed of three interconnected sub-systems: the collector system (4000 square feet), the storage system and the hot water distribution system. The sub-systems will be interconnected by piping. The interaction of the sub-systems will have a major effect on the efficient operation of the entire system.

The collectors can be mounted on the roof of General Poultry on structural steel frames with access platforms for maintenance.

The flash tank and condensate return systems will be located near the rendering cooker area and scalders.

A preliminary engineering cost estimate for this conceptual design is presented in Appendix -A-.

Conclusions and Recommendations

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

Conclusions

1. The General Poultry geographical location is a good application site for demonstrating the use of solar thermal IPH because the solar resource is exceptional and the location is good for monitoring and evaluation.

2. The daily scalder demand fluctuates, therefore the sizing of the solar array is based on the average daily demand.

3. The most economically feasible and most reliable choice, for a solar collection system, is a flat plate type with minimum hot water storage. The flat plate system will benefit other poultry plants and low temperature food processing plant.

4. The design, operation, maintenance, and repair experience with flat plate solar arrays that can be obtained through this field test will form a strong technical base for the design and application of solar IPH.

Recommendations

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

2. Return all steam condensate to the boilers.

3. Install a flat plate collector array of approximately 4000 square feet (370 square meters), with storage tank, controls, and piping to provide hot water for the scalding process.

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 Flash Steam Technology and Condensate Return Systems, for the poultry processing industry.

The application of Solar IPH, Flash Steam, and Condensate Return Systems for poultry processing at Heliopolis will serve as a demonstration of the capability of the combined technology 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 Steam and Condensate Return Systems so that each system can be evaluated independently.

2.2 Project Background

The Egyptian Electricity Authority (EEA), USAID/Cairo, and a group of U.S. consultants form a team responsible for conducting field test demonstration projects of eleven renewable energy applications in Egypt. These include the use of photovoltaic, wind, and solar thermal systems for water pumping, ice making, desalination, industrial process heat, and grid-connected electricity. The specific objectives of the 4-year program are threefold: (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 the country.

Three tasks are planned:

(1) Field Tests - Assess selected renewable energy systems/applications which could be suitable for commercial use in Egypt; develop detailed engineering design hardware specifications and system performance requirements; prepare RFP packages for procuring equipment; supervise the work of hardware contractors; and collect and evaluate data generated from the field tests.

(2) Supporting Analysis - Conduct technical, social, financial, economic, and market analysis of renewable systems related to the field tests. Develop a computer-based Renewable Energy Information System (REIS).

(3) Training - Improve the skills of the Government of Egypt, and the private sector in evaluating renewable energy technologies, applications, economics, and markets, and provide technical assistance in system design, installation, operation, and maintenance.

The Renewable Energy Resource Field Testing Project sponsored by the USAID mission in Cairo provides an opportunity to investigate selected renewable energy options and to:

1. Comprehensively strengthen Egyptian technical and institutional capabilities in the full spectrum of renewable energy planning, decision-making, 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, install, operate, and evaluate a series of field test installations which utilize commercially available technologies in applications having potential for widespread use in Egypt.

4. Conduct a formal management and technical training program, both on-the-job and specialized, and establish an intensive information dissemination program.

2.3 Description of Field Test #3

This field test is designed to demonstrate the feasibility of solar thermal IPH operating in parallel with fuel oil fired boilers. The Egyptian Electricity Authority (EEA) and USAID/Cairo established that the capacity of the solar array should be approximately 4,000 square feet. The proposed location for the solar thermal IPH is the General Poultry Company in Heliopolis, near Cairo. The system sizing and selection of this specific location for this field test were based on a preliminary analysis of the General Poultry Company, where the poultry scalder is a candidate for IPH and the rendering cookers are a source of waste heat. These factors were investigated in detail during a site visit by personnel from the EEA and the U.S. Project Team. An analysis of the application based on data obtained during the site visit is presented in the Field Test #3 Application Review.

2.4 Intent of the Conceptual Design

The Conceptual Design subtask is an integral part of the Application Review, the Technology Review (including the identification and quantification of system performance specifications), and hardware specifications where appropriate, which constitute a major portion of the Statement-of-Work. The Annual Operating Plan (AOP) for the REFT Project, dated May 1985, specifies that the conceptual design activities "establish technical objectives, develop a system design data base, and

screen candidate system designs to establish a system sizing and operating baseline that satisfies site-specific operational, environmental and user requirements."

Specific subtask statements in the AOP specify that the conceptual design shall:

- Develop site-specific energy source profile and application-specific load demand profile
- Define hardware performance and environmental specifications
- Conduct system sizing and performance trade-off analyses
- Specify monitoring instrumentation requirements

These tasks were completed as part of the Application Review and Technology Review activities, in conjunction with visits to the U.S. of Egyptian engineers from the EEA and the General Poultry Company. Elements of the conceptual design appear in the Application Review and the Technology Review.

- A site-specific energy source profile and an application-specific load demand profile are included in the FT #3 Application Review.
- Hardware performance and environmental specifications will be included in the FT #3 SOW.
- System sizing and trade-off analyses are summarized in the Application Review.

3.0 APPLICATION REVIEW SUMMARY

3.1 Field Test Criteria

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 IPH system. These criteria are listed below, although not necessarily in order of importance.

1. Current and future user needs
2. Size and stability of the solar array
3. Evidence of a viable solar resource
4. Availability of proven and reliable commercial systems
5. Appropriate site characteristics and infrastructure for installation
6. Capability of the host organization for successful operation and maintenance of the systems
7. Potential for widespread use including social, economic, and institutional aspects

The following paragraphs summarize the findings of various studies and analyses addressing these criteria.

3.2 User Requirements

General Poultry is a large poultry processing plant, packing 50,000 chickens per day. An ongoing expansion will increase processing capacity 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 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 psia).

Each morning the scalders are filled with water and the water temperature is increased to 60°C (140°F) using low pressure steam in a coil. The steam is from two (2) oil-fired boilers.

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; boiler feed is therefore 100% make-up.

3.3 Existing Operating Conditions

"(x)" identify process streams from the mass and energy balance shown in Appendix -C-

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 cooker time: 11 hr/day

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

Renderings temperature in cookers: 170°C (338°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)

3.4 Existing Poultry Process Energy Demand (from Appendix -C-)
Denotes "(x)" energy stream from Appendix -C-

(1)	Birds in	=	2,063.9	MBtu/hr (2.17 x 10^6 KJ/hr)
(2)	Birds out	=	-2,635.4	MBtu/hr (-2.77 x 10^6 KJ/hr)
(2")	H_2O W/bird	=	-771.6	MBtu/hr (-0.81 x 10^6 KJ/hr)
(21)	Evaporative losses	=	-36.5	MBtu/hr (-0.04 x 10^6 KJ/hr)

(22)	Radiation losses	=	-122.6	MBtu/hr	(-0.13 x 10^6 KJ/hr)
(10B)	Fill water	=	286.7	MBtu/hr	(0.30 x 10^6 KJ/hr)
(10C)	Make-up water	=	299.3	MBtu/hr	(0.32 x 10^6 KJ/hr)
(23)	Fill water out	=	-773.9	MBtu/hr	(-0.82 x 10^6 KJ/hr)
	dQ1.0 (scalder)	=	-1,690.1	MBtu/hr	(1.78 x 10^6 KJ/hr)

Rendering Cookers Streams

(3)	Renderings in	=	658.9	MBtu/hr	(0.69 x 10^6 KJ/hr)
(4')	Vapor out	=	-8,558.2	MBtu/hr	(-9.00 x 10^6 KJ/hr)
(4")	DOA vapor out	=	-1,188.6	MBtu/hr	(-1.25 x 10^6 KJ/hr)
(6)	DOA poultry	=	41.9	MBtu/hr	(0.044 x 10^6 KJ/hr)
(7)	Renderings out	=	-711.9	MBtu/hr	(-0.75 x 10^6 KJ/hr)
(25)	Radiation losses	=	-975.8	MBtu/hr	(-1.03 x 10^6 KJ/hr)
dQ3.0	(rendering cookers)		-10,733.8	MBtu/hr	(11.3 x 10^6 KJ/hr)

The energy demand for the scalder,

dQ1.0 = 1,690 1MBtu/Hr (1.78 x 10^6 KJ/hr),

and the energy demand for the rendering cookers,

dQ3.0 = 10,733.8 MBtu/hr (11.3 x 10^6 KJ/hr),

require (12) 1,736 lb/hr (787.3 Kg/hr), and

(24) 12,297 lb/hr (5,577 Kg/hr) of steam respectively.

The scalders energy demand requires a steam flow of (12) 2,071 MBtu/hr (2.18 x 10^6 KJ/hr). The rendering cookers energy demand requires a steam flow of (24) 14,670 MBtu/hr (15.5 x 10^6 KJ/hr).

3.5 Existing Poultry Steam Consumption

(12)	Scalder Steam Demand	=	2.18×10^6 KJ/hr (2,071 MBtu/hr)
(24)	Rendering Cooker Steam Demand	=	15.5×10^6 KJ/hr (14,670 MBtu/hr)
	Total Steam Demand		17.7×10^6 KJ/hr (16,741 MBtu/hr)

3.6 Existing Energy Resources

High Pressure Steam Condensate

The high pressure condensate from the rendering cookers should be flashed to low pressure steam. The low pressure steam can 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)

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, since 100% of the boiler steam will be returned as condensate.

This will require the combining of all steam systems.

Insolation Profiles

Based on the insolation and ambient temperature data supplied by EEA, an optimum tilt for 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, (the latitude of the site), 35, 40, 45, and 50 degrees over the year. Exhibit 3-1 is a graph of the resulting insolation values.

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

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 significantly reduces the insolation during the summer.

Solar-Specific Data

Insolation values were calculated based on recorded data (sunlight hours) from a meteorological station. This data was supplied by EEA. The data is shown in Appendix D.

There are two system-specific conditions which affect the choice of tilt angle for the array in this application. 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 theoretical 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 analys's shows that the increase 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.

3.7 Conclusions and Recommendations

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

Conclusions

1. The General Poultry geographical location is a good application site for demonstrating the use of solar thermal IPH because the solar resource is exceptional and the location is good for monitoring and evaluation.

2. The most economically feasible and most reliable choice for a solar collection system is a flat plate system with minimum hot water storage. The flat plate and low temperature food processing plants.

3. The design, operation, maintenance, and repair experience with flat plate solar arrays that can be obtained through this field test will form a strong technical base for the design and application of solar IPH.

Recommendations

1. Install a steam flash tank, where high pressure condensate from the rendering cookers is reduced to a lower pressure steam and condensate. Low pressure steam can be used in the scalders and feedwater heating and condensate returned to the boilers.

2. Return all steam condensate to the boilers.

3. Install a flat plate collector array of approximately 4000 square feet (370 square meters), with storage tank, controls, and piping to provide hot water to the scalding process.

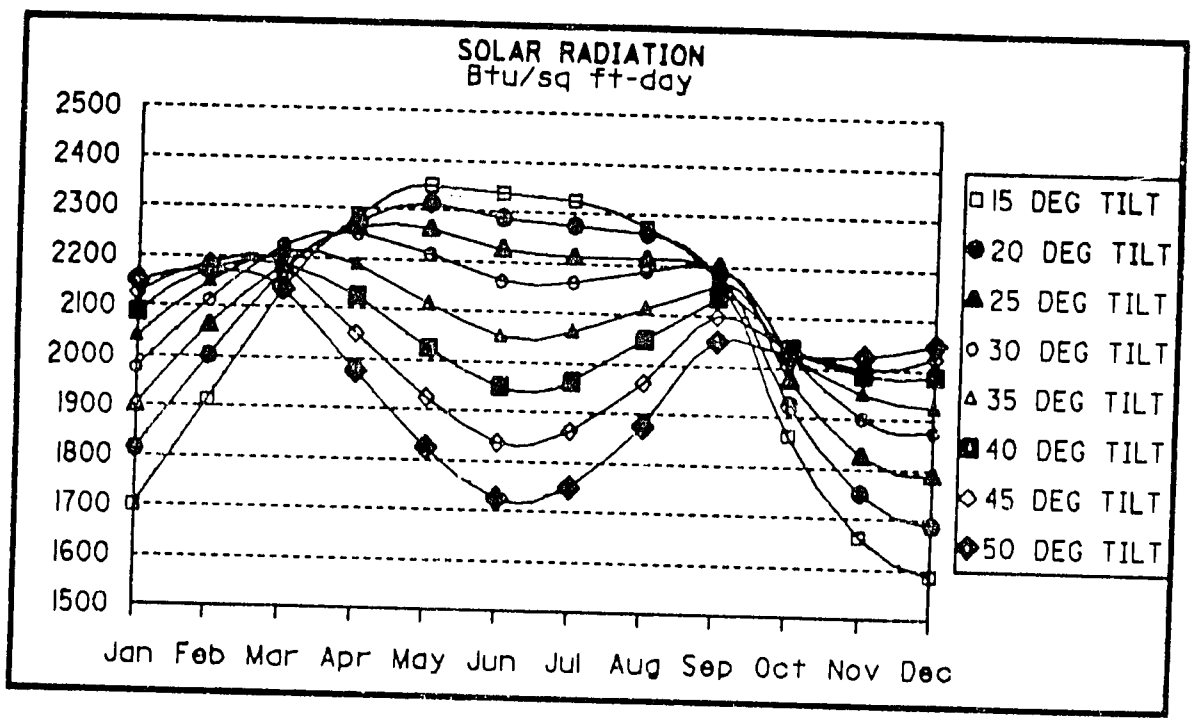


EXHIBIT 3-1

EEA INSOLATION DATA WITH TILT ANGLES

4.0 TECHNOLOGY REVIEW SUMMARY

General background technical information has been 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.

4.1 Design Objectives

For a solar thermal application, an extensive technology data base of applicable project analysis methods and a listing of current manufacturers with descriptions of available equipment 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.

4.2 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 established 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 wet bulb temperature ranges for the Cairo, Egypt, environment are low. The resulting relative humidity is low, with a design point estimate of 35%.

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.

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 actuation devices. 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.

4.3 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.

Process control modifications must also be considered, but flexibility must be maintained in order to allow full utilization of each alternate energy system (flash steam, 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 General Poultry's scalder process energy requirements are primarily met by hot water; representative configurations of hot water systems 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 4-1 and 4-2. A direct hot water system is shown in the first exhibit, and an indirect system is shown in the second. 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 heat transfer oil in the collector loop.

Liquid collectors are designed to use water in direct systems. Liquid collectors are also used in indirect hot water systems. Liquid-based flat-plate collectors, evacuated-tube collectors, and parabolic troughs are all appropriate.

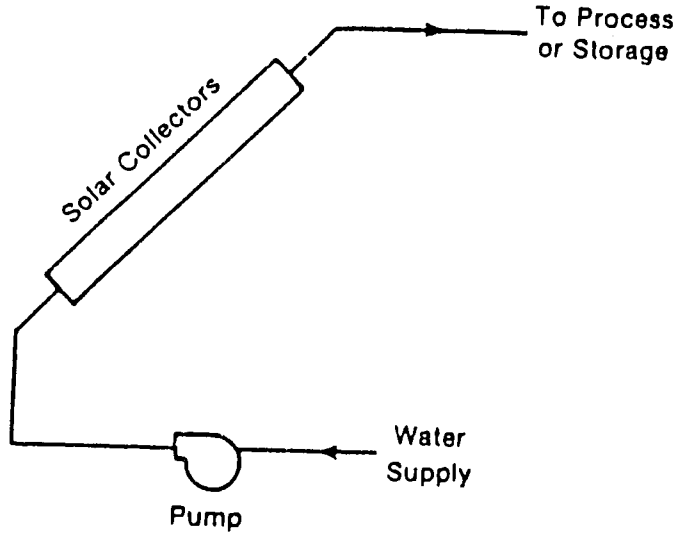


EXHIBIT 4-1

A DIRECT SOLAR HOT WATER SYSTEM

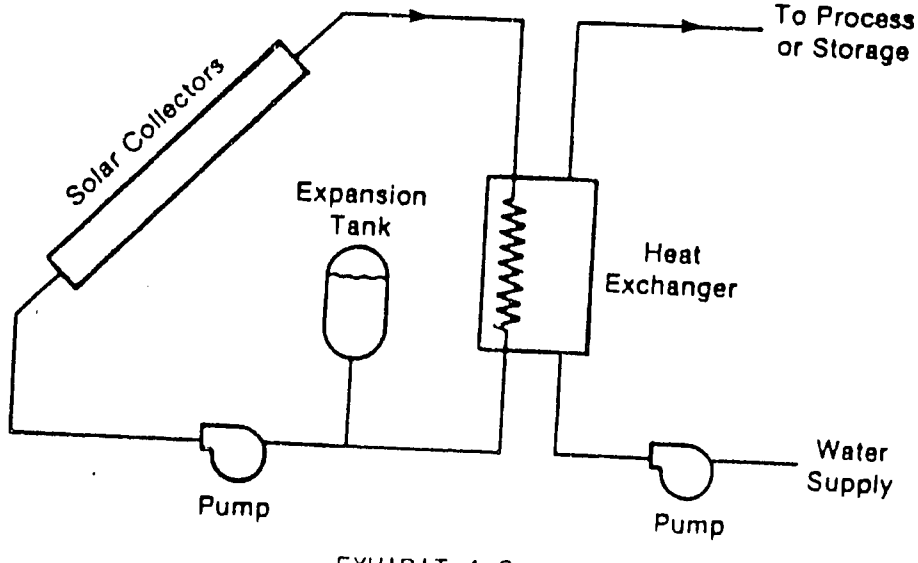


EXHIBIT 4-2

AN INDIRECT SOLAR HOT WATER SYSTEM

4.4 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 types of collectors are described.

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.

Collector construction consists of extruded aluminum framework, anodized dark or electrostatically painted and baked to 232°C (450°F). Glazing will be no-iron, tempered glass having 90% + transmissivity and patterned to minimize surface reflectivity. The panel will be insulated with fiberglass having a minimum value of R=8. An aluminum sheet backing will be used, and waterproofed with silicone adhesive. Frame will be structurally sound with rib angles for lateral torque stability. The absorber will be all copper fins and waterways, and have a non-selective black paint or selective black chrome finish.

The selected collector shall be provided with test results in accordance with ASTM 93-77.

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 4-3, 4-4, 4-5, and 4-6. These exhibits illustrate direct systems that incorporate process water passing through the collector array.

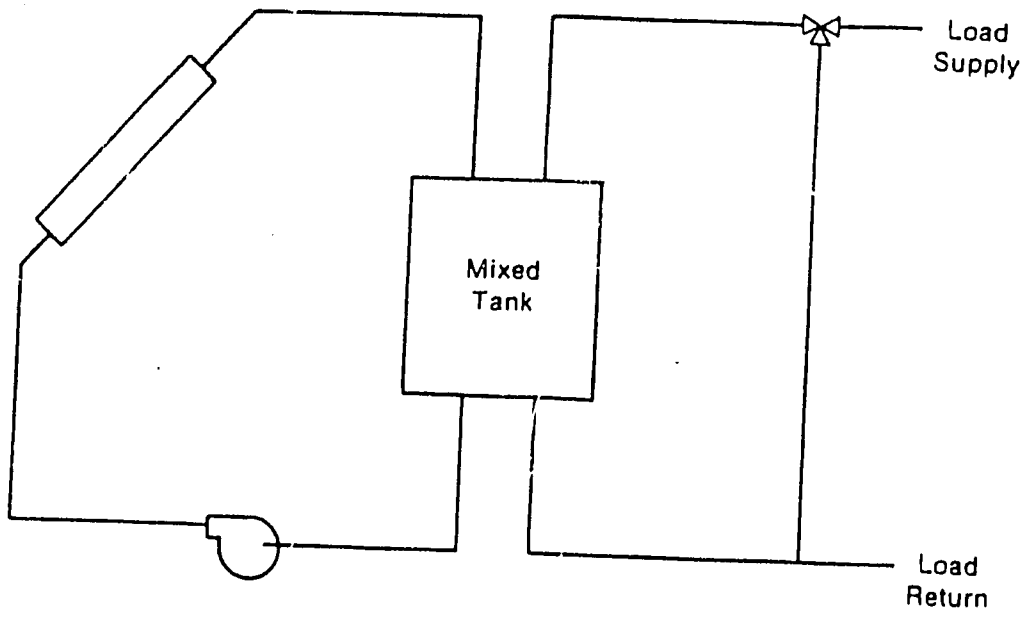


EXHIBIT 4-3

FOUR PIPE STORAGE CONFIGURATION

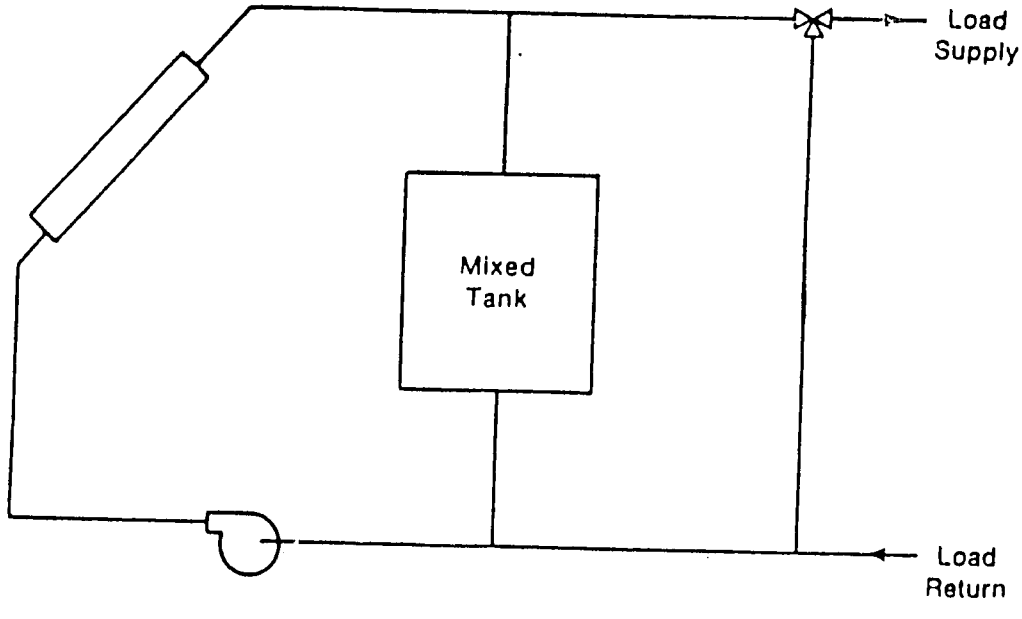


EXHIBIT 4-4

TWO-PIPE STORAGE CONFIGURATION

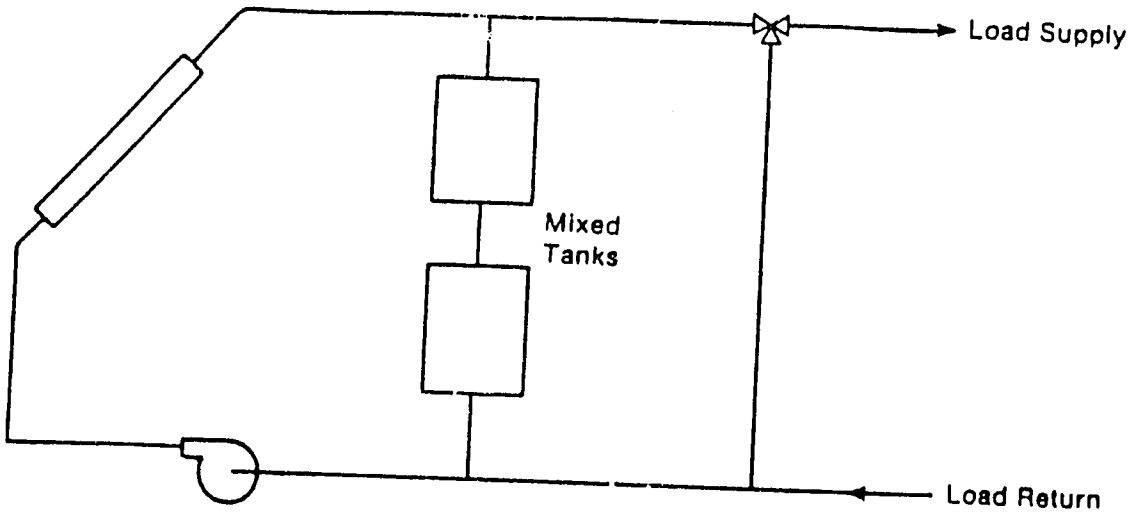


EXHIBIT 4-5

MULTIPLE-TANK STORAGE CONFIGURATION FOR ACHIEVING STRATIFICATION

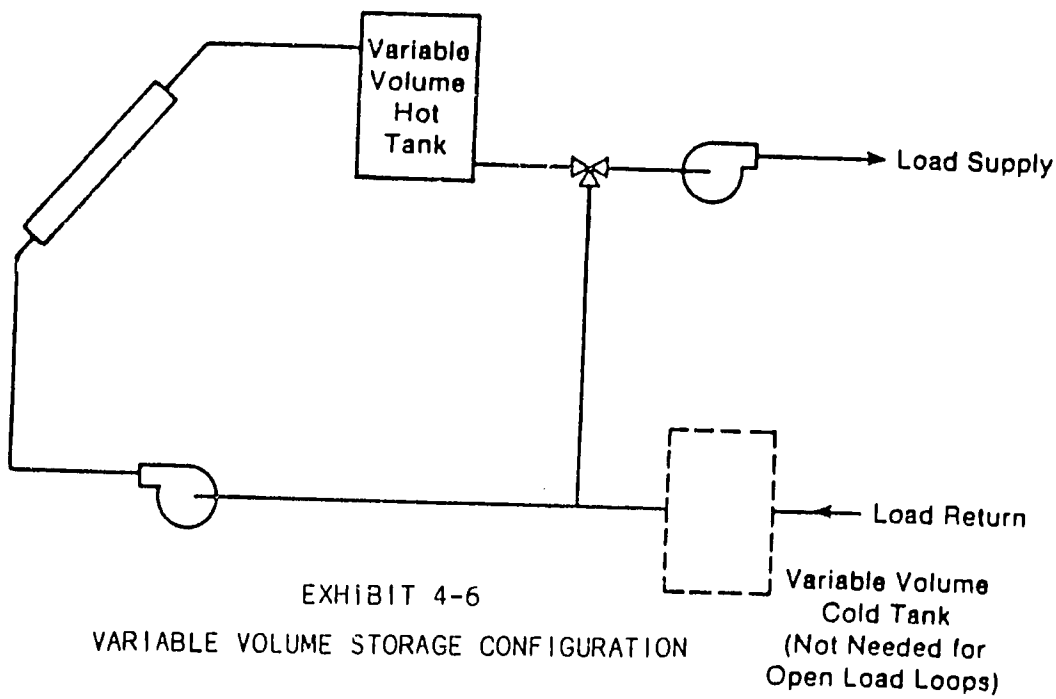


EXHIBIT 4-6

VARIABLE VOLUME STORAGE CONFIGURATION

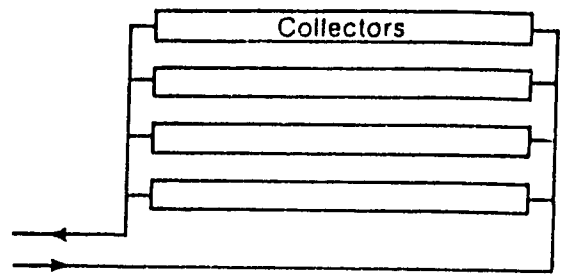
Pumps

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.

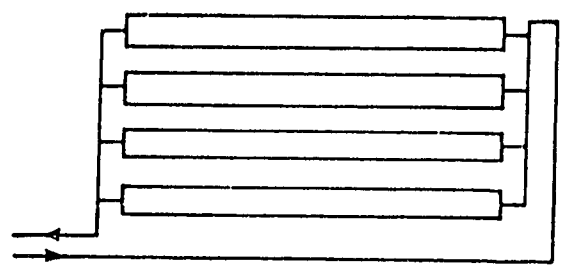
The pumps for General Poultry will be end suction industrial duty design with heavy ball bearings and foot mounted frame. Bearings will be isolated from the temperature effect of the hot water. The pump and motor with coupling will be furnished with a rugged fabricated steel base. The coupling will be a flex type with protective guards.

Piping

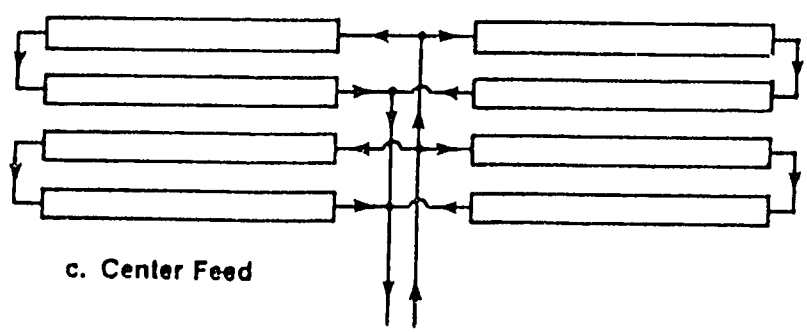
Three basic types of collector field layouts are employed in solar IPH systems. These layout types -- direct return, reverse return, and center feed--are shown schematically in Exhibit 4-7. In each case, the hot outlet piping is shorter than the supply piping, to minimize thermal losses. There are advantages and disadvantages to each of these configurations.



a. Direct Return



b. Reverse Return



c. Center Feed

EXHIBIT 4-7

COLLECTOR FIELD LAYOUTS

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.

Control Definition

As in nonsolar process applications, controls 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.

5.0 CANDIDATE FOR CONCEPTUAL DESIGN

5.1 Design Approach

The system configuration is developed utilizing the loads identified in the Application Review. The equipment under consideration is discussed in the Technology Review. The conceptual design's purpose includes development, demonstration, training, and selection of a lowest cost option. The conceptual design is an iterative process conducted to determine a preferred solar IPH system, specifically for General Poultry, which is 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.

5.2 Solar System Iteration and Selection

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 5-1.

The first array sizing option is Curve 1 in Exhibit 5-1 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 Daily 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.

CURVE 1:

FUEL DISPLACEMENT

SOLAR ARRAY, NO STORAGE

NO EXCESS CAPACITY

$SOLAR ARRAY = $FUEL

SOLAR THERMAL 25 - 30% OF LOAD

CURVE 2:

PARTIAL DAILY LOAD SUPPLY

MINIMAL HOT WATER STORAGE

$SOLAR ARRAY + $HOT WATER =<$FUEL

$SOLAR ARRAY < $FUEL

$SOLAR ARRAY/STORAGE 70% OF LOAD

CURVE 3:

PARTIAL DAILY LOAD SUPPLY

MINIMAL HOT WATER STORAGE

$SOLAR ARRAY + $HOT WATER STORAGE = <$FUEL

$SOLAR ARRAY/$FUEL

$SOLAR ARRAY/$STORAGE = 25 - 70% OF LOAD

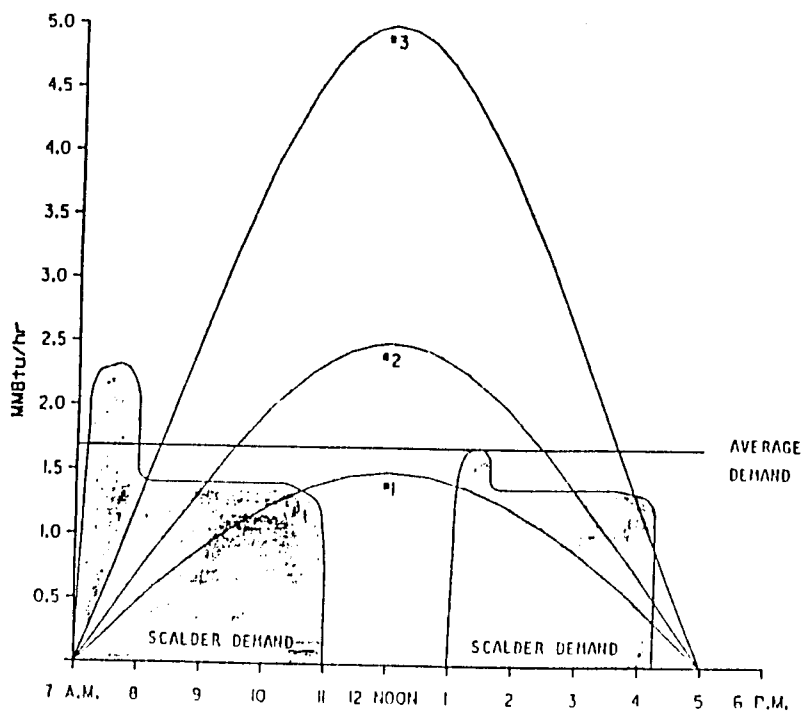


EXHIBIT 5-1

ARRAY SIZING OPTIONS

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.

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 optimum percentage is a function driven by the economics of the system components, primarily the solar array, hot water storage, and boiler 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-fired 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, the energy conditioning efficiency, and losses associated with hot water storage. FCHART-4R shows the relationship among these factors to calculate an approximate solar size (see Appendix -E-).

In the FCHART-4R calculation, energy attributed to hot water storage loss is determined for the amount of energy passing through the system which must be made up due to system energy losses.

Insolation and solar array operating efficiency values are also determined. Site-specific insolation and ambient temperature data were used and the array tilt angle set. Appendix -E- contains the results from 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 (280-560 square meters) square feet is considered reasonable. The technical analysis portion of this Conceptual Design is performed using a 4000 (370 square meters) square foot array.

When the optimum solar array size is calculated based on fuel cost, the array size is one square foot, not practical for this installation.

The 4,000 square foot (370 square meters) array will provide hot water for filling and maintaining the scalder's level. The design, operation, maintenance, and repair experience with the 4,000 square foot (370 square meters) array will form a strong technical base for the design and application of solar IPH for other poultry and low temperature food processing plants.

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 to be 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.

The General Poultry storage tank is required to batch fill the scalders each morning. The batch fill operating procedure requires a minimum of 13 m^3 per scalder (3,500 gal.). Therefore, the solar storage is sized to accommodate the batch filling operation. The storage tank temperature and Btu/month are graphically represented on Exhibit 5-2. The values plotted are calculated in FChart-4R, Appendix -E-.

5.3 Operating Concept

The operating concept behind the solar thermal, flash steam, 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.

The Solar Thermal IPH Controls

The Solar Thermal IPH Controls will be designed to maximize the energy delivery. Experience has shown that the control system should be as simple as possible to ensure that it provides trouble-free operation.

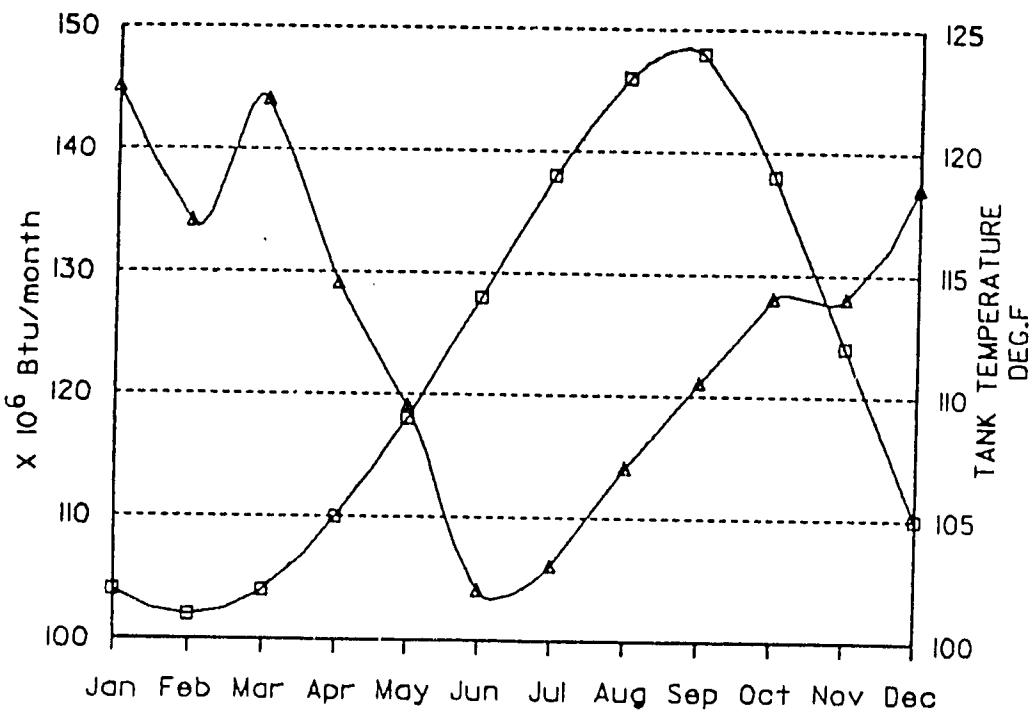
General Poultry's Array will be controlled by a differential temperature control loop measuring temperature at the array inlet and storage tank. The water circulation will increase to control the differential temperature.

The storage tank level controller will maintain the storage tank fill rate to maximize the storage tank temperatures, i.e. the storage tank level will drop each morning as the scalders are filled, rather than quickly filling the storage tank and cooling the remaining make-up water, the level controller will "ramp" to the level setpoint over a pre-determined time period.

The Flash Tank Controls

The liquid level in the flash tank will be maintained via level control valve in the condensate line leaving the flash tank.

The flash tank pressure "floats" with the low pressure steam system.



MONTHS	Btu/month x10^6 △	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 5-2

BTU, STORAGE TANK TEMPERATURE VS MONTHS/YEAR

The Condensate Return System

The liquid level in Condensate Return Tank will be maintained via a high level switch that turns the pumps on and a low level switch that turns the pumps off.

5.4 Performance Modeling

A computerized simulation model has been developed to accomplish a dynamic heat balance of the total energy requirements in order to establish a design basis for the flash steam, condensate return, 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 determined 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.

Performance Assumptions

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

2. Tilt angle 45°.

3. Boiler stack losses are 25%.

4. The energy content of fuel oil is 140,000 Btu/gallon (35,057 kJ/l), and there are 42 gals/barrel.

5. 100% of the condensate is returned to the boiler feed tank. The boiler feed tank operates at 212°F (100°C).

6. Excess steam from the flash tank can be used to preheat boiler feedwater.

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

5.5 System Fuel Savings

Solar System Savings

Solar System Savings are calculated using FCHART-4R. Appendix -E- lists pertinent FCHART-4R input data as determined from the Application Review and the Technology Review. To optimize the solar array the hot water storage system the process load, 12,718 gal/day (48 cubic

meters/day) was calculated using the ratio 330/365, i.e the operating days versus days per year. The results are:

(M19) H_2O to the scalder	14,648 lb/hr
Scalder operating time	* 8 hrs/day
Mass per unit volume	÷ 8.33 lb/gal
	14,067 gal/day
14,067 gal/day * (330/365) =	12,718 gal/day

FCHART-4R's thermal performance analysis indicates that 1,508.92 x 10^6 Btu/yr be can supplied from a 4000 square foot array Reference Appendix -E-.

Solar System Energy Savings

Mass Flow gal/day	1. Energy Flow Water to Scalder Btu/day	Energy Flow From FCHART-4R Btu/yr
12,718	4,572 x 10^3	1,509 x 10^6
2. Fuel Saved @ 0.75 Boiler Eff. Btu/yr	3. Fuel Saved gal/yr	4. Fuel Saved BBL/yr
2,012 x 10^6	14,372	342

Solar System Savings Calculations

1. $1,509 \times 10^6$ Btu/yr ÷ 330 days/yr = $4,572 \times 10^3$ Btu/day

2. $1,509 \times 10^6$ Btu/yr ÷ Boiler Eff. (0.75) = $2,012 \times 10^6$ Btu/yr

3. $2,012 \times 10^6$ Btu/yr ÷ 140,000 Btu/gal = 14,372 gal/yr

4. 14,550 gal/yr ÷ 42 gal/BBL = 342 BBL/yr

Flash Tank System Savings

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 source. 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.

Flash Tank Savings

Mass flow Condensate From Rendering Cookers (M3) lbs/hr	Energy Flow Condensate From Rendering Cookers (Q8) Btu/hr	1. Flash Steam %
12,297	3,922,688	10.6
2. Mass Flow Flash Steam @ 15 psig lb/hr	3. Energy Saved @ 15 psig Btu/hr	4. Energy Saved @ 15 psig Btu/yr
1,301	$1,229.5 \times 10^3$	$3,246 \times 10^6$

5. Fuel Saved @ .75 Boiler Eff. Btu/yr	6. Fuel Saved @ 140,000 Btu/gal gal/yr	7. Fuel Saved @ 42 gal/BBL BBL/yr
$4,328 \times 10^6$	30,919	736

Flash Tank Fuel Savings Calculations

1. $\% \text{ Flash STM} = \frac{H8 - HI \text{ @ } 15 \text{ PSIG}}{Hlv \text{ @ } 15 \text{ PSIG}} = \frac{319 - 219}{945} = 10.6\%$

2. $10.6\% * M8 = 10.6\% * 12,297 = 1,301$ lb/hr

3. $M8 * Hlv \text{ @ } 15 \text{ psig} = 1,303 \text{ @ } 945 = 1,229.5 \times 10^3$ Btu/hr

4. $1,231.3 * 10^3$ Btu/hr * 330 days/yr * 8 hr/day = $3,246 \times 10^6$ Btu/yr

5. $3,246 \times 10^6 \div$ Boiler Eff. (0.75) = $4,328 \times 10^6$ Btu/yr

6. $4,392 \times 10^6$ Btu/yr ÷ 140,000 Btu/gal = 30,919 gal/yr

7. 31,301 gal/yr ÷ 42 gal/bbl = 736 BBL/yr

The Steam Condensate Return System Savings

The steam condensate return system is a "waste energy 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 to 175°C (347°F). 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 by 8 to 12%.

Steam Condensate Return System Savings

Condensate From Rendering Cookers and Scalders lb/hr		Condensate From Rendering Cookers and Scalders Btu/hr		Using Hlv (Hl @ 212F - (Hv @ 212F) Btu/lb
(M8)	12,297	(Q8)	3,922,688	180
(M13)	+1,736	(Q13)	+ 380,251	-40
Total	14,033		4,302,939	140

1. Energy Saved Btu/hr	2. Energy Saved Btu/yr	3. Fuel Saved @ 0.75 Boiler Eff. Btu/yr
$1,964 \times 10^3$	$5,186 \times 10^6$	$6,916 \times 10^6$

4. Fuel Saved Gal/yr	5. Fuel Saved BBl/yr
49,400	1,176 BBL/yr

The Steam Condensate Return System Fuel Savings Calculation

1. M total * Hlv = 14,032 * 140 = $1,964 \times 10^3$ Btu/hr

2. $1,964 \times 10^3$ Btu/hr * 330 days/yr * 8 hrs/day = $5,186 \times 10^6$ Btu/yr

3. $5,186 \times 10^6$ ÷ Boiler Eff (0.75) = $6,916 \times 10^6$ Btu/yr

4. $7,001 \times 10^6$ Btu/yr ÷ 140,000 Btu/gal = 49,400 gal/yr

5. 50,011 ÷ 42 gal/BBL = 1,176 BBL/yr

Summary of Fuel Savings (Appendix -C-)

	BBL/yr	% Savings
The 4000 square foot solar array	342	3.5
The Steam Flash Tank	736	7.6
The Condensate Return System	1,176	12.1
Total Annual Fuel Savings	2,254	

5.6 Flow Diagram Development

General

FIELD TEST NO. 3
GENERAL POULTRY COMPANY
Heliopolis, Egypt

Latitude	30° 08° N
Longitude	31° 24° E
Elevation	367 ft.

Annual Heating Degree Days (base = 65) = 689HDD
Annual Cooling Degree Days (base = 65) = 3089CDD

Summer	97°F (36°C) Dry Bulb
	74°F (23°C) Wet Bulb
	25°F (14°C) Mean Daily Range
	6 Knots NNW Prevailing Wind

Winter	46°F (8°C)
	6 Knots (11 Kilometers/hr)
	SSW Prevailing Wind

Average Annual Ground Water Temperature = 72°F (22°C)

Building size, orientation, location of existing utilities (boilers, etc.), and feasible location for solar collection array (roof only) should be determined by the contractor at the job site.

The Solar radiation for Cairo, Egypt, used in the solar energy design calculations is shown in Appendix D. This data was supplied by the Egyptian Electricity Authority Project Management Team. Both metric and English units are provided.

Flow Diagram

The enclosed Flow Diagram M-1, Exhibit 5-3 indicates the proposed process flows, pressures, temperatures, and relationships to the system described by this Conceptual Design.

Existing heat and mass balances for individual equipment and for the overall plant are shown in Appendix "C".

The following list describes the Flow Diagram streams.

(1) Poultry In - the poultry supplied to the scalder for processing

(2') Poultry Out - the poultry solids coming out of the scalder

(2") Poultry Water Out - the water carried in the feathers of the poultry

(3) Rendering In - the poultry solids from the processing to the rendering cooker.

(4') Vapor Out - the process vapor released from the rendering cooker

(4") Vapor Out - the vapor released from the rendering cooker to the preheater from the dead poultry (DOA)

(5') Processed Poultry to Packaging - the poultry that has been processed and is ready for packaging

(5") Process Water to Drain -

(6) Poultry DOA - the poultry that dies before arriving at the plant site

(7) Rendering Out - the solid waste from the rendering cooker

(8) Rendering Condensate Out - the high pressure vapor exiting the rendering cooker to the flash tank

(9) Flash Steam - the flashed steam from the rendering cooker condensate

(10b) Make Up Water - the daily refill water from the solar system to refill the scalder before the start of each process day.

(10c) Make Up Water - the water from the solar system required to maintain the level in the scalder during a process day.

(11) System Out - the steam produced at 8 bar by the boiler delivered to the scalder and rendering cooker

(12) Steam to Scalder - the portion of steam produced by the boiler that is reduced to 1 bar pressure and delivered to the scalder.

(13) Condensate Out - the condensed steam out of the scalder.

(14) Make Up - the water that is returned to the boiler as make up for losses.

(15) Low Pressure Condensate - the condensed steam from the scalder and returned to the make up tank

(16) Not used

(17) Flash Condensate - the water condensed from the rendering cooker steam and returned to the make up tank

(18) Make-up Steam to Scalder

(19) Make Up Water In - water supplied to the solar system to make up for system losses

(20) Not used

(21) Evaporation Losses - the losses in the scalder due to evaporation

(22) Radiation Losses - the losses in the scalder due to radiation

(23) Fill Water Out - the water dumped out of the scalder at the end of a process day

(24) Steam In - the steam supplied to the rendering cooker by the boiler at 8 bar

(25) Radiation Losses - the losses in the rendering cooker due to radiation

(26) Fuel Used - the fuel consumed in the production of the steam required

(27) Burner Losses - the losses due to burner inefficiency

(28) Other Losses - the losses due to radiation and distribution inefficiencies

(29) Steam In - the steam supplied to the deaerator to maintain the required temperature

(30) Other Losses - the losses from the deaerator due to radiation

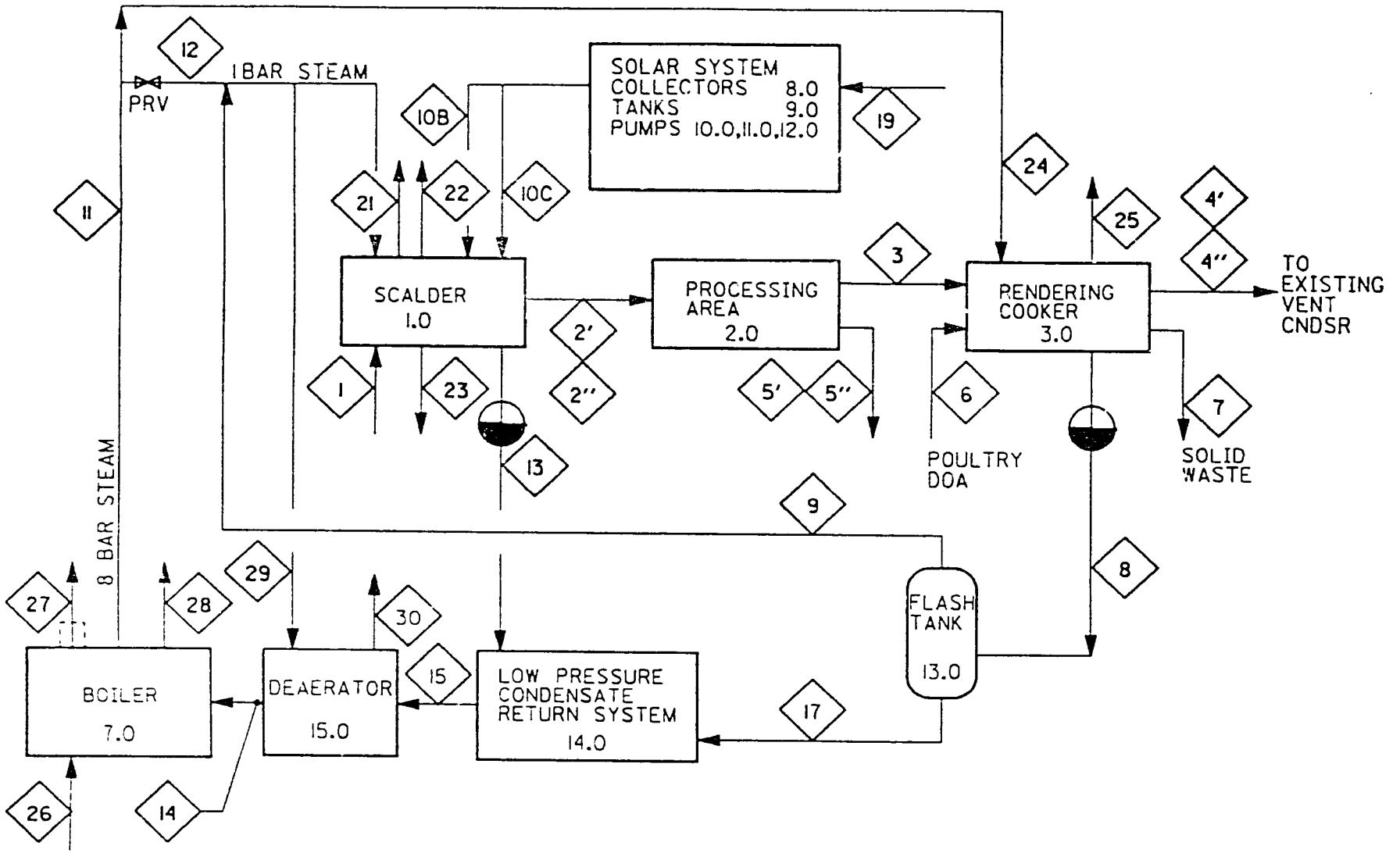


EXHIBIT 5-3

PROPOSED FLOW DIAGRAM FOR GENERAL POULTRY COMPANY

LOCKWOOD GREENE
Planners/Engineers/Architects/Managers
Spartanburg, South Carolina

FLOW DIAGRAM
GENERAL POULTRY COMPANY

84208.02 | 3/13/85 | NONE | 84-1

46

5.7 Simplified Process and Instrument Diagram Development

Using the proceeding Flow Diagram, with the mass and heat balance (Appendix -C-), the Simplified Process and Instrument Diagram was developed.

The Simplified Process and Instrument Diagram, Exhibit 5-4 indicates the existing and new equipment, with representative instrumentation sensing points identified.

The sextet symbol represents a mechanical "tie-in" location to the existing system. The host client must provide the "tie-in" and an isolation valve.

In addition to the mechanical "tie-in" the host client must provide electrical power to a motor control center.

1.0 SCALDERS-EXISTING
NO. OF UNITS-2
SIZE-6.6M x 3.35M x 0.85M
FILL VOLUME-13 CU.M.
PROCESS DESIGN Bar, DEG.C
PROCESS OPERATING ATM 6bar, 60DEG.C
STEAM DESIGN Bar, DEG.C
STEAM OPERATING 18bar, 170DEG.C

2.0 PROCESSING AREA-EXISTING
NO. OF PROCESS LINES-2
PROCESS DESIGN Bar, DEG.C
PROCESS OPERATING ATM 6bar, 60DEG.C
STEAM DESIGN Bar, DEG.C
STEAM OPERATING 18bar, 170DEG.C

3.0 RENDERING COOKERS-EXISTING
NO. OF UNITS-5
PROCESS DESIGN Bar, DEG.C
PROCESS OPERATING Bar, DEG.C
STEAM DESIGN Bar, DEG.C
STEAM OPERATING 18bar, 170DEG.C

4.0 VENT CONDENSERS-EXISTING
NO. OF UNITS-4
STEAM DESIGN Bar, DEG.C
STEAM OPERATING Bar, DEG.C
CTW DESIGN Bar, DEG.C
CTW OPERATING Bar, DEG.C

5.0 COOLING TOWER-EXISTING
NO. OF UNITS-1
CTW DESIGN Bar, DEG.C
CTW OPERATING Bar, DEG.C

6.0 VACUUM PUMP-EXISTING
NO. OF UNITS-2
CAPACITY M3/MIN M HEAD
SIZE X X
CONNECTION RATING TYPE
NE 5mTa

7.0 BOILERS-EXISTING
NO. OF UNITS-3
2 WATER UNITS
4 WATER UNITS

8.0 SOLAR COLLECTOR-NEW
TOTAL AREA 378 M2
WEIGHT 6100 Kg
NO. OF PANELS 25
ARRANGEMENT 5 ROWS OF 25

9.0 SOLAR COLLECTOR TANK-NEW
SIZE 8 (2.5 MIDAL X 22.6 FT M)
FILL VOLUME M3
INSULATION THICKNESS 4" (100 MM)
DESIGN Bar, 95DEG.C
OPERATING Bar, 60DEG.C
WEIGHT 3000Kg

10.0 SOLAR CIRCULATING PUMPS-NEW
CAPACITY (2001, 30 M HEAD)
SIZE 2" x 1" x 7" (50 X 25 X 175)
CONNECTION 10bar RATING, FLG TYPE
WEIGHT 200 Kg

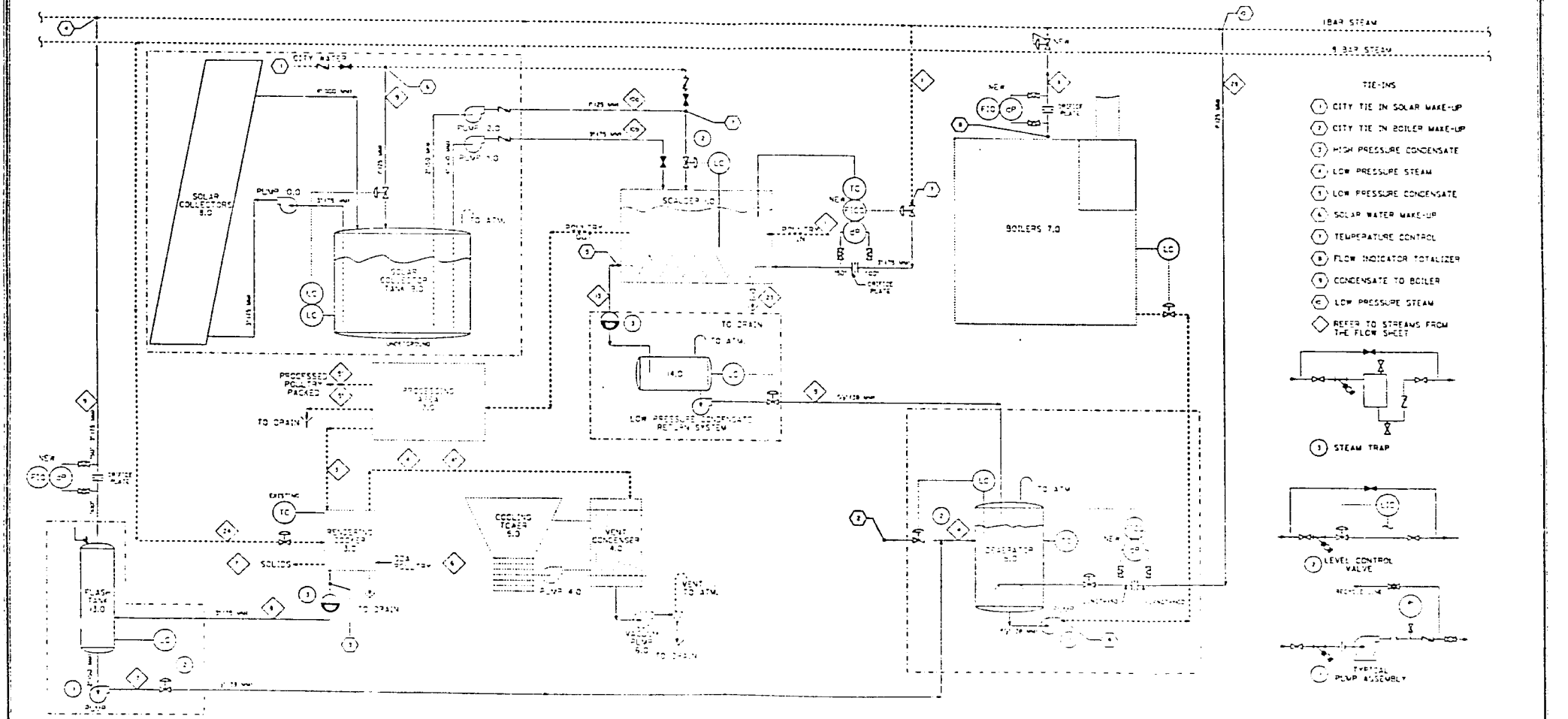
11.0 BATCH FILL PUMP-NEW
CAPACITY (2001, 15 M HEAD)
SIZE 3" x 3" x 10" (75 X 75 X 250)
CONNECTION 10bar RATING, FLG TYPE
WEIGHT 250Kg

12.0 CONTINOUS MAKE-UP PUMP NEW
NO. OF UNITS 1 (1 MINIMUM)
CAPACITY (240 L, 5 M HEAD)
SIZE 2" x 1" x 7" (50 X 25 X 175)
CONNECTION 10bar RATING, FLG TYPE
WEIGHT 220 Kg

13.0 FLASH TANK SYSTEMS
NO. OF UNITS 1 (1 MINIMUM)
VOLUME 1200 L
CAPACITY (40 L, 30M HEAD)
CONNECTIONS 10bar RATING, FLG TYPE, 75 MM
DESIGN 10 Bar, 350DEG.C
OPERATING 1 Bar, 120DEG.C
WEIGHT 250 Kg

14.0 LOW PRESS. CONDENSATE RETURN SYSTEMS-NEW
NO. OF UNITS 1 (1 MINIMUM)
VOLUME 1200 L
CAPACITY (100 L, 20 M HEAD)
SIZE 1" x 1" x 6" (25 X 25 X 150)
CONNECTIONS 10 Bar RATING, FLG TYPE
DESIGN 10 Bar, 350 DEG.C
OPERATING 0 Bar, 100DEG.C
WEIGHT 275 Kg

15.0 DEAERATOR
NO. OF UNITS 2
CAPACITY 30 (1000M HEAD)
PUMP SIZE 1" x 1" x 4" (25 X 25 X 200)
VOLUME 1200 L
CONNECTIONS 10bar RATING, FLG TYPE
DESIGN 10 Bar, 350DEG.C
OPERATING 10 Bar, 90DEG.C
WEIGHT 180 Kg



LOCKWOOD GREENE
Planners/Engineers/Architects/Managers
Spartanburg, South Carolina

PROPOSED CONDITIONS
7 & 10
CONCEPTUAL DESIGN

U.S. AID
GENERAL POULTRY

84JC8.02 | 9-13-85
NONE

5.8 Preliminary Equipment Specification Development

The equipment list and following preliminary descriptions should be used as a guide to develop equipment specifications.

EQUIPMENT NUMBER	NAME	CAPACITY	SIZE	DESIGN PSIG	DESIGN TEMP	SERVICE	REMARKS
1.0	SCALDER	13 M^3	6.6X3.35X8	15	212		EXISTING
2.0	PROCESS-ING AREA						EXISTING
3.0	RENDERING COOKERS						EXISTING
4.0	VENT CON-DENSERS						EXISTING
5.0	COOLING TOWER						EXISTING
6.0	VACUUM PUMPS						EXISTING
7.0	BOILERS						EXISTING
8.0	SOLAR COL-LECTORS		4,000 FT^2		212	WATER	
9.0	STORAGE TANKS	8,500 GAL.	8' X 22.6'	0	212	WATER	6" INSU-LATION
10.0	CIRCULA-TION PUMPS	300 GPM.	2" X 1.5"	150	450	WATER	
11.0	FILL PUMP	300 GPM.	3" X 3"	150	450	WATER	
12.0	MAKE-UP PUMP	60 GPM.	2" X 1.5"	150	450	WATER	
13.0	FLASH TANK	300 GAL	10 GPM	15	450	STM	PUMP OP-TIONAL
14.0	CONDENSATE	300 GAL	25 GPM	15	450	COND.	
15.0	DEAERATOR	300 GAL	30 GPM	15	450	COND.	

5.8 Preliminary Equipment Specification Development

The equipment list and following preliminary descri,tions should be used as a guide to develop equipment specifications.

EQUIPMENT NUMBER	NAME	CAPACITY	SIZE	DESIGN BARS	DESIGN TEMP °C	SERVICE	REMARKS
1.0	SCALDER	13 M^3	6.6X3.35X8		100		EXISTING
2.0	PROCESS-ING AREA						EXISTING
3.0	RENDERING COOKERS						EXISTING
4.0	VENT CON-DENSERS						EXISTING
5.0	COOLING TOWER						EXISTING
6.0	VACUUM PUMPS						EXISTING
7.0	BOILERS						EXISTING
8.0	SOLAR COL-LECTORS		370 M^2		100	WATER	
9.0	STORAGE TANKS	32,175 l	2.4 x 6.9 M		100	WATER	15" IN--SULATION
10.0	CIRCULA-TION PUMPS	1,135 LPM.	5 x 4 cm	10	235	WATER	
11.0	FILL PUMP	1,135 LPM.	3 x 8 cm	10	235	WATER	
12.0	MAKE-UP PUMP	230 LPM.	5 x 4 cm	10	235	WATER	
13.0	FLASH TANK	1,135 l	40 LPM	1	235	STM	PUMP OP-TIONAL
14.0	CONDENSATE	1,135 l	95 LPM	1	235	COND.	
15.0	DEAERATOR	1,135 l	115 LPM	1	235	COND.	

New Equipment Descriptions

Solar System

A. Collectors

The collectors shall be flat plate construction with an extruded casing of aluminum suitably treated to insure reliable operation and life expectancy compatible with the Egyptian environment. The glazing shall be low iron glass suitably mounted and sealed to maintain collector integrity. The headers and collection tubes shall be constructed of copper and shall be joined together in such a manner as to insure proper collector operation through out the system life without joint degradation between the headers and the tubes. The absorber plate shall be constructed of copper or aluminum sheet and shall be bonded to the absorber tubes in a manner conducive to effective heat transfer. The plate and tubes are to be treated with a selective coating to enhance the collectors ability to collect incident solar radiation. The collector shall be insulated with closed cell insulation, which minimizes heat loss to the environment. The collector shall be mounted in such as manner as to provide adequate support during a 25 M/S wind load.

The collector shall be tested in accordance with ASHRAE 93-77 and shall be sized to provide the quantity of solar energy as specified in the RFP.

B. Pumps

Electrically driven pumps shall be compatible with hot water service. Consideration should be made for stagnation temperatures which would be much higher than normal operating temperatures.

Pumps shall be sized to provide the flow required at the heads imposed by the solar system. The circulation pump should be sized to meet the requirements of the collection system so as to circulate water through the collectors at a flow rate that produces optimum efficiency.

The distribution pumps should be sized for the flow requirements of the process load. The use of multiple pumps in parallel should be considered when throttling of one pump would bring flow below manufacturer's recommended minimum.

C. Valves

Valves shall be constructed of materials compatible with hot water service. This should include body, shafts, seals, and valve mechanism. The correct style valve design should be chosen for each location in the hydraulic circuit. Each pump shall have isolation valves. A high performance butterfly valve would be a good choice in this application. Straight-through swing check valves should be installed where required. Vents, drains and gauge isolation values should be ball valves. Isolation valves for rows of collectors should be minimized, thus minimizing safety valves. Valves or orifice plates should be used to balance flow through individual collector circuits. Control valves should be butterfly valves with possible electrical actuation.

D. Thermal Storage Tanks

Solar collection water storage tank(s) shall be sized to provide short-term storage to meet the process demand requirements for initial scalder fill, daily evaporation losses, and product carryover.

The tank(s) shall be designed and fabricated to meet or exceed all applicable codes and standards. The tanks shall have all flanged connections required for proper installation, operation, and control.

Preference shall be given to ground level or below grade storage; overhead or roof-mounted tanks shall not be considered.

Tank material shall be selected as appropriate for installation and service requirements (above/below grade).

E. Controls

The control system shall be designed and constructed such that high system reliability in a harsh environment is attained. Simplicity should be a prime goal in the design of the control system. The system is to be assembled and tested prior to shipment.

The contractor shall design and install a control system for the solar collection system compatible with the operational requirements.

The operational requirements for the General Poultry system would be:

Operating personnel activate the batch fill pump, number 11. The scalder(s) are filled and the fill pump stopped.

The scalder temperature controller maintains the scalder water temperature via a low pressure steam coil as the poultry passes through the scalder.

The scalder's operating level is maintained by the continuous make-up pump, number 12, and the level control valve.

The solar collector tank, tank number 9.0, is "ramped" from the morning low point to the level setpoint. By "ramping" the level the maximum collector tank temperature is maintained and the storage tank is full and at maximum temperature at the end of the day.

The solar collector tank, tank number 9.0, temperature is controlled by varying the flow rate through the collectors. Flow rate is controlled by differential temperature measured across the solar collectors.

The solar collector tank has a high temperature cut off switch.

Flash Tank System

A. The contractor shall design, specify, and supply a steam flash tank system by combining the discharge from high pressure steam condensate streams. The combined flows shall enter the flash tank through a tangential nozzle. The percent flash steam, lb/hour (Kg/hour) and btu/hour (kJ/hour) shall be calculated by the contractor. The steam velocity leaving the liquid surface shall not exceed three (3) feet per second (1 meter/sec). The system shall operate at 1 bar gauge.

B. The flash tank shell shall be constructed of heavy pressure vessel quality steel in a thickness exceeding that of conventional flash tanks, thereby affording greater corrosion allowance and longer service life. The thickness shall not be less than 0.25 inches (0.635 cm).

C. A heavy duty welded structural steel stand with integral pump support shall be provided to support the flash tank system. Two pumps shall be provided each with twice the normal flow capacity. The pumps shall be centrifugal type designed for heavy industrial service with low NPSH characteristics. 1750 rpm motors are preferred, with integral- mounted pump bearing frame housing and shall be "C" flange type to assure proper alignment.

D. When the flash tank is located near the condensate return system or the deaerator, the pumps can be eliminated and the flash tank pressure (1 Bar) used to transfer condensate to the receivers.

E. The flash tank's condensate level control system shall be continuous discharge using a side-mounted level control unit located in an adjacent compartment with isolation, drain and vent valves. A side-mounted reflective gage glass shall be located on the flash tank chamber so that maintenance and operating personnel can observe the gage glass and monitor the condensate level control. The flash tank(s) shall be equipped with a pump cut off type low level alarm controller. Electrical control circuits shall be pre-wired internally with all wiring clearly color coded and connected to a numbered terminal block to facilitate field connection of electrical equipment external to the packaged system.

F. An approved pressure relief valve shall be provided to met all local and government codes. The pressure relief valve discharge shall be directed away from the building and operating personnel. The discharge line shall be sized to prevent back pressure exceeding one psig.

G. Commercial packaged systems are encouraged and should be sized based on the maximum rate of condensate flow.

H. Vessel fabrication shall meet all local and government codes.

Deaerator System (Boiler Make-up)

A. The contractor shall design, specify, and supply a single tank deaerator system. The system shall act as a boiler feed system that effectively removes excess oxygen and carbon dioxide in the effluent to a maximum of .03cc/liter. The system should operate fully vented to the atmosphere and utilize live steam injection below the water level to maintain boiler feed temperature and provide proper scrubbing action to physically separate air molecules from the water.

B. The receiver shell shall be constructed of heavy pressure vessel quality steel in a thickness exceeding that of conventional deaerators, thereby affording greater corrosion allowances and longer service life. The thickness shall not be less than 0.25 inches (0.635 cm).

C. A heavy duty welded structural steel stand with integral pump support shall be provided to support the receiver.

D. Make up water shall be admitted to the system at a controlled rate proportional to the demand by a modulating control valve.

E. System make up valves shall be sized to provide 50% of the system capacity.

r. Make up water and pumped condensate shall be combined in a blending tee and admitted to the receiver through a spray nozzle. The nozzle shall create a full shroud in the area of the open vent connection to effectively condense any steam vapor.

G. The system shall be equipped with a pump cutoff type low level alarm controller.

H. The boiler feed water pumps shall be multi-stage centrifugal type designed for heavy duty industrial service and have low NPSH characteristics. The electric motors shall be mounted integral with the pump bearing frame housing and shall be a "C"-flange type to assure proper shaft alignment.

I. Electrical control cabinets shall be pre-wired internally with all wiring clearly color coded and connected to a numbered terminal block to facilitate field connection of electrical equipment external to the packaged system.

Condensate Return System(s)

A. The contractor shall design, specify, and supply condensate return system(s) by combining the charge from low pressure steam condensate streams. The system shall operate at atmospheric pressure.

B. The condensate receiver shell shall be constructed of heavy pressure vessel quality steel in a thickness exceeding that of conventional condensate receivers, thereby affording greater corrosion allowances and longer service life. The thickness shall not be less than 0.25 inches (0.635 cm).

C. A heavy duty welded structural steel stand with integral pump support shall be provided to support the condensate receiver system.

D. Two pumps shall be provided each with twice the normal flow capacity. The pumps shall be centrifugal type designed for heavy industrial service with low NPSH characteristics. 1750 rpm electric motors are preferred; with integral mounted pump bearing frame housing and shall be "C" flange type to assure proper alignment.

E. The condensate system shall be continuous discharge using a level control unit side mounted in an adjacent compartment to the flask tank chamber. A side mounted reflective gage glass shall be located so that maintenance and operating personnel can view the gage glass and monitor the condensate level.

The system shall be equipped with a pump cut off type low level alarm controller.

F. Electrical control cabinets shall be pre-wired internally with all wiring clearly color coded and connected to a numbered terminal block to facilitate field connection of electrical equipment external to the packaged system.

Piping, Valves, and Piping Specialties

A. Piping systems shall be designed and installed to include all control and isolation valving, traps, strainers, unions, anchors, guides, hangers, supports, instrumentation ports, and insulation as required for a completed system. All systems shall be disinfected and flushed prior to use.

B. Piping material for the solar collection system shall be seamless, drawn type K hard temper copper with wrought or cast copper fittings. Solder joint shall be made with 95-5 (tin-antimony) solder.

C. Piping material for other systems (heat recovery) shall be galvanized, malleable iron, carbon steel, stainless steel, threaded or flanged as required.

D. Valves shall be specified as required for a complete, safe operation. Ball valves shall be full bore, bronze body. Butterfly valves shall have stainless steel disc in carbon steel body. Swing-check valves shall be bronze construction with bronze disc.

E. Anchors, guides and expansion joints shall be provided as required for proper restraint and alignment.

F. Hangers and supports shall be selected or designed to carry the loads with ample safety margin, provide for expansion and vibration, and give suitable support without contributing to piping stress.

G. Unions shall be provided at control valves, specialties, and equipment to allow easy disassembly for removal and maintenance. In general, unions should be 300-pound, malleable iron, screwed, with ground iron to brass seats. Dielectric unions shall be used between dissimilar metals.

H. Steam traps shall be provided as required and shall be inverted bucket traps with thermic vents, internal strainers, and orifices designed for the maximum pressure of the steam main. Use straight-through body style where possible. Each trap shall be followed by a check valve and equipped with unions for easy removal.

I. Strainers shall be provided in the suction inlet to all pumps, and shall be basket or "Y" type.

J. Vacuum breaker check valves shall be provided downstream from each steam control valve and as required for a complete system.

K. Safety relief valves (P&T) and automatic air relief valves shall be incorporated in the solar system design as required for a continuous, safe operation.

L. All piping shall be identified in English and Egyptian based on the American National Standards Institute, Standard No. A13.1-1956, or English System equivalent.

Insulation

Piping

A. All piping serving the solar collection system shall be insulated with form-fitted, heavy-density fiberglass having an all-service jacket composed of an outer layer of vinyl, fiberglass scrim cloth, aluminum foil, and kraft paper, in that order from outside to inside of pipe covering. An embossed aluminum jacket may be substituted for the vinyl. No duct tape shall be used.

B. The insulation product shall not support combustion. It shall have a flame spread rating not exceeding 25 and a smoke developed rating not exceeding 50 (ASTM E84 or UL 723 or English System equivalent). Insulation protection saddles shall be used at each hanger location. "Blocking" shall be employed on all insulated piping 2-1/2" diameter or larger. Unions shall not be insulated.

C. Insulation thicknesses shall be selected to provide an overall heat loss equal to or less than 0.16 W/m^2 °C (0.10 $BTUH/ft^2$ °F). In no case shall the piping insulation thickness be less than 1.9 cm (0.75 inch).

D. Piping insulation is not required where piping is installed within equipment, or where piping surface temperatures do not exceed 43°C (110°F).

Equipment

A. All above-grade thermal storage tanks and heat recovery equipment shall be insulated with heavy-density unfaced industrial fiberglass board conforming to equipment contours and banded in place. A field-applied surface finish will be required. Outdoor equipment will require a metal covering.

B. Insulation thicknesses shall be selected to provide an overall heat loss equal to or less than 0.06 W/m^2 °C (0.10 $BTUH/ft^2$ °F).

C. The insulation product shall not support combustion. It shall have a flame spread rating not exceeding 25 and a smoke developed rating not exceeding 50 (ASTM E84 or UL 723 or English System equivalent).

D. Below-grade thermal storage tanks shall be insulated, as appropriate for the site conditions, using a hydrophobic material compatible with the equipment material (chemically inert).

Electrical

A. The contractor shall provide all electrical design, specifications materials, tools and construction labor to complete a ready to operate electrical system.

B. All electrical work shall conform with the requirements and recommendations of the designated code, local codes and all applicable government codes.

C. The contractor shall provide all necessary raceways, offsets, fittings, and boxes and adjust all fixtures and equipment and provide all supporting materials required for a planned, coordinated and neat installation.

D. The Contractor shall commission and check for correct operation of all electrical devices.

Instrumentation

A. The contractor shall provide all instrumentation design, specifications, materials, tools, and construction labor to complete a ready to operate instrumented system.

B. All instrumentation work shall conform with the requirements and recommendations of the designated codes, local codes, and all applicable government codes.

C. The contractor shall design, purchase and install all panels and instruments and provide all electrical and electronic interconnections between the various components in the system and their local source of electrical energy. The contractor shall calibrate, commission, and check for correct operation of all instrument devices.

D. The contractor shall submit manufacturer's data or shop drawings of the following items giving full information as to dimension, weight, materials, operating instruction, spare parts lists, and all other information pertinent to the adequacy of the items.

5.9 Additional Considerations

Training and Familiarization of Design Engineers, Operators, and Maintenance Personnel

General: The Engineer/Contractor shall provide Technical Manhours by qualified personnel, including manufacturer's representatives, to cover the instruction and familiarization with installed equipment and systems.

Equipment and Systems: At the time of Initial Acceptance, all systems shall be fully operational and ready for turn-over to the General Poultry and EEA personnel. Instruction and familiarization shall be presented to General Poultry and EEA personnel. The period of familiarization will not commence earlier than three (3) months prior to Initial Acceptance. The presence of General Poultry and EEA personnel at the worksite during the three months of instruction and familiarization shall constitute a scheduled part of the Contractor's performance of the Work.

Equipment Operating Personnel: Training for equipment operating personnel shall consist of instruction and education on the use, function, routine maintenance, replacement of minor parts, safety precautions, testing and operating of various items of equipment as determined applicable by the LBII or his representative. The period of instruction and education shall be performed within a 30 consecutive day period following Initial Acceptance unless otherwise directed by the LBII or his Representative.

Interfacing with Existing Structures

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 Exhibit 5-5 and 5-6. 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	15 Kqs/sq meter
Framing Dead Load	= 4 psf	20
Total	= 7 psf	35 Kqs/sq meter

B. Wind Loads V = 85 mph (135 Kms/hr)

$q = 0.0256\ V^2\ cg$ 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 (245 Kqs/sq meter) psf live load.

The weight of solar panels is 3 psf (15 Kqs/sq meter). The load from the support structure is approximately 4 psf (20 Kqs/sq meter). The total load of 7 psf (35 Kqs/sq meter) from this equipment is negligible. Therefore, reinforcing of the existing structure will not be required.

The solar tank will be located underground near the No. 2 boiler house.

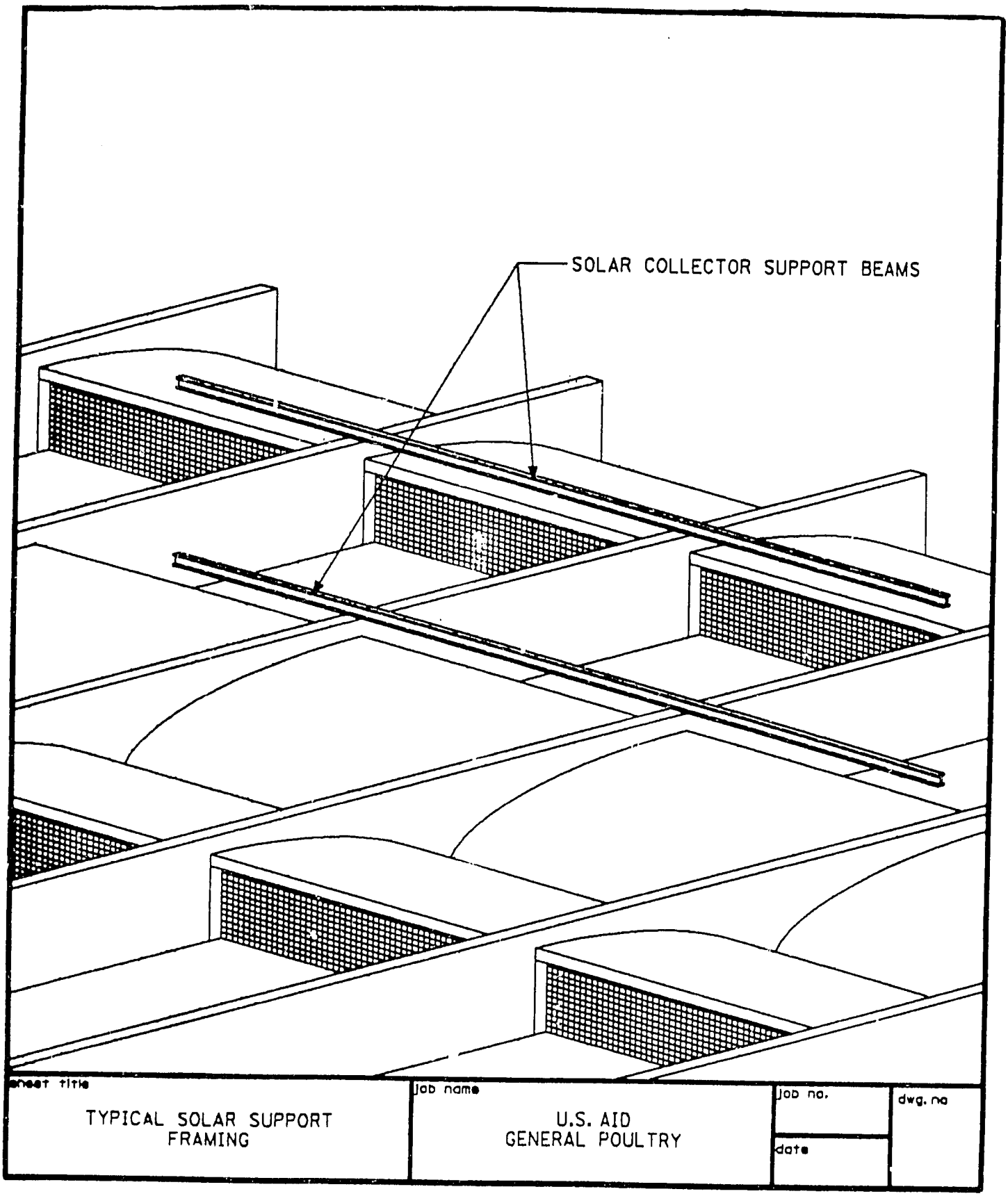


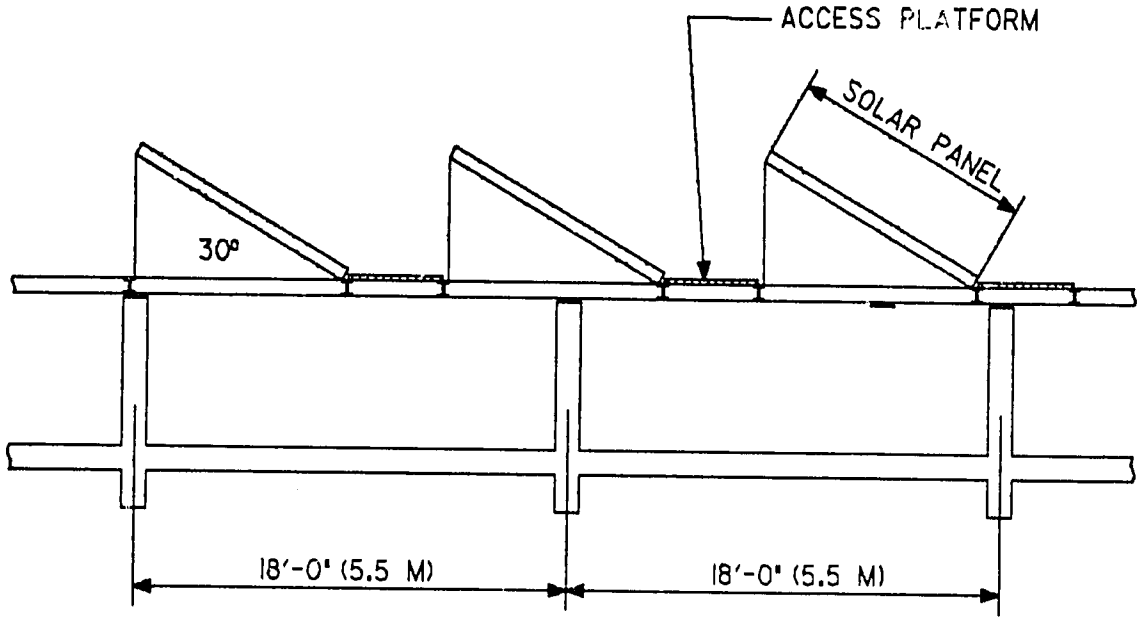
EXHIBIT 5-5

TYPICAL SOLAR SUPPORT FRAMING

84208.02
R573/9.dt

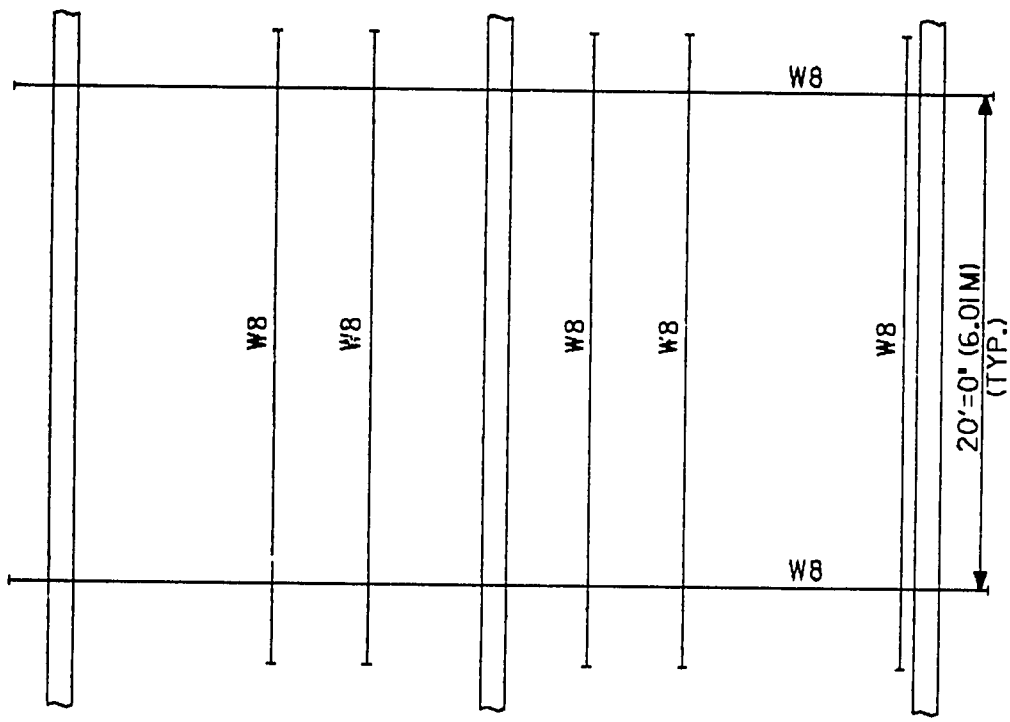
LOCKWOOD GREENE
ARCHITECTS-ENGINEERS
NEW YORK - SPARTANBURG - ATLANTA - DALLAS

no	date	REVISION	by	ck.	appr



SECTION

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



PLAN

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

sheet title	job name	job no.	dwg. no
EXHIBIT 5-6 TYPICAL SOLAR SUPPORT FRAMING	U.S. AID GENERAL POULTRY	date	

QS7:[100,150]8420802M.005

5.10 CONCEPTUAL DESIGN PLANT LAYOUT

The Plant Layout is determined from General Poultry's Application Review, the Technology Review, the Flow Diagram, the Process and Instrument Diagram, and Preliminary Equipment Specifications.

General Poultry's Application review provided both user requirement and existing operating conditions. These parameters define the mass and heat balance, which establishes the equipment and its location. The locations are shown on Exhibit 5-9 the Plant Layout. The layout provides the contractor/engineer an over-all view of the existing facility and equipment.

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 $5,778.00 (US). (1.35 LE vs $1.00 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 severty 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.

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 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.

CONSTRUCTION COST ESTIMATE
A. STEAM FLASH TANK SYSTEM

DESCRIPTION	SUBTOTAL	TOTAL
TOTAL EQUIPMENT(MID-1986)	$7,500	
ESCALATION FACTOR	1.1	
TOTAL EQUIPMENT (MID-1987)		$8,250
PIPING COST @	40.00%	$3,300
INSULATION COST @	25.00%	$825
TOTAL MATERIAL COST	$12,375	
LABOR COST @ __.__% MATERIAL COST	71.50%	
LABOR COST	$8,848	
MODIFIER,LABOR MIX @	43.00%	
MODIFIED LABOR COST		$3,805
MATERIAL + LABOR	$16,180	
CONTRACTOR OVERHEAD @	30.00%	$4,854
SUB TOTAL	$21,034	
ENGINEERING @	6.00%	$1,262
SUB TOTAL	$22,296	
CONTINGENCY @	10.00%	$2,230
A. STEAM FLASH TANK SYSTEM COST.....		$24,525

B. CONDENSATE RETURN SYSTEM

DESCRIPTION	SUBTOTAL	TOTAL
TOTAL EQUIPMENT(MID-1986)	$21,500	
ESCALATION FACTOR	1.1	
TOTAL EQUIPMENT (MID-1987)		$23,650
PIPING COST @	40.00%	$9,460
INSULATION COST @	25.00%	$2,365
TOTAL MATERIAL COST	$35,475	
LABOR COST @ __.__% MATERIAL COST	71.50%	
LABOR COST	$25,365	
MODIFIER,LABOR MIX @	43.00%	
MODIFIED LABOR COST		$10,907
MATERIAL + LABOR	$46,382	
CONTRACTOR OVERHEAD @	30.00%	$13,915
SUB TOTAL	$60,296	
ENGINEERING @	6.00%	$3,618
SUB TOTAL	$63,914	
CONTINGENCY @	10.00%	$6,391
B. CONDENSATE RETURN SYSTEM COST.....		$70,306

C. SOLAR THERMAL COLLECTION SYSTEM VARIABLE COST (MID-1987)

DESCRIPTION	SUBTOTAL	TOTAL
SOLAR COLLECTORS @ $10.00/FT2	$10	
COLLECTOR AREA 4000 FT2	4000	
COLLECTOR COST	$40,000	
SOLAR STORAGE TANK	$9,000	
SOLAR CIRCULATING PUMPS	$1,750	
SOLAR DISTRIBUTION PUMPS	$1,250	
STRUCTURAL STEEL	$17,500	
SOLAR CONTROLS	$3,000	
INSTRUMENT AIR SYSTEM/PIPING	$750	
LOW VOLTAGE CABLE	$1,500	
EXCAVATION AND FOUNDATIONS	$3,000	
ELECTRICAL	$500	
TOTAL EQUIPMENT(MID-1986)	$78,250	
ESCALATION FACTOR	1.1	
TOTAL EQUIPMENT (MID-1987)		$86,075
PIPING COST @ __.__% COLLECTOR COST	40.00%	$16,000
INSULATION COST @ __.__% PIPING COST	25.00%	$4,000
TOTAL MATERIAL COST	$106,075	
LABOR COST __.__% MATERIAL COST	71.50%	
LABOR COST	$75,844	
MODIFIER,LABOR MIX	43.00%	
MODIFIED LABOR COST		$32,613
MATERIAL + LABOR	$138,688	
FREIGHT,DUTY,TAXES TO EGYPT @	10.00%	$13,869
SUBTOTAL	$152,557	
CONTRACTOR OVERHEAD @	30.00%	$45,767
SUB TOTAL	$198,323	
ENGINEERING @	6.00%	$11,899
SUB TOTAL	$210,223	
CONTINGENCY @	10.00%	$21,022
TOTAL VARIABLE COST.....		$231,245
COST PER FT^2>>>>>>>>>>>>>>>>>>>>>>>>>>>>	$58	

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GENERAL POULTRY MWJPAC

FIXED COST (MID 1987)

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
CONTRACTOR OVERHEAD @	30.00%	$7,050
SUB TOTAL	$30,550	
ENGINEERING @	6.00%	$1,833
SUB TOTAL	$32,383	
CONTINGENCY @	10.00%	$3,238
TOTAL FIXED COST.....		$35,621

LGE COST BASED ON CURRENT FIELD TEST PROJECT

TOTAL VARIABLE COST	$231,245
TOTAL FIXED COST	$35,621
TOTAL SYSTEM CONSTRUCTION COST	$266,866

EEA COST DATA BASED ON CURRENT PROJECTS
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	$24,525
B. CONDENSATE RETURN SYSTEM	$70,306
C. SOLAR THERMAL COLLECTION SYSTEM	$266,866
TOTAL CONSTRUCTION COST A,B, & C	$361,697

GENERAL POULTRY MWJPAC

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	$230,646
TOTAL FIXED COST	$39,186
TOTAL SYSTEM CONSTRUCTION COST	$269,832

EEA COST DATA BASED ON CURRENT 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	$269,832
TOTAL CONSTRUCTION COST A,B, & C	$360,546

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.

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 7/8/1983 to 3/9/1983

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 8/17/1983:

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 8/18/1983.

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 and temperature of 220°c. 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

<u>Waste Section</u>: 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.

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

LOCKWOOD GREENE
Planners/Engineers/Architects/Managers

August 16, 1985

Lockwood Greene Engineers, Inc
Post Office Box 991
Spartanburg, SC 29304
(803) 578-2000 Telex 809 136

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:

1. 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.

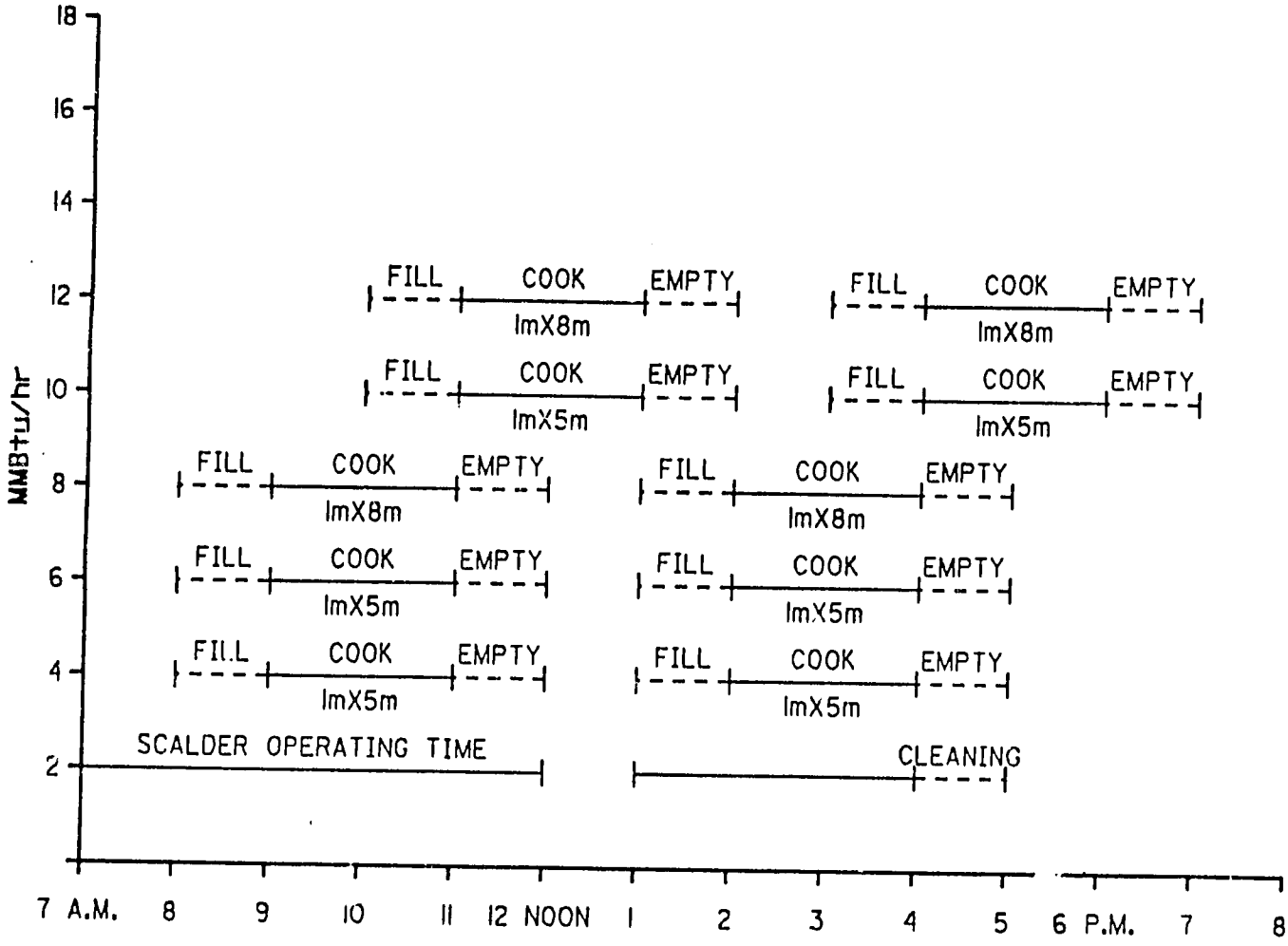
6. Final report incorporating the results of this work is expected by 8/__/85 from LGE.

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

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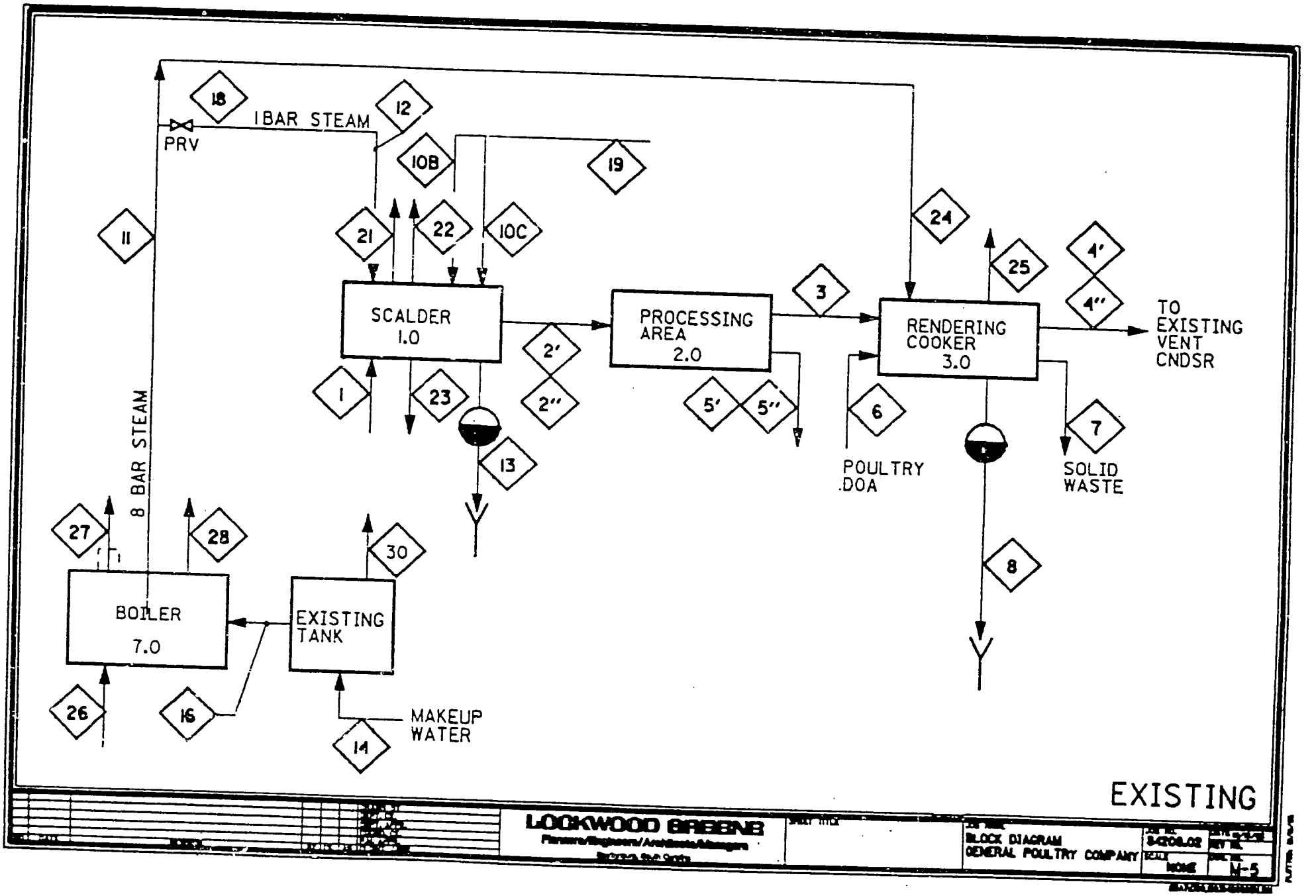
Appendix -C-
Energy Balance Calculations

C.1 General Existing Conditions Flow Sheet

C.2 Lotus Model Results
Existing Conditions (GP0100)



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GENERAL POULRTY MWJPAC

EXISTING MWJPAC01	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
DESCRIPTION									
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	8,558,156	1,188,633	1,976,562	771,574	41,895

GENERAL POULRTY MWJPAC

EXISTING MWJPAC01	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
DESCRIPTION										
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	299,287	16,740,623	2,070,508	380,251	561,295	N/A

GENERAL POULRTY MWJPAC

EXISTING MWJPAC01	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
DESCRIPTION										
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)	14,672,115	(975,798)

GENERAL POULRTY MWJPAC

EXISTING MWJPAC01	FUEL TO	STACK	BOILER
DESCRIPTION	BOILER	LOSSES	RAD LOSSES
LOCATION	26	27	28
M (LB/HR)	NR	0	0
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)

dQ1.0 BTU/HR	dQ3.0 BTU/HR	dQ7.0 BTU/HR
(1,690,258)	(10,733,777)	(21,575,134)

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				
SOLAR SYSTEM ENERGY SAVINGS				(1,690,258)	
SOLAR SYSTEM FUEL SAVINGS		1,508,920,000	4,572,485	571,561	-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					
FLASH TANK FUEL SAVINGS			10.6%	1,301	1,229,560

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 Hlv (Hl @ 212F)-(Hl @ 72F)= BTU/LB	ENERGY SAVED BTU/HR M*dHlv=
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%

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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

Data Supplied 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

Conversion from SI to English
by LGE

Appendix E

Results from FCHART-4R

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** FCHART-4R VERSION 2.00 **
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PROJECT: General Poultry — DATE: 04/03/86
COMMENT: Application Review-Final — FILE NAME: MWJPAC

THERMAL DATA

GENERAL INFORMATION:

1	SYSTEM TYPE (1-5)	2.00	
	1 = DHW-1TANK 4 = DHW-PREHEAT-LOADSIDE HX		
	2 = DHW-2TANK 5 = CONSTANT TEMP-COLLECTOR ONLY		
	3 = PROCESS HEAT		
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

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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	130.12	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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FCHART-4R DESCRIPTION

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.

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 collecror 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	[illegible].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

9h

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.

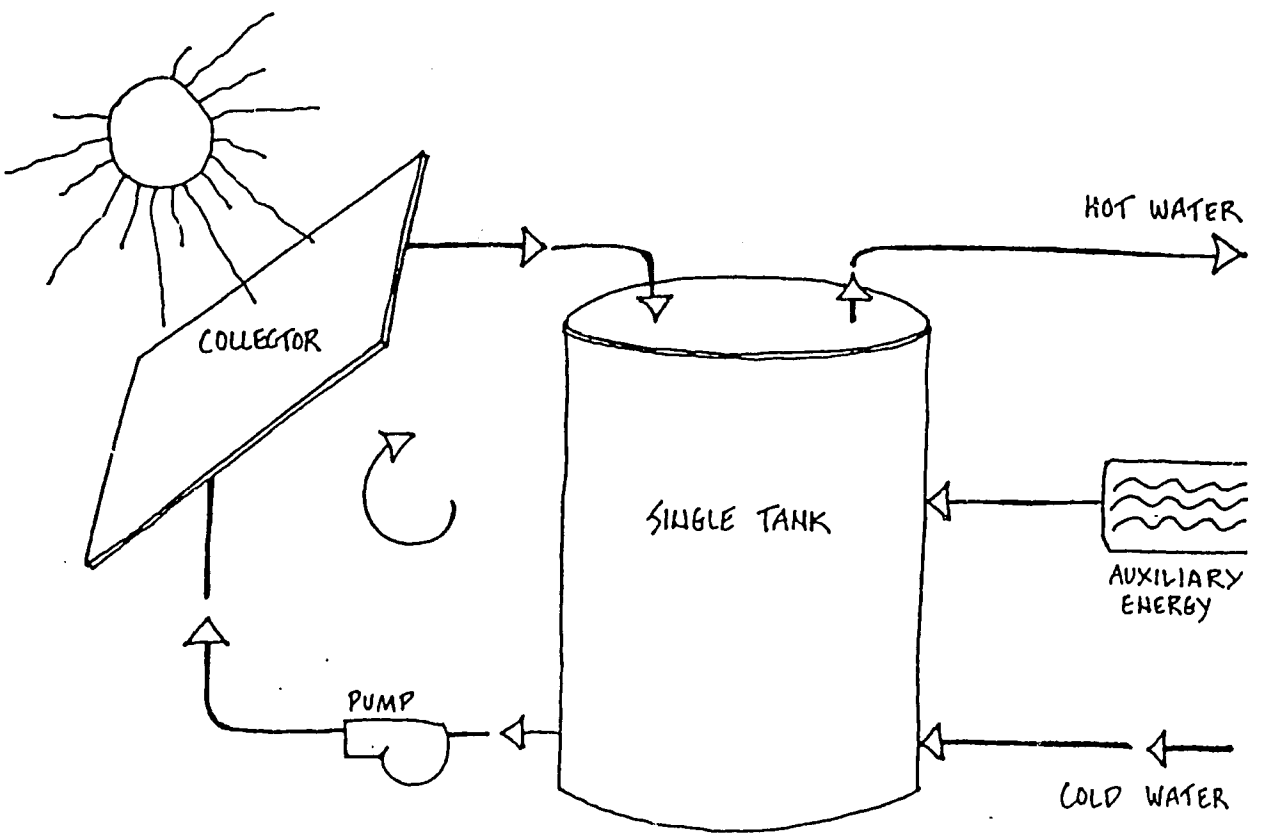
Enter the temperature of the cold water supplied to the water heating system (DHW). If a value of -1000 is used, temperature will be set equal to monthly ground water temperature (which is in the weather data file).

THERMAL ANALYSES

System Descriptions

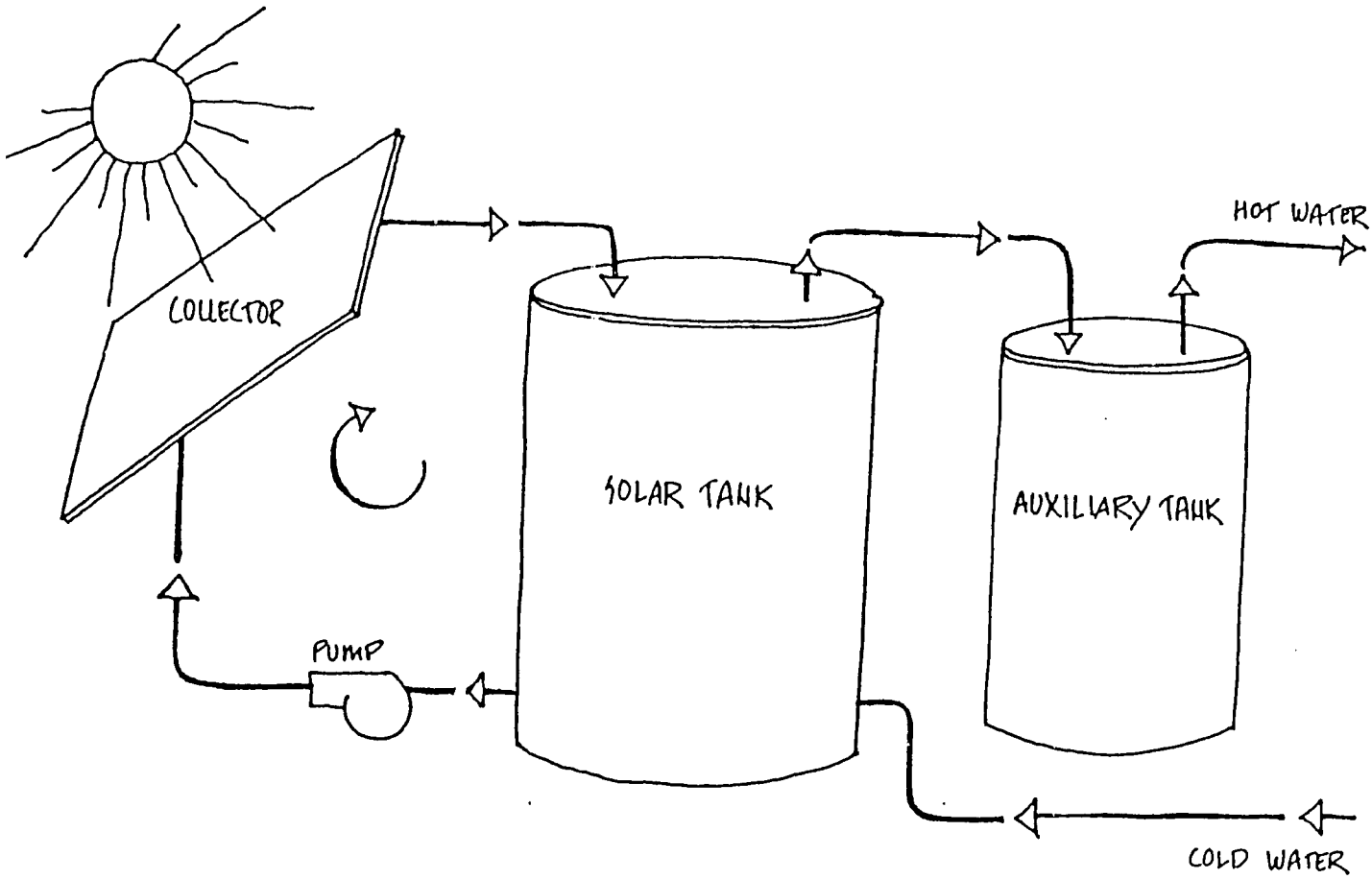
FCHART-4R can model five basic types of solar energy systems.

One tank solar water heater with backup in the solar tank.



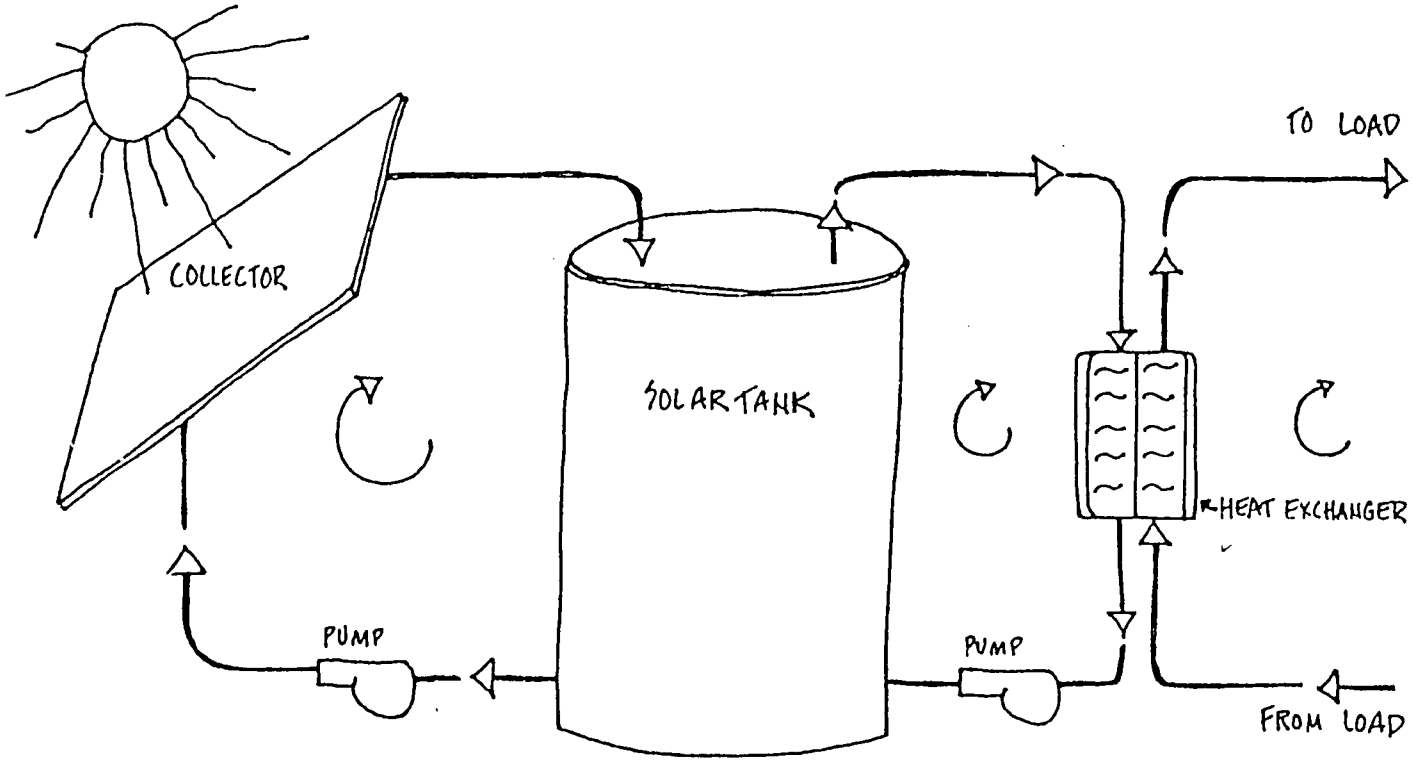
This system type includes a collector with an optional heat exchanger, and a single storage tank. The single tank serves as both the primary solar storage tank and the auxiliary tank. It performs differently than the standard two tank system because the auxiliary heating in the single tank can cause the system to operate at somewhat higher collector inlet temperatures than would be the case without the auxiliary element. The performance of this system type is sensitive to the thermostat setting and collector flow rate.

Two tank solar water heater with separate auxiliary tank.



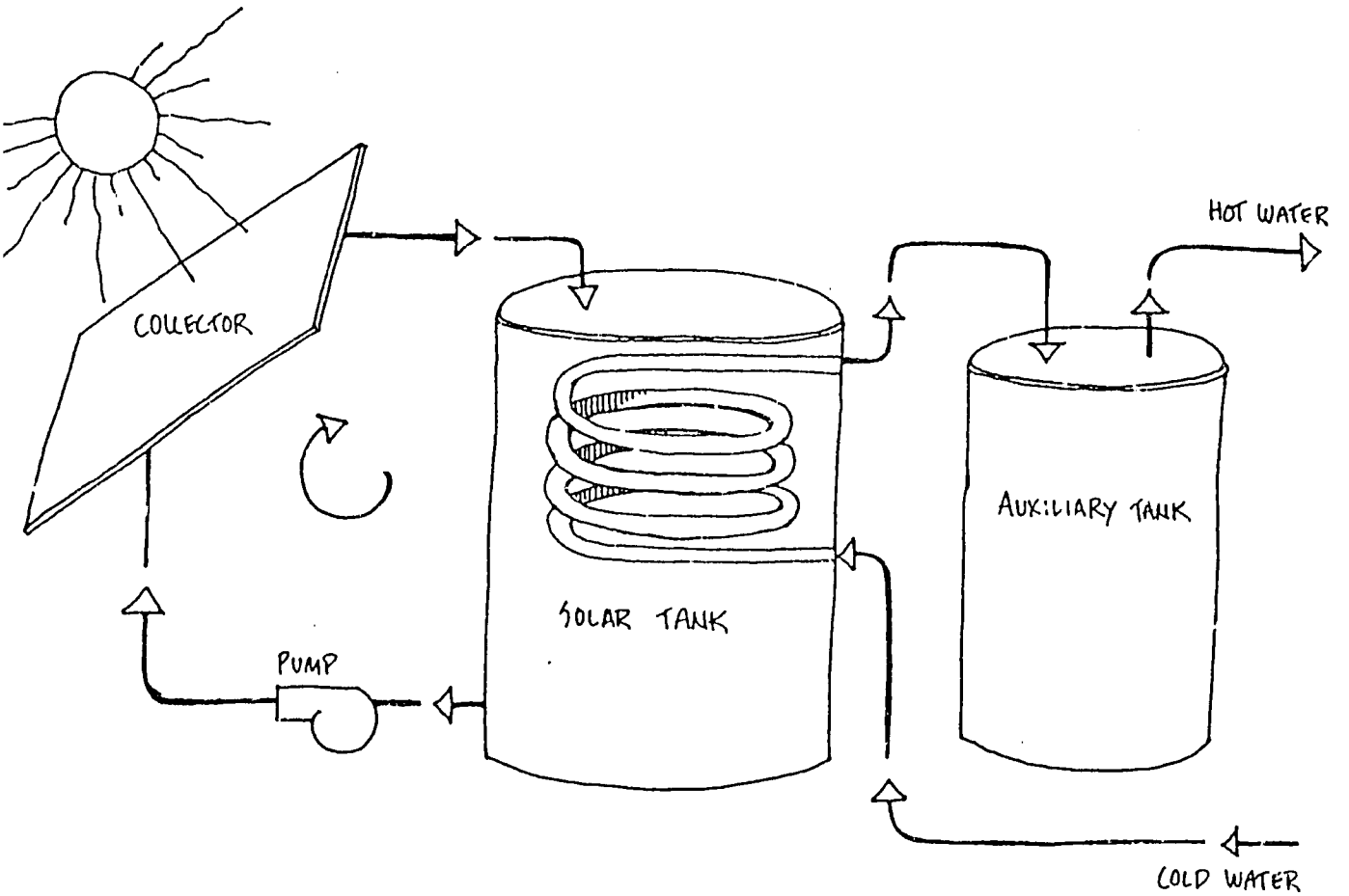
This type of system includes a collector with an optional heat exchanger, a solar storage tank and a separate auxiliary tank. In this system water flows between the solar storage tank and the collector, where it is heated. Makeup water is supplied to the solar tank. When there is a hot water demand, 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. This type of system is referred to as a standard dhw or open system.

Solar process heat system delivering energy through a heat exchanger.



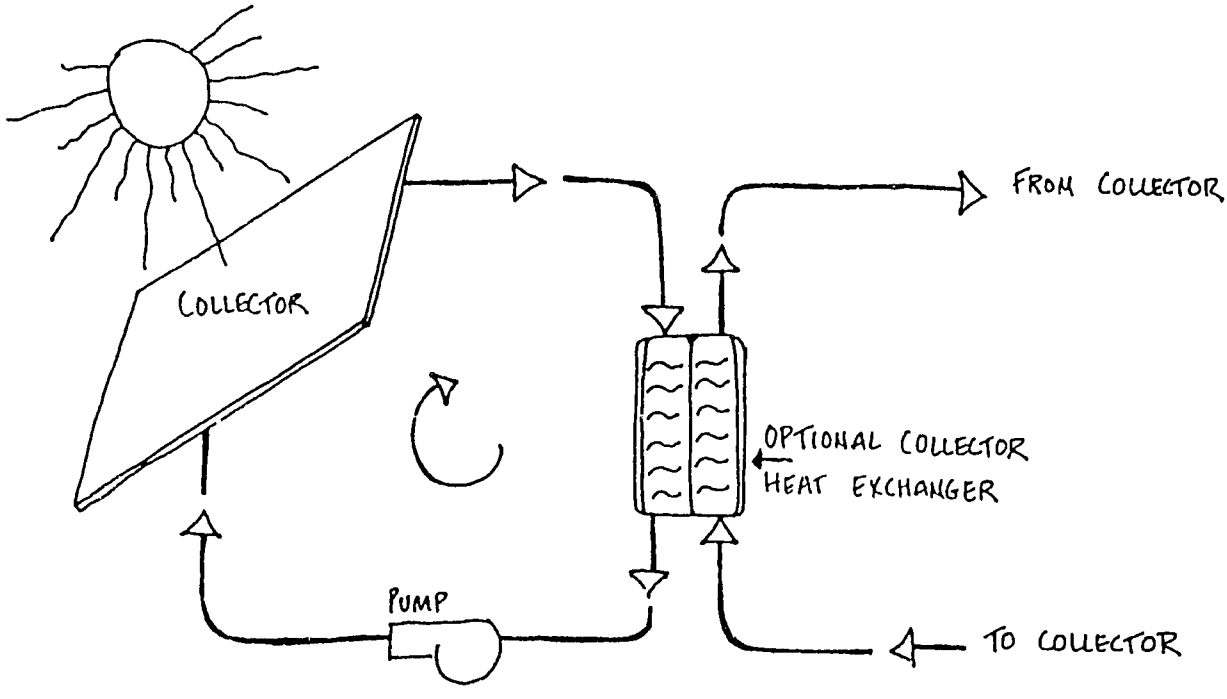
This type of system includes a collector with an optional heat exchanger, a solar storage tank, and a load heat exchanger. Water flows in a loop between the solar tank and the collector as in the standard two tank dhw system, but there is no water flow out of the system. Instead, heat is removed from the solar tank by a load side heat exchanger. This type of system is referred to as a process heat or closed system.

Load side dhw preheat solar water heater.



This type of system includes a collector with an optional heat exchanger, a solar storage tank, and a load heat exchanger. The load heat exchanger is located inside of the solar storage tank. Water flows in a loop between the solar tank and the collector as in the standard two tank dhw system, but there is no water flow out of the solar tank. Heat is transferered to the water passing through the load side exchanger. This water may then go directly to the dhw load or to an auxiliary tank in series with the load.

Collector only.



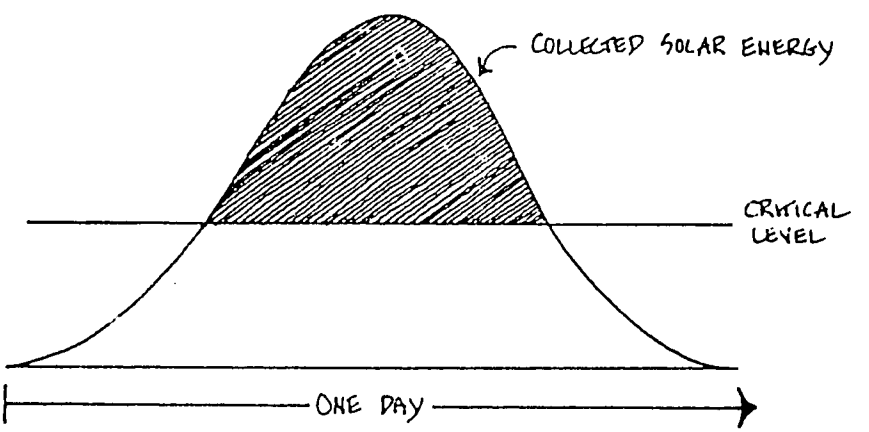
This system type differs from the others in that it is a model of a collector only. It can model a collector in any orientation at any location operating at a constant inlet temperature. It may optionally include a collector heat exchanger. This system type is useful for modeling a non-standard system type where the collector inlet temperature is relatively constant (swimming pools, slab heating systems, systems with very large storage, or systems with no storage but constant inlet temperature).

System Analyses

Utilizability Method

The utilizability method is employed in all the system types to determine the solar energy output.

Utilizability is defined as the fraction of radiation incident upon a surface during a specified period of time which is above a fixed level. It is represented by ϕ.



$$\phi = \frac{\int^{day} (G_T - G_c)^+ \, dt}{H_T}$$

where

ϕ = daily average utilizability based on the total incident radiation.

H_T = monthly average daily radiation incident on the collector surface.

G_T = instantaneous solar radiation incident on the collector surface (per unit area).

G_c = critical level of solar radiation necessary for net useful energy collection on an instantaneous basis (per unit area).

The superscript + is used to indicate that only positive values are considered in the intergal.

The critical level G_c of solar radiadion required for a net output is

$$G_c = \frac{F_R U_L - (T_i - T_a)}{F_R(\tau\alpha)}$$

The energy incident on the panel above the critical level is the net collected energy. An hourly ϕ is calculated each hour and summed to determine the daily ϕ which is used to calculate the daily solar output.

$$Q_u = A_c \, F_R(\tau\alpha) \, H_T \, \phi$$

where

Q_u = daily solar energy collected.

A_c = collector area.

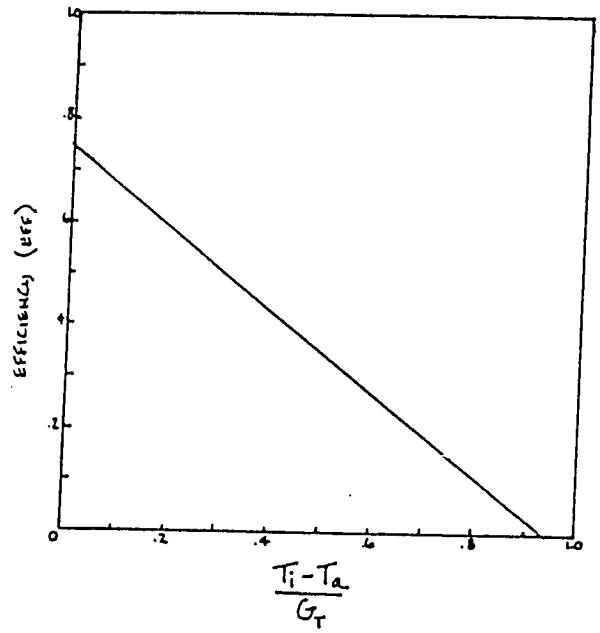
$F_R(\tau\alpha)$ = y-intercept of collector efficiency curve, corrected for non-normal solar incidence, collector heat exchanger, collector line losses, and collector flowrate effects.

H_T = monthly average daily solar radiation on the collector surface (per unit area).

ϕ = daily utilizability.

The monthly solar output is obtained by summing the daily output over the number of days per month. The annual output is obtained by summing the monthly outputs over the year.

The ASHRAE Test Curve



The ASHRAE 1st order efficiency equation for a flat plate collector is

$$\text{eff} = F_R(\tau\alpha) - (F_R U_L)\ \frac{(T_i - T_a)}{G_T}$$

where

$F_R(\tau\alpha)$ = y-intercept of the ASHRAE efficiency curve; the transmittance and absorptance factor

$F_R U_L$ = slope of the ASHRAE efficiency curve; the collector heat loss factor.

T_i = instantaneous collector inlet temperature.

T_a = instantaneous ambient air temperature.

G_T = instantaneous solar radiation incident upon the collector surface per unit area.

The instantaneous output of a collector with area A_c, for some G_T, T_i and T_a is given by

$$Q_u = (\text{eff})(A_c)(G_T)$$

or

$$Q_u = A_c\ [F_R(\tau\alpha)\ G_T - F_R U_L\ (T_i - T_a)]$$

Collector Heat Exchanger, Line Losses, and Flowrate

The effects of a collector heat exchanger, line losses, and collector flowrates different from the test flowrate are accounted for in FCHART-4R using the following adjustment factors.

$$F_R U_L \Big|_{use} = \left(\frac{F'_R}{F_R}\right) \left(\frac{r_{use}}{r_{test}}\right) \left(\frac{U'_L}{U_L}\right) F_R U_L \Big|_{test}$$

$$F_R(\tau\alpha) \Big|_{use} = \left(\frac{F'_R}{F_R}\right) \left(\frac{r_{use}}{r_{test}}\right) \left(\frac{U''_L}{U_L}\right) F_R(\tau\alpha) \Big|_{test}$$

where

collector heat exchanger effect

$$\frac{F'_R}{F_R} = \left\{ 1 + \left(\frac{A_c F_R U_L}{\dot{m}C_p}\right) \left(\frac{\dot{m}C_p}{\varepsilon C_{min}} - 1\right) \right\}^{-1}$$

collector flowrate effect

$$r = \frac{\dot{m}C_p}{A_c F' U_L} \left\{ 1 - \exp(A_c F' U_L / (\dot{m}C_p) \right\}$$

where

$$F' U_L = \frac{\dot{m}C_p}{A_c} \ln \left(1 - \frac{F_R U_L A_c}{\dot{m}C_p}\right)$$

collector line loss effect

$$\frac{U'_L}{U_L} = \frac{F_R U_L \left[1 - \frac{(UA)_i}{\dot{m}C_p} + \frac{(UA)_i + (UA)_o}{A_c F_R U_L} \right]}{1 + \frac{(UA)_o}{\dot{m}C_p}}$$

and

$$\frac{U''_L}{U_L} = \left\{ \frac{1 + (UA)_o}{\dot{m}C_p} \right\}^{-1}$$

Open and Closed Loop Solar Energy Systems.

An energy balance on the solar storage tank for an average day each month for a solar energy system is expressed as

$$Q_u(T_S) - Q_S(T_S) - Q_{LS}(TBAR) + \text{Delta } U = \emptyset$$

where

Q_u = solar energy collected by the collector and delivered to the solar storage tank daily.

Q_S = net solar energy delivered from the solar storage tank to the load or auxiliary tank daily.

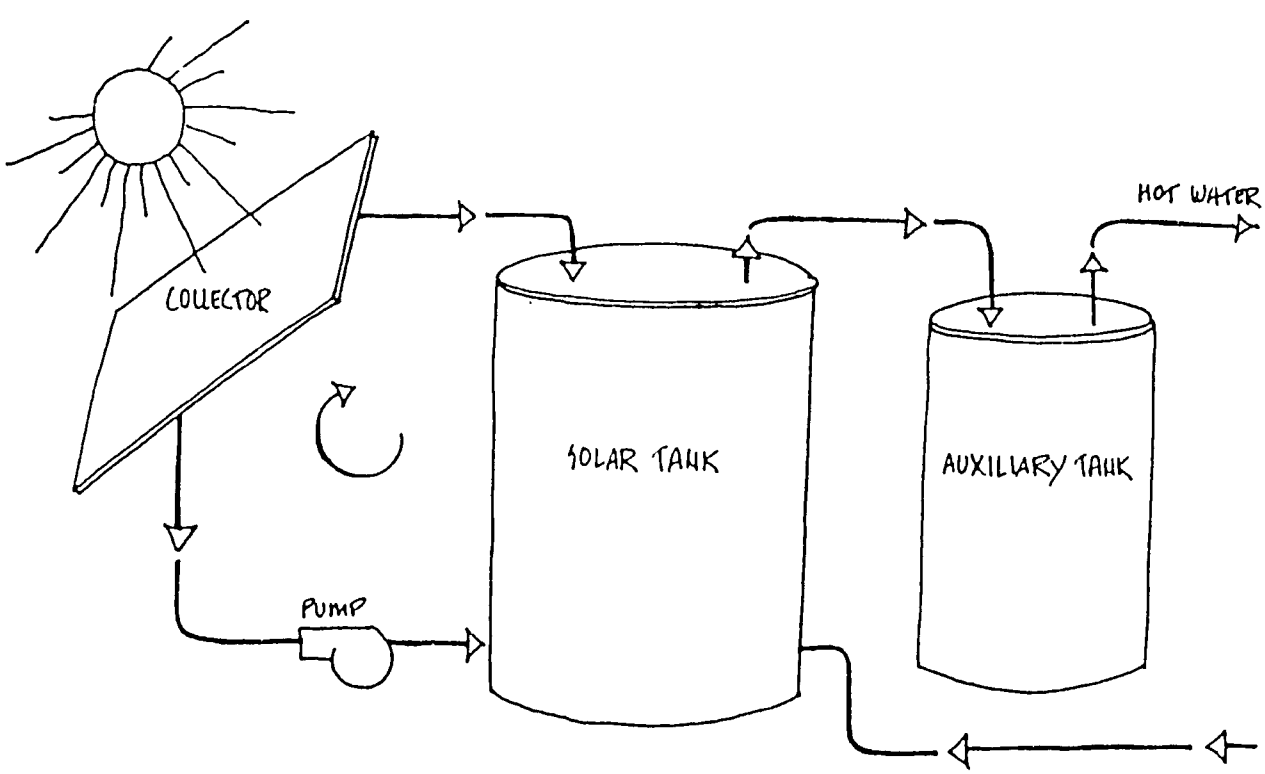
Q_{LS} = the heat loss from the solar storage tank daily.

Delta U = change in internal energy of the solar storage system over the time period. Set equal to zero.

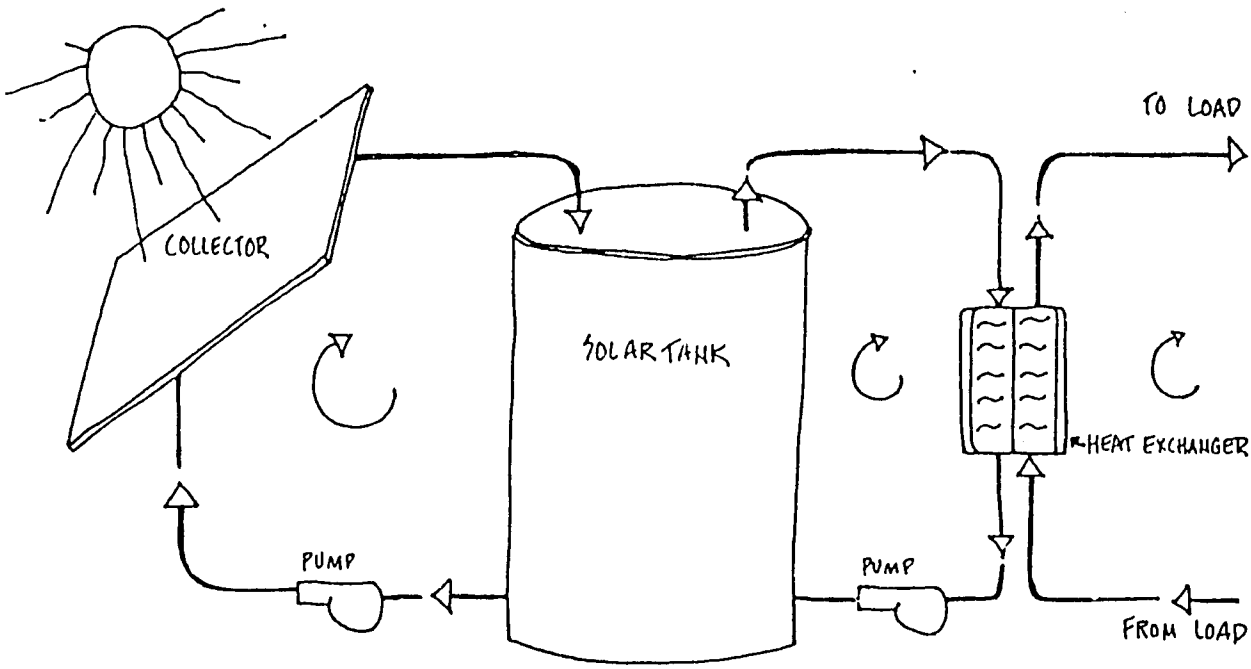
T_S = average temperature supplied from storage to the collectors and to the load.

TBAR = average temperature from which storage losses occur.

L = total daily load.



Open System



Closed System

The program guesses an intial value for the storage temperature T_S and computes the solar energy collected (Q_u), storage losses (Q_{LS}), and net solar energy delivered (Q_S). The programs then checks to see if the energy is balanced at this temperature. If it is not, it then determines another T_S based on the results of the first guess. After successive attempts, the correct T_S for the month is found. Now Q_u, Q_S, and Q_{LS} are known for an average day. This procedure is repeated for each month and the monthly results are summed to give the annual result. The solar fraction f is defined by

$$f = Q_S/L$$

Collector Output

$$Q_u = A_c F_R(\tau\alpha)\ \phi\ H_T - Corr$$

where

A_c = collector area

$F_R(\tau\alpha)$ = y-intercrept of the efficiency curve

ϕ = daily utilizability

H_T = monthly average daily solar radiation on the collector surface per unit area

$$Corr = a(e^{bf}-1)(1-e^{cX})e^{dz}Q_s$$

where

$a = .015(C_s/15.41)^{-.76}$

$b = 3.85$

$c. = -0.15$

$d = -1.959$

$f = Q_S/L$

$X = A_c F_R U_L(180^oF)dt/L$

$z = L / epsC_{min}dt(180^oF)$ for process heat systems

$z = L / M_w C_p(180^oF)$ for dhw systems

dt = hours per day the load operates

Storage Losses

$$Q_{LS} = (UA)_T(TBAR-T_{env})\ dt$$

where

$(UA)_T$ = overall heat loss coefficient of the storage tank.

T_{env} = temperature to which losses occur.

$$TBAR = T_S + g(e^{kf}-1)e^{hz}$$

where

$g = (0.3845^oF)(C_s/15.4 btu/ft^2-^oF)^{-.704}$

$h = -4.002$

$k = 4.702$

$f = Q_S/L$

C_s = capacitance of storage

dt = 24 hours

Energy delivered from storage

For process heat (closed loop) systems,

$$Q_S = \min (\varepsilon C_{min}(T_S - T_R)dt , L)$$

where

ε = heat exchanger effectiveness

C_{min} = minimum capacitance rate of the load heat exchanger.

T_S = temperature of the solar storage tank

T_R = load heat exchanger return temperature (from process).

dt = hours per day of load operation

L = daily load

For dhw (open loop) systems,

$$Q_S = \min (M_w C_p (T_S - T_{main}) , L)$$

where

M_w = monthly mass usage of water

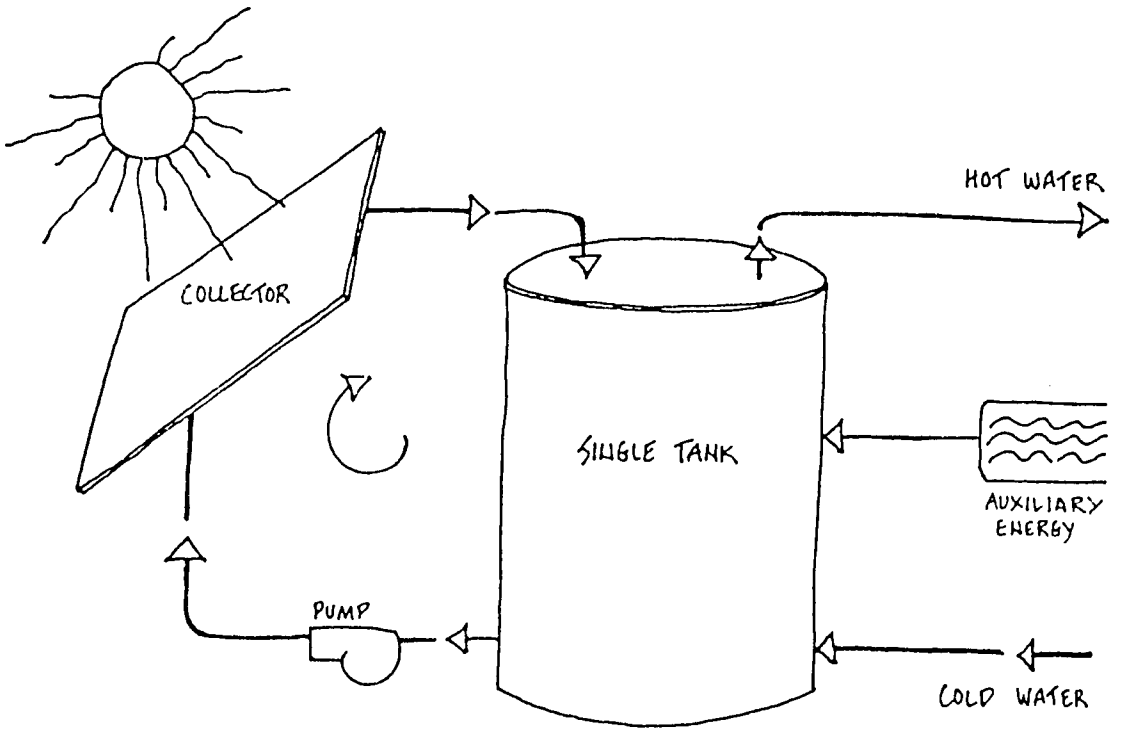
C_p = specific heat of water

T_S = temperature of the solar storage tank

T_{main} = temperature of cold water entering system

L = daily load

One Tank Systems



One Tank System

In the one tank system, the auxiliary heat is introduced into the tank when the tank temperature is below the temperature set point. Since there is flow between the collectors and the tank, there is mixing of the water in the tank and the temperature of the tank may reach the thermostat setting. The negative effect is that the water arriving at the collector may be significantly warmer than it would be if there were no heating source in the tank. The positive effect is that there are no thermal heat losses off the second tank since there isn't a second tank.

The output of the one tank system is determined in the following way. An upper bound (most optimistic) and a lower bound (least optimistic) performance estimate is made. A factor is determined which adjusts between the two bounds resulting in a one tank system performance prediction.

The upper bound performance prediction is obtained by modeling the system as a two tank system with no auxiliary tank losses. This is the most optimistic because there are no auxiliary heat effects on the solar tank and no second tank losses.

The lower bound performance prediction is obtained using the solar utilization method (Klein) to predict the net collector output when the collector operates at a constant inlet temperature. The temperature used is the thermostat set temperature. This represents the case where the tank is uniformly heated to a set point and the collector inlet temperature operates at this temperature with the result being decreased collector performance.

The adjustment factor is referred to as a mixing factor. A one tank system which is fully mixed will be at the temperature of its set point. A tank which has no net fluid (water) flow through it is considered not mixed. Since the collector flow and the load flow are in the opposite direction, the net flow is defined as the collector flow rate minus the average load flow rate. A mixing factor, called MIX, is determined by dividing the net hourly mass flow rate through the tank by the mass of the tank. If the net quantity of water through the tank in one hour equals the mass of the tank, then MIX has a value of one. If two times the tank mass flows through the tank each hour then the MIX is two. A turn over of three tank masses an hour is considered fully mixed.

Therefore the performance prediction of the one tank system involves four steps.

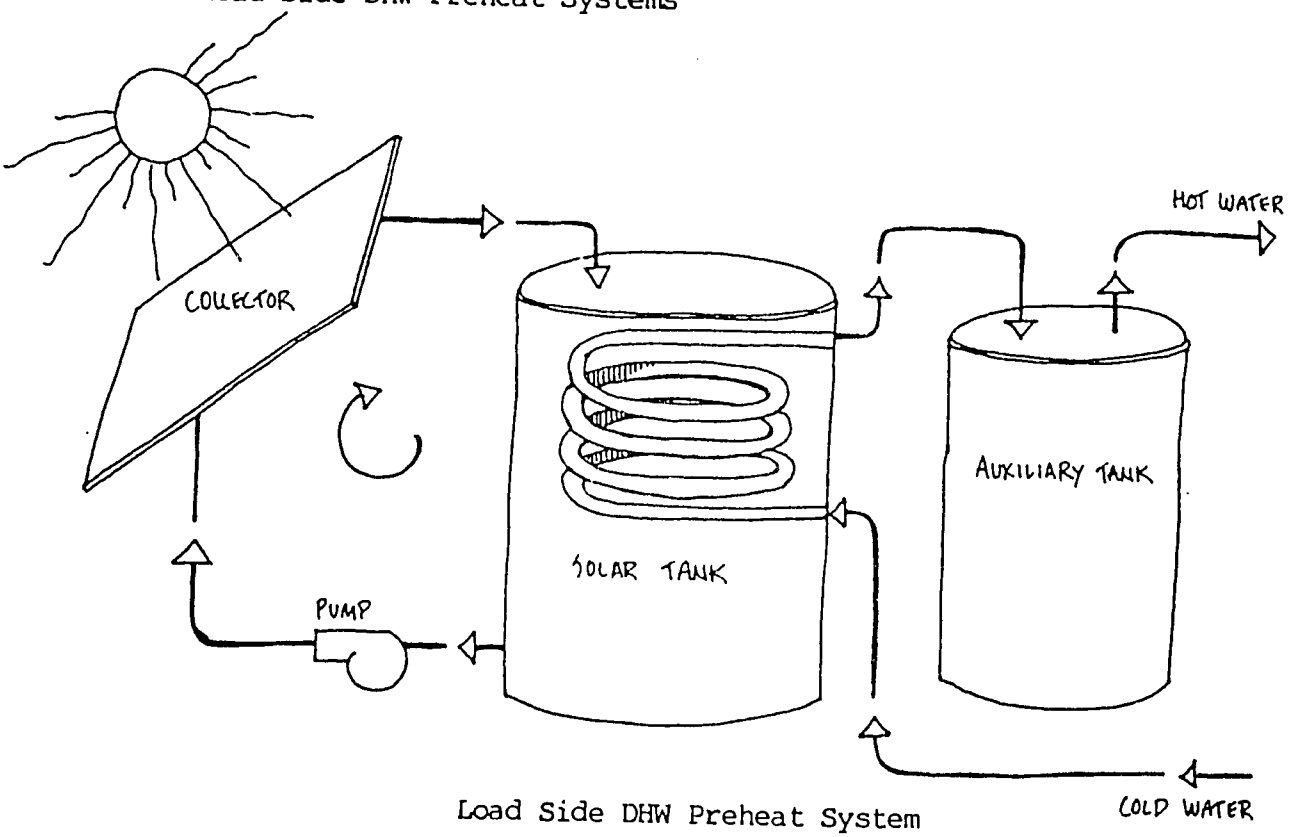
1. Upper Bound Prediction.

2. Lower Bound Prediction.

3. Calculation of MIX factor for proportionality between upper and lower bounds.

4. Interpolation between upper and lower bound predictions to obtain system performance monthly.

Load Side Dhw Preheat Systems



Load Side DHW Preheat System

The load side dhw preheat system is a form of the process heat system where certain input parameters have been set equal to standard values by the program automatically. These are:

T_{min} = monthly water main temperature (instead of process return temperature)

T_{ret} = also set equal to the monthly water main temperature

T_{set} = set to the temperature required for the load (may be the thermostat setting of the auxiliary tank or a recirculation loop)

T_{Li} = flowrate through load heat exchanger determined by distributing daily usage equally over the 24 hour day

APPENDICES

Units Conversion Factors

The following unit conversions are performed by FCHART-4R automatically with the units command.

Type	Units English	Standard International	To Convert E --> SI	Multiply by SI --> E
Energy Flux				
	Btu/hr-sqft-F	W/sqm-C	.17611	5.67826
	Btu/hr-ft-F	W/m-C	.58717	1.70307
	Btu/hr-F	W/C	1.89563	.52753
Energy				
	MMBtu/day	MJ/day	.94781	1.05506
Flow Rate				
	lb/hr-sqft	kg/hr-sqm	4.89269	
	gal/day	l/day	.26417	3.78544
	gal/min	l/min	.26417	3.78544
Length/Area				
	ft	m	3.27869	.305
	sqft	sqm	10.76392	.09290
Temperature				
	deg F	deg C	(T*9/5)+32	(T-32)*5/9
Specific Heat				
	Btu/lb-F	J/kg-C	.0002387	4190
Storage Size				
	gal/sqft	l/sqm	.02454	40.74979