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16666

Distr.
RESTRICTED

IO/R.65
21 January 1988

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

MANUFACTURING OF SOLAR WATER HEATER FOR INDUSTRIAL APPLICATIONS

TF/JOR/82/001

JORDAN

Terminal report*

Prepared for the Government of Jordan
by the United Nations Industrial Development Organization

Based on the work of Messrs Kebariti and Tougan**

Backstopping officer: H. Seidel, Engineering Industries Branch

727

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** Solar Energy Research Center of the Royal Scientific Society, Amman, Jordan.

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I. INTRODUCTION

The project TF/JOR /82/001 entitled "Assistance to the RSS: MANUFACTURING OF SOLAR WATER HEATER FOR INDUSTRIAL APPLICATION" was originated after the approval of the official request made by the Government of Jordan for assistance in the field of solar energy research and applications. The United Nations Industrial Development Organization (UNIDO) has allocated the required funds obtained through special trust fund contributions to the project for which the Royal Scientific Society (RSS) in Jordan has played the role of government co-operating agency.

A study was made to analyze the solar energy programme at the RSS, taking into consideration all related past and ongoing activities related to solar energy, and to identify the potential application of solar energy for industrial and domestic use. The main conclusion was that there exist in Jordan, very favourable conditions for undertaking ambitious programmes in the field of utilizing alternative sources of energy, above all solar technology, with emphasis on applied research and development and local production of hardware needed for solar energy installations and specifically for industrial applications.

2. BACKGROUND INFORMATION

The Royal Scientific Society (RSS) is the main science and technology research institution in Jordan with special attention to industrial research and services. The research and development work in solar energy started at the Mechanical Engineering Department (MED) in 1972.

Since the very beginning of the development programme the MED had devoted extensive efforts towards development and optimization of solar water heaters (SWH) for domestic use. The established product was the result of the trade-offs between all important design parameters covering thermal efficiency, manufacturing complexity, availability of raw materials and production cost. Many prototypes were manufactured and tested and the results were very promising.

The MED then turned to the problem of utilizing solar energy for hot water production in industry since there is a large potential fo existing industries in Jordan to use SWHs. MED needed assistance to amplify the workshop capacity so as to enable the establishment of prototype solar industrial water heating plants to be installed in a selected industrial enterprise or large public building, and to generate a design which is economically feasible utilizing locally available materials, and requiring only minimum of maintenance.

3. PROJECT OBJECTIVES

The project TF/JOR/82/001 aims at designing, manufacturing, installing and testing of an efficient and economical pilot demonstration SWH systems for industrial and large applications, based on the experience and state-of-the art technology at the RSS. It could be considered as a logical follow-up of the activities conducted during recent years in the field of domestic SWHs.

The objectives of this project are the following:

a) Increase of the self-reliance of Jordan in the field of renewable energy through the utilization of solar energy.

b) Transformation of locally applied research and development into commercially viable projects and advice on local manufacturing programme.

c) Maximum utilization of already existing know-how to be adapted to the manufacturing of large solar water heater plants for industrial use.

d) Establishment of designs and models intended to be used in industrial areas, with particular emphasis on low cost production that can actually be manufactured utilizing locally available materials.

e) Dissemination of all findings and results including designs and specifications for manufacturing of solar energy equipment for the benefit of Jordan, the region, and other developing countries.

4. ACTIVITIES AND OUTPUTS PRODUCED

The activities carried out in fullfilment of the project objectives were the following:

a) The design of an efficient and economical solar water heater system for industrial application taking into account all relevant parameters leading to a low cost installation.

b) An industrial estate or public building selection, where the first prototype SWH system should be installed serving as a pilot test demonstration plant. The Jordan Dairy Company was selected for the first prototype installation as will be described later.

c) The manufacturing of the first pilot plant with the existing and newly acquired workshop machine tools and equipments.

d) The SWH system installation, testing, and modification to arrive at an optimum performance.

This activity began on December 1985, where the manufacturing of the system has been needlessly delayed because of materials problem, where a lot of the materials received was defective or degraded to a stage of uselessness, while another part of the materials were missing.

e) The second prototype system manufacturing and installation in another industrial enterprise or public building, which should serve as a second pilot demonstration system. The Coral Beach Hotel in Aqaba, south of Jordan was choosen for the second installation.

This activity took place on July 1987, where the manufacturing of the system was conducted according to schedule, due to local purchase of the needed materials with a short delivery time. Also all the experience gained from the first pilot plant has it s effect in improving the way of work, time spent, and in avoiding all the problems that occur before.

f) All design drawings and specifications of the SWH systems will be given to local manufacturers, so that the manufacturing of large systems will be carried out under the supervision and control of the RSS.

g) Further promotion of the application of SWHs for industrial use by dissemination of all specific information for the benefit of Jordan, the region, and other developing countries will be envisaged.

The project inputs needed to perform the above activities are shown in Appendix-1.

4.1 Consultant

The project inputs include a consultant mission to help in selecting the location, and designing the two SWH pilot plants.

In close cooperation with the national project manager and RSS staff, the consultant was expected to:

a) Assist in the identification of site locations for prototypes of large SWH systems to be installed in industrial enterprises or public buildings.

b) Aid in optimization of parameters and in the design of large SWH systems.

c) Recommend ways and means for an effective experimental setup and its implementation.

d) Prepare a final report setting out the findings and recommendations for future design aspects.

Dr. Steven V. Szokolay from the University of Queensland in Australia came as a consultant in two split missions. The first mission was from November 11 to 26,1983 and was covered by the report submitted on December 1983, which includes the design of the first SWH system of the Jordan Dairy Company. The second mission was performed from January 3 to 19, 1987 and was covered by the report submitted on January 1987, which includes the design of second SWH system of the Aqaba Coral Beach Hotel.

The two missions of Dr. Szokolay was a great assistant for project activities, where discussions and recommendations took place regarding site selection and systems design.

4.2 Jordan Dairy Company SWH System

A survey was made to identify the possible candidate factory for the first pilot project that will utilize the SWH system for its needs. Jordan Dairy Company was chosen for many reasons; e.g. for the required consumption of hot water, the suitable location and the available area for the installation of the flat plate collectors required in the design.

To give a quick description of the factory we can say that Jordan Dairy Company is located in a small industrial town named Ruseifa. It produces milk, cheese, yoghurt, ice cream and various juice drinks.

The solar heating of water was an improvement to the process of dissolving the imported powder milk that produce reconstituted milk. Cold water was used for this process, however in order to reduce process time and consequently reduce electrical consumption of blenders, hot water quality of 40-45°C temperature is needed. The hot water is also needed for container washing purposes with water quality of 60°C. The solar system is thus used to provide these two requirements.

The total collecting area installed was 128 m^2 (96 flat plate collectors, 1.3 m^2 each) with storage tank of 5 m^3 capacity, in order to keep water at acceptable temperature. The fabrication of all components (collectors, tank, collector stands) as well as the complete installation was carried out by RSS personnel.

The installation was almost exactly as the initial design made in assistance with the consultant. The only significant

change is that it is not a pre-heater to the existing boiler-based hot water system, but a completely independent system, supplying hot water for processes, as was ordered by the factory production management.

The installation has been completed in 1985, where a report describing the system and its performance was submitted to UNIDO on May, 1986. Figure (1) shows a schematic diagram of the SWH system, and a two days data and evaluation are shown in Appendix-2 as an example of the data recorded.

4.3 Coral Beach Hotel SWH System

First a decision was made to install the second SWH system to a hotel in Aqaba, which is one of the hotest areas, located South of Jordan.

The Coral Beach Hotel, which is a low-rise (3 storey) building having 95 rooms, was chosen for many reasons:

a) Its reasonable quantity of oil that is used for water heating (4900 Liter of diesel oil/month), therefore a significant oil saving could be achieved by installing the solar system.
b) There is a space for the collector array with area as required in the design, on the roof of the single-storey boiler house and service building.

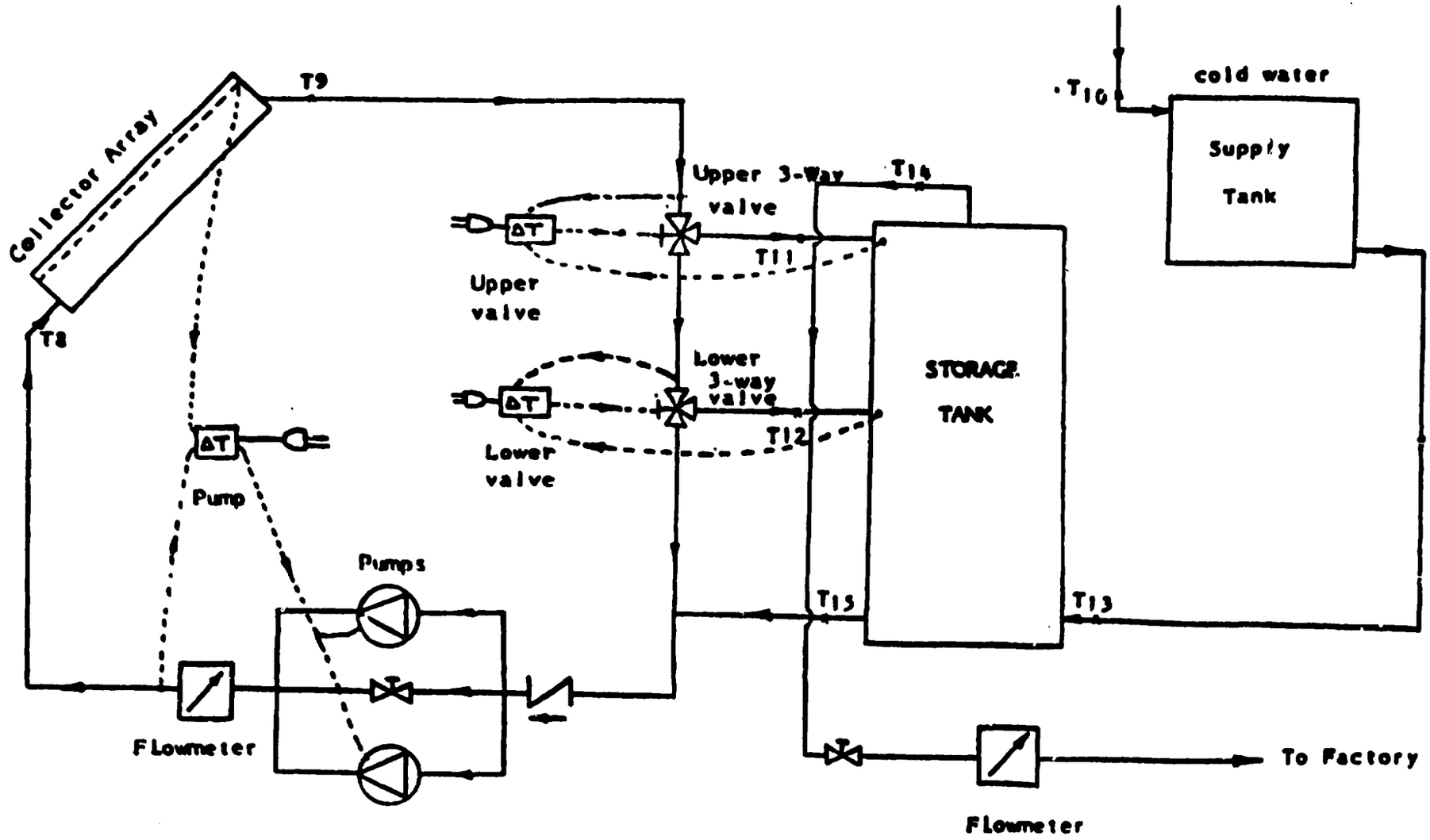

Fig. (1): Schematic diagram of the Jordan Dairy Company SWH System.

c) There is adequate space for the storage tank (6 m^3) near the boiler room.

The SWH system was installed as a pre-heater to the existing boiler system, where a thermostat controls the temperature of hot water inside the existing cylinder, which is connected tc the boiler through a heat exchanger.

The total collecting area installed was 180 m^2 (90 flat plate collectors, 2 m^2 each), with a storage tank size of 6 m^3 required to keep hot water at the acceptable temperature, taking into consideration the available 6 m^3 cylinder, so that the total storage volume is 12 m^3.

Fabrication of all components (collectors, tank, collector stands) as well as the complete installation was carried out by RSS personnel. The installation was almost as the initial design made in cooperation with the consultant. Some rearrangements was made with regard to the collectors plan, where connection pipes between panels were not taken into account in the arrangement made by the consultant, also the collectors were a little larger in size when manufacturing. So 5 instead of 6 collectors were put in each set and one more row was added to get the required

collection area, which follows a reduction in the space between the rows from about 2.4 m to 1.85 m. This will cause a slight overshadowing after 3.00 p.m. in December, which should not affect the overall efficiency of the system concerned.

The collector used were more developed than the collectors used for the first system both in materials and in size (1 x 2 m), where an improvement was done to avoid welding points in the absorber plate and using aluminum frame for the case of the collector.

The installation was completed this year 1987, where a report describing system installation including instrumentation needed for evaluation, was submitted to UNIDO on October 1987. Figure (2) shows a schematic diagram of the SWH system, and a two ..... days data and evaluation are shown in Appendix-3, as an example of the data recorded, where the system testing and evaluation has been carried out since two months, and until this time.

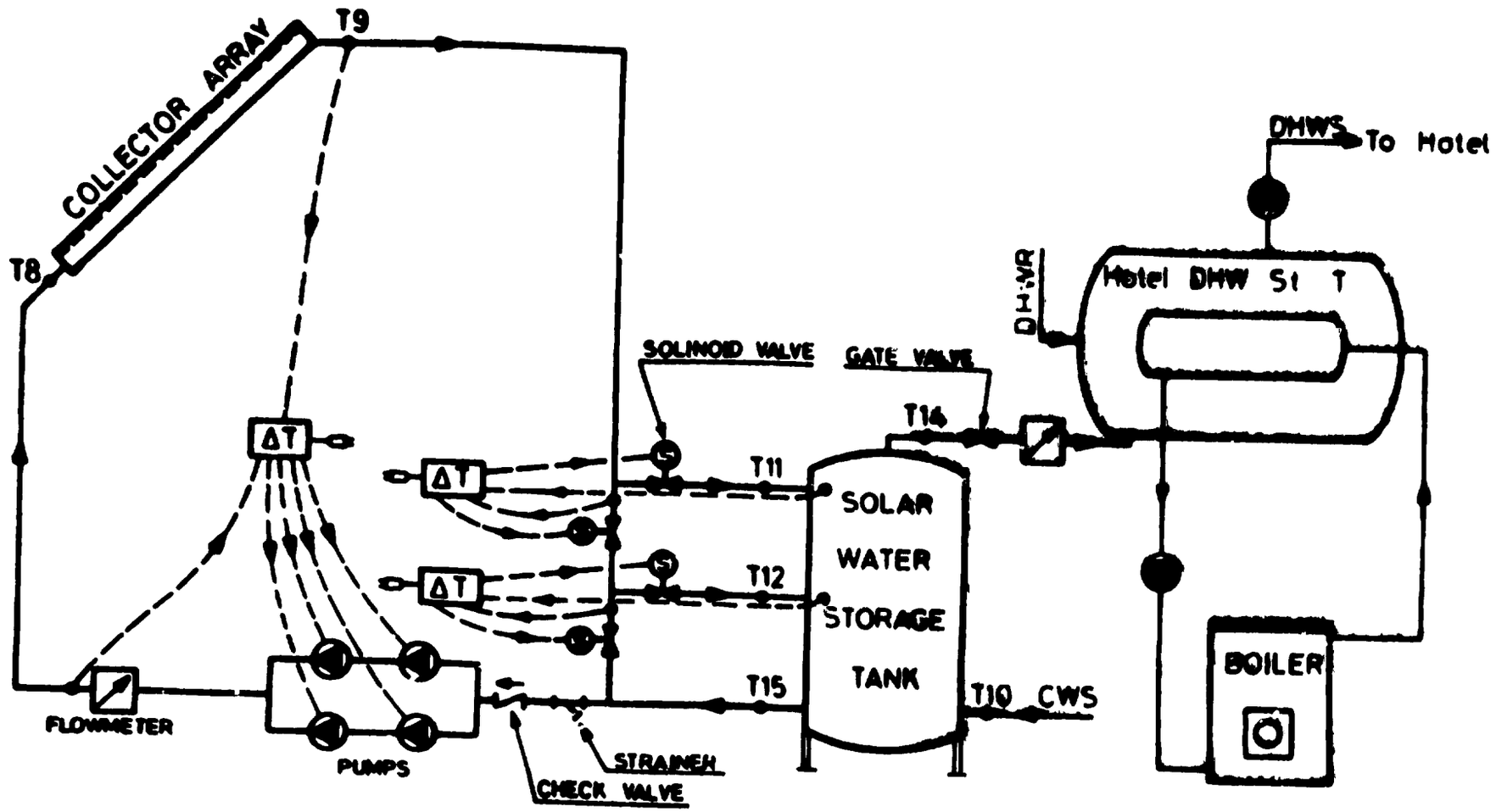

Fig. (2): Schematic diagram of the Coral Beach Hotel SWH System.

5. ACHIEVEMENT OF IMMEDIATE OBJECTIVES

To state the extent to which the immediate objectives were achieved we have to mention the following:

a) Jordan self-reliance was increased so much in the field of solar energ, where the activities on solar energy began in 1972 by manufacturing units of SWH at the MED, but afterwards and considering the importance of energy, and as a result of the remarkable success in developing the use of solar energy for different purposes, the RSS upgraded the Solar Energy Section at the MED by establishing a Solar Energy Research Center (SERC) on November 1983, with the objective of placing more emphasis on research and development work in the field of renewable energy. A main section of the SERC is the solar collector application section which works mainly in water heating by solar energy for domestic and industrial uses. The other two sections are a wind energy section, and a photovoltaic section.

b) A lot of research and development work related to the equipment and instruments used in solar collector applications was conducted. The RSS had designed and produced pilot

systems of SWH in its well equiped workshop and signed three agreements with local manufacturers for mass production for local market and exports under supervision and control of the RSS.

c) The previously designed flat plate collectors and SWH's were improved and upgraded, where RSS has successfully developed SWHs for different applications taking into consideration:
   - Low cost of units,
   - High effeciency,
   - Ease of installation to existing structures,
   - Use of materials normally available in the country,
   - Ease of production using simple machine shop equipment.

d) The existing know-how which was developed by strengthening the local manpower capabilities in the field of SWH industry was utilized in the design, manufacturing, installation, and evaluattion of large SWH plants which was executed in a good and competent manner.

e) In the field of dissemination of findings and results we can say that the RSS is always participating in the training of local manpower working in local industries related to SWH's.

Training courses are always held for both engineers and techniciancs. A special training course for 20 engineers and technicians from eleven Arab countries was held in 1980. Also a seminar on manufacturing and installation of SWH was held for local manufacturers in 1986. Two seminars for local manufacturers were held in 1987 in cooperation with Ministry of Energy and Mineral Resources. All related information are provided for developing countries whenever its needed.

6. UTILIZATION OF PROJECT RESULTS

Since this project in its original objective reprsents a logical follow-up of the past activities, one of its main results was strengthening of local know-how and manpower capabilities in the field of SWH application through the different project activities and inputs (workshop equipment and expendable equipment). Also since SWH technology for industrial applications was not readily available, new designs and manufacturing techniques of flat plate collectors and SWH systems were developed in order to reach optimum designs for different applications, one of which is the large and industrial application.

Utilizing the new workshop equipments and the improved local know-how the RSS produced many SWH units as a pilot production. These units were installed at different locations in Jordan. The experience gained in this process lead to lots of changes and final designs. Afterwards the SWHs became more popular and widely accepted and utilized with the continuous back-up provided by the RSS to local manufacturers to upgrade and improve their products.

Nowadays there are approximately 40 manufacturers of SWH in and around Amman, 3 of which are large factories who works according to RSS specifications and supervision, while the rest are normal workshops, who gets recommendations and advice on their designs and production techniques from the RSS.

About 25% of the total number of houses in Jordan utilizies SWH for domestic use, which means about 90,000 units. This number is expected to reach 250,000 units by the year 1995.

Also during the execution of this project, two efficient and economical pilot demonstration SWH systems for industrial application were designed, manufactured, installed and tested one for a factory, while the other is for a hotel.

The two systems are well-utilized leading to a significant energy savings perhaps for the hotel more than for the factory, but the two managements are satisfied and greatfull for such new technology that was proved to be economically feasible.

Many other industrial enterprises and public buildings were encouraged to utilize such technology as a result of the remarkable success of the two prototype systems.

7. CONCLUSIONS

1. The experience gained from this project leads to lots of changes in the designs and manufacturing techniques in the field of SWH applications. Nowadays Jordan has passed the stage of prototype production and can offer comercialized, technically well-designed and tested SWH systems for both domestic and industrial applications following the local well strengthened know-how.

2. As a result of the assistance and back-up provided through this project, the RSS designed SWHs following the criteria of low cost of units which can be easily installed, maintained, and produced using the available materials and simple machine stop equipments.

3. The pay-back time of the well designed and manufactured SWH (3 collectors with an area of 4 m^2, 150 L storage, 1 m3 cold water tank, including piping and racks) is 4 years with an expected lifetime of at least 15 years.

4. The Jordan Dairy Company SWH system is a success producing quite high temperatures. An inspection of the long term readings shows the following results concerning the performance of the system:

   a) The system is capable of producing hot water of quality more than 50°C throughout the year, eventhough no high radiation would occur for several days,

   b) The net daily energy collection varies from about 100 to 250 kWh, averaging some 150 kWh,

   c) The collection efficiency at the time of peak irradiance can reach 0.4 and often exceeds 0.3,

   d) The daily average efficiency of the whole system rarely reaches 0.3 and the long-term average is only about 0.15,

   e) The daily amount of energy supplied to the factory varies between about 0 and 200 kWh.

5. The Coral Beach Hotel SWH system is another success serving as a preheater to the existing hot water system, showing a significant energy savings, and quite high efficiency. An inspection of the available readings show the following general results concerning system performance, taking into consideration that the available data was recorded during winter time:

a) The performance of the system is better than that installed at the Dairy Company which is due to higher consumption of hot water ($5m^3$/day minimum - 15 m^3/day maximum) which allows for more energy collection, and so higher effeciency,

b) The daily energy collection varies from about 250 to 400 kWh averaging some 340 kWh,

c) the hourly collection effeciency at time of peak irradiance can reach 0.50, and often exceeds 0.30,

d) The daily average effeciency of the whole system is about 0.19,

e) The daily amount of energy supplied to the hotel from the solar system varies from 100 to 400 kWh.

6. In fact, these experimental installations of the two large solar water heatng systems in Jordan forms a starting point for better and more effecient systems which may be installed in the future.

7. One of the main benefits of this project is the "hands on" experience gained by all the people involved, from design engineers to technicians, workers and the monitoring personnel. These experiences will be put to good use in the next future projects.

8. RECOMMENDATIONS

At present stage, the RSS has done as much as could be done with the galvanized steel for low and medium temperature applications, with lots of developments regarding the improvement of thermal contact between absorber plate and riser tubes. These developed technologies has already been transfered to several commercial firms.

With regard to future work, an extension of this project is desirable, where technical assistance is needed in the field of introducing selective solar surface technology for transparent covers and for absorber plates of SWH systems in

industrial areas through local manufacturing. Through these surfaces, it is possible to extend the operational temperature of flat plate collectors to possible more than 100°C, thus opening a wide range of application in industrial process heat and boiler preheat. Also an increased collector performance based on selective surface technology would allow a decrease in the size of collectors needed.

The technical assistance needed fits within the proposed activities mentioned by UNIDO industrial development officer Mr. J. Furkus in his report submitted on 26 of May 1987, covering his mission to the RSS between 8 - 15 May, 1987.

The scope of technical assistance proposed would enable the country to take appropriate decisions and to find respective solutions required.

APPENDIX - 1

Project inputs

6. Project Inputs

(1) Consultants

a) Design engineer

(2) Special workshop equipment

- 1 Stamping machine
- 1 Shearing machine
- 1 Bending manchine
- 1 Automatic welding machine
- 1 Automatic drilling machine
- 1 Working/assembly bench

(3) Special testing equipment

- Data acquisition systems
- Thermocouples
- Flowmeters
- Solarimeters
- Integrators

(4) Expendable equipment

This item includes:

- Tools
- Raw material for workshop activities
- Necessary material for two sequential prototypes production and installation

(5) Miscellaneous

- Transport vehicle
- Trave'ling
- Monitoring reviews and evaluation meetings.

APPENDIX - 2

Two days data and evaluation sheets of the SWH system
in the Jordan Dairy Company

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COLLECTOR APPLICATION SECTION
JORDAN DAIRY COMPANY SOLAR HOT WATER SYSTEM

TABLE(1-A): HOURLY AVERAGE DATA

DATE: 24/08/86

HOUR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
00	-	-	-	-	-	-	0	0	0	21	0	0	0	-	0	59	59
01	-	-	-	-	-	-	0	0	0	20	0	0	0	-	0	59	59
02	-	-	-	-	-	-	0	0	0	19	0	0	0	-	0	59	59
03	-	-	-	-	-	-	0	0	0	18	0	0	0	-	0	59	59
04	-	-	-	-	-	23	0	0	0	18	0	0	0	70	129	59	58
05	-	-	-	-	-	24	0	0	0	17	0	0	0	70	733	58	50
06	-	-	-	-	-	-	0	27	15	17	0	0	0	-	0	50	50
07	-	-	-	-	-	-	0	176	63	20	0	0	0	-	0	50	50
08	21	38	-	-	-	-	43.22	367	106	22	.04	0	0	-	0	50	50
09	32	51	-	-	-	-	42.52	566	129	26	.09	0	0	-	0	50	50
10	50	69	26	-	20	-	44.34	723	146	28	.28	0	.1	-	0	50	52
11	58	78	27	29	24	-	46.47	828	156	31	.49	.16	.03	-	0	52	57
12	52	73	31	80	25	-	48.3	879	163	33	.46	.17	.02	-	0	57	62
13	60	76	39	29	28	-	48.32	869	175	34	.46	.15	.01	-	0	62	66
14	68	83	54	27	81	-	47.27	776	258	35	.32	.13	.01	-	0	66	68
15	52	26	38	81	82	29	49.86	632	410	34	.36	.07	.06	27	1220	68	66
16	57	65	-	-	-	-	49.22	438	392	32	.05	0	0	-	0	66	66
17	-	-	-	-	-	-	0	233	222	31	0	0	0	-	0	66	66
18	-	-	-	-	-	-	0	44	44	29	0	0	0	-	0	66	66
19	-	-	-	-	-	-	0	0	0	27	0	0	0	-	0	66	66
20	-	-	-	-	-	-	0	0	0	26	0	0	0	-	0	66	66
21	-	-	-	-	-	-	0	0	0	24	0	0	0	-	0	66	66
22	-	-	-	-	-	-	0	0	0	23	0	0	0	-	0	66	66
23	-	-	-	-	-	-	0	0	0	22	0	0	0	-	0	66	66
TOTAL								6558	2279						2132		

1) COLLECTOR INLET TEMPERATURE
2) COLLECTOR OUTLET TEMPERATURE
3) BOTTOM STORAGE OUTLET
4) TOP STORAGE INLET
5) MID STORAGE INLET
6) BOTTOM STORAGE INLET FROM COLD WATER SUPPLY
7) COLLECTOR FLOW RATE (LPH)
8) TOTAL RADIATION (WATT/sq. m)
9) DIFFUSE RADIATION (WATT/sq. m)
10) AMBIENT TEMPERATURE
11) PERCENTAGE OF TIME DURING WHICH PUMPS WERE ON
12) PERCENTAGE OF TIME DURING WHICH UPPER VALVE WAS OPEN
13) PERCENTAGE OF TIME DURING WHICH LOWER VALVE WAS OPEN
14) TEMPERATURE OF HOT WATER TO FACTORY
15) FACTORY CONSUMPTION OF WATER (LITER)
16) INITIAL AVE. TEMP. OF STORAGE TANK
17) FINAL AVE. TEMP. OF STORAGE TANK

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TABLE(1-B): HOURLY AVERAGE DATA & ENERGY

DATE: 24/08/86

HOUR	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
00	30	33	52	63	66	69	71	71	71	59	-	0	0	0	0
01	30	33	52	63	66	69	71	71	71	59	-	0	0	0	0
02	30	33	51	63	66	69	71	71	71	59	-	0	0	0	0
03	30	34	51	63	66	69	70	70	71	59	-	0	0	0	0
04	30	34	51	63	66	69	70	70	70	59	18	0	0	0	5553
05	26	27	30	43	59	65	67	70	70	51	19	0	0	0	39260
06	26	26	28	40	58	64	67	70	70	50	-	0	0	0	0
07	26	27	28	40	58	64	67	70	70	50	-	0	0	0	0
08	26	27	28	40	57	64	67	70	70	50	-	971	0	0	0
09	26	27	28	40	57	64	67	70	70	50	-	3844	0	0	0
10	26	27	31	45	60	66	67	69	70	52	-	17314	0	12835	0
11	27	31	43	58	67	69	69	70	70	57	-	30929	24826	4471	0
12	31	46	60	68	71	72	72	72	72	64	-	33313	27327	2499	0
13	41	61	68	71	74	75	75	75	75	70	-	27057	19681	1532	0
14	53	68	71	74	76	77	77	77	77	73	-	16313	9440	216	0
15	52	59	63	71	74	76	77	77	77	66	23	22647	11358	9525	32615
16	38	34	66	70	76	77	77	77	77	66	-	1548	0	0	0
17	30	34	66	70	75	77	77	77	77	66	-	0	0	0	0
18	30	35	65	70	75	77	77	77	77	66	-	0	0	0	0
19	30	36	64	70	75	77	77	77	77	66	-	0	0	0	0
20	30	36	63	70	75	77	77	77	77	66	-	0	0	0	0
21	30	36	63	70	75	77	77	77	77	66	-	0	0	0	0
22	30	37	62	70	75	77	77	77	77	66	-	0	0	0	0
23	30	37	62	70	75	77	77	77	77	66	-	0	0	0	0
TOTAL												153936	92632	31578	77428

18-26) WALL TEMP.OF STORAGE TANK AT 9 POINTS EQUALLY SPACED ALONG VERTICAL LINE; WITH 18 IS TEMP. AT THE LOWEST POINT AND 26 IS AT THE HIGHEST
27) AVE. TEMP. OF STORAGE TANK
28) TEMP. OF COLD WATER TO SUPPLY TANK
29) SOLAR ENERGY COLLECTED (WATT.HR)
30) ENERGY TO STORAGE THROUGH UPPER VALVE (WATT.HR)
31) ENERGY TO STORAGE THROUGH LOWER VALVE (WATT.HR)
32) ENERGY FROM STORAGE TO USER (WATT.HR)

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JORDAN DAIRY COMPANY SOLAR HOT WATER SYSTEM

TABLE(1-C): DATA EVALUATION

DATE: 24/08/86

HOUR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
00	0	0	-	-	0	0	0	0	-269	269	-
01	0	0	-	-	0	0	0	0	-180	180	-
02	0	0	-	-	0	0	0	0	-308	308	-
03	0	0	-	-	0	0	0	0	-228	228	-
04	0	0	-	-	0	0	0	5553	-5553	0	-
05	0	0	-	-	0	0	0	39260	-45872	6612	-
06	82	12	-	-	0	0	0	0	0	0	-
07	176	113	-	-	0	0	0	0	0	0	-
08	367	261	7	360	0	0	0	0	0	0	.02
09	566	437	30	536	0	0	0	0	-172	172	.05
10	723	522	135	588	0	12835	12835	0	12835	0	.19
11	828	672	242	586	24826	4471	29297	0	29297	0	.29
12	879	716	260	619	27327	2499	29826	0	29826	0	.3
13	869	694	211	658	19681	1532	21213	0	21213	0	.24
14	776	518	127	649	9440	716	10156	0	10156	0	.16
15	632	222	177	455	11358	9525	20883	32615	-11732	0	.28
16	438	46	12	426	0	0	0	0	0	0	.03
17	233	11	-	-	0	0	0	0	-56	56	-
18	44	0	-	-	0	0	0	0	-359	359	-
19	0	0	-	-	0	0	0	0	-204	204	-
20	0	0	-	-	0	0	0	0	-163	163	-
21	0	0	-	-	0	0	0	0	-691	691	-
22	0	0	-	-	0	0	0	0	0	0	-
23	0	0	-	-	0	0	0	0	0	0	-
TOTAL	6998	4279	1201	4877	92632	31578	124210	77428	37464	9318	

1) TOTAL SOLAR INCIDENT (WATT.HR/sq.m)
2) DIRECT SOLAR INCIDENT (WATT.HR/sq.m)
3) SOLAR ENERGY COLLECTED (WATT.HR/sq.m)
4) COLLECTOR HEAT LOSS (1-3) (WATT.HR/sq.m)
5) ENERGY TO STORAGE THROUGH UPPER VALVE (WATT.HR)
6) ENERGY TO STORAGE THROUGH LOWER VALVE (WATT.HR)
7) ENERGY TO STORAGE (5+6) (WATT.HR)
8) ENERGY FROM STORAGE TO USER (WATT.HR)
9) HOURLY INCREASE IN STORED ENERGY (WATT.HR)
10) STORAGE HEAT LOSS (7-8-9) (WATT.HR)
11) HOURLY INTEGRATED COLLECTOR EFFECIENCY (3/1)

A) DAILY EFF. OF SOLAR COLLECTOR STORAGE SYSTEM = .14

B) DAILY EFF. OF STORAGE TANK = .92

C) DAILY SOLAR RADIATION (WATT.HR) = 837325

D) DAILY COLLECTED ENERGY (WATT.HR) = 153343

ROYAL SCIENTIFIC SOCIETY
SOLAR ENERGY RESEARCH CENTER
COLLECTOR APPLICATION SECTION
JORDAN DAIRY COMPANY SOLAR HOT WATER SYSTEM

TABLE(2-A): HOURLY AVERAGE DATA

DATE: 29/08/86

HOUR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
00	-	-	-	-	-	-	0	0	0	21	0	0	0	-	0	66	66
01	-	-	-	-	-	-	0	0	0	20	0	0	0	-	0	66	66
02	-	-	-	-	-	-	0	0	0	20	0	0	0	-	0	66	65
03	-	-	-	-	-	-	0	0	0	21	0	0	0	-	0	65	65
04	-	-	-	-	-	24	0	0	0	21	0	0	0	76	1051	65	54
05	-	-	-	-	-	-	0	0	0	19	0	0	0	-	0	54	54
06	-	-	-	-	-	21	0	27	15	18	0	0	0	76	418	54	49
07	-	-	-	-	-	21	0	175	67	20	0	0	0	75	365	49	44
08	22	32	-	-	-	-	41.51	377	105	22	.04	0	0	-	0	44	44
09	33	52	24	-	53	-	43.36	555	137	25	.12	0	.07	-	0	44	45
10	46	62	24	-	64	-	48.18	707	159	28	.35	0	.12	-	0	45	48
11	45	66	24	-	73	-	50.28	812	168	31	.41	0	.17	-	0	48	53
12	54	72	25	-	77	-	49.86	859	182	31	.43	0	.14	-	0	53	57
13	57	75	29	78	76	-	49.02	855	203	32	.45	.13	.01	-	0	57	61
14	59	76	41	79	80	-	49.53	777	333	32	.37	.13	.02	-	0	61	64
15	31	78	-	-	-	29	48.01	638	484	32	.15	0	0	76	994	64	62
16	69	74	-	-	-	29	50.42	449	427	30	.06	0	0	76	240	62	59
17	-	-	-	-	-	-	0	240	231	29	0	0	0	-	0	59	59
18	-	-	-	-	-	-	0	44	44	26	0	0	0	-	0	59	59
19	-	-	-	-	-	-	0	0	0	24	0	0	0	-	0	59	59
20	-	-	-	-	-	-	0	0	0	23	0	0	0	-	0	59	59
21	-	-	-	-	-	-	0	0	0	22	0	0	0	-	0	59	59
22	-	-	-	-	-	-	0	0	0	21	0	0	0	-	0	59	59
23	-	-	-	-	-	-	0	0	0	20	0	0	0	-	0	59	59
TOTAL								6514	2955						3068		

1) COLLECTOR INLET TEMPERATURE
2) COLLECTOR OUTLET TEMPERATURE
3) BOTTOM STORAGE OUTLET
4) TOP STORAGE INLET
5) MID STORAGE INLET
6) BOTTOM STORAGE INLET FROM COLD WATER SUPPLY
7) COLLECTOR FLOW RATE (LPM)
8) TOTAL RADIATION (WATT/sq. m)
9) DIFFUSE RADIATION (WATT/sq. m)
10) AMBIENT TEMPERATURE
11) PERCENTAGE OF TIME DURING WHICH PUMPS WERE ON
12) PERCENTAGE OF TIME DURING WHICH UPPER VALVE WAS OPEN
13) PERCENTAGE OF TIME DURING WHICH LOWER VALVE WAS OPEN
14) TEMPERATURE OF HOT WATER TO FACTORY
15) FACTORY CONSUMPTION OF WATER (LITER)
16) INITIAL AVE. TEMP. OF STORAGE TANK
17) FINAL AVE. TEMP. OF STORAGE TANK

ROYAL SCIENTIFIC SOCIETY
SOLAR ENERGY RESEARCH CENTER
COLLECTOR APPLICATION SECTION
JORDAN DAIRY COMPANY SOLAR HOT WATER SYSTEM

TABLE(2-B): HOURLY AVERAGE DATA & ENERGY

DATE: 29/08/86

HOUR	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
00	38	37	61	70	75	77	77	77	77	66	-	0	0	0	0
01	38	38	61	70	75	76	76	76	76	65	-	0	0	0	0
02	38	38	60	70	75	76	76	76	76	65	-	0	0	0	0
03	38	38	60	70	74	76	76	76	76	65	-	0	0	0	0
04	28	33	47	60	70	74	76	76	76	61	19	0	0	0	63844
05	26	26	28	41	62	71	75	76	76	54	-	0	0	0	0
06	25	25	26	32	49	66	72	76	76	50	20	0	0	0	26762
07	24	24	24	28	40	59	70	74	76	46	22	0	0	0	23117
08	24	24	24	26	35	54	68	74	76	44	-	1206	0	0	0
09	24	24	24	27	38	55	68	74	76	45	-	10230	0	5700	0
10	24	24	26	33	52	59	66	74	75	48	-	18436	0	15010	0
11	24	26	34	51	63	67	67	71	74	54	-	30106	0	27219	0
12	25	34	51	63	69	71	71	71	73	60	-	28146	0	23035	0
13	38	51	63	69	73	74	74	74	74	67	-	28687	21487	2095	0
14	48	61	68	72	74	75	75	75	75	70	-	22253	16574	7484	0
15	50	57	68	72	74	76	76	76	76	70	23	3736	0	0	9954
16	38	51	34	62	69	72	74	76	76	59	28	783	0	0	13280
17	38	38	33	62	68	72	74	75	76	59	-	0	0	0	0
18	38	38	34	62	68	72	74	75	75	59	-	0	0	0	0
19	38	38	34	61	68	72	74	75	75	59	-	0	0	0	0
20	38	38	35	61	68	72	74	75	75	59	-	0	0	0	0
21	38	38	35	60	68	72	74	75	75	59	-	0	0	0	0
22	38	38	36	60	68	72	74	75	75	59	-	0	0	0	0
23	38	38	36	60	68	72	74	75	75	59	-	0	0	0	0
TOTAL												143583	38061	79443	136957

18-26) WALL TEMP.OF STORAGE TANK AT 9 POINTS EQUALLY SPACED ALONG VERTICAL LINE, WITH 18 IS TEMP. AT THE LOWEST POINT AND 26 IS AT THE HIGHEST
27) AVE. TEMP. OF STORAGE TANK
28) TEMP. OF COLD WATER TO SUPPLY TANK
29) SOLAR ENERGY COLLECTED (WATT.HR)
30) ENERGY TO STORAGE THROUGH UPPER VALVE (WATT.HR)
31) ENERGY TO STORAGE THROUGH LOWER VALVE (WATT.HR)
32) ENERGY FROM STORAGE TO USER (WATT.HR)

ROYAL SCIENTIFIC SOCIETY
SOLAR ENERGY RESEARCH CENTER
COLLECTOR APPLICATION SECTION
JORDAN DAIRY COMPANY SOLAR HOT WATER SYSTEM

TABLE(2-C): DATA EVALUATION

DATE: 29/08/86

HOUR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
00	0	0	-	-	0	0	0	0	0	0	-
01	0	0	-	-	0	0	0	0	-475	475	-
02	0	0	-	-	0	0	0	0	-344	344	-
03	0	0	-	-	0	0	0	0	-90	90	-
04	0	0	-	-	0	0	0	63844	-67735	3891	-
05	0	0	-	-	0	0	0	0	-262	262	-
06	27	12	-	-	0	0	0	26762	-28486	1724	-
07	175	108	-	-	0	0	0	23117	-25717	2600	-
08	327	272	9	368	0	0	0	0	-146	146	.03
09	555	418	80	475	0	5700	5700	0	5700	0	.14
10	707	548	144	563	0	15010	15010	0	15010	0	.2
11	811	643	235	576	0	27219	27219	0	27219	0	.29
12	859	677	220	639	0	23039	23039	0	23039	0	.26
13	855	652	224	631	21487	2095	23582	0	23582	0	.26
14	777	444	174	603	16574	2384	18958	0	18958	0	.22
15	638	154	29	609	0	0	0	9954	-9954	0	.05
16	449	22	6	443	0	0	0	13280	-10537	9257	.01
17	240	9	-	-	0	0	0	0	-420	420	-
18	44	0	-	-	0	0	0	0	-420	420	-
19	0	0	-	-	0	0	0	0	-485	485	-
20	0	0	-	-	0	0	0	0	0	0	-
21	0	0	-	-	0	0	0	0	-621	621	-
22	0	0	-	-	0	0	0	0	-376	376	-
23	0	0	-	-	0	0	0	0	0	0	-
TOTAL	6914	3959	1121	4907	38061	75443	113504	136957	-40564	17111	

1) TOTAL SOLAR INCIDENT (WATT.HR/sq.m)
2) DIRECT SOLAR INCIDENT (WATT.HR/sq.m)
3) SOLAR ENERGY COLLECTED (WATT.HR/sq.m)
4) COLLECTOR HEAT LOSS (1-3) (WATT.HR/sq.m)
5) ENERGY TO STORAGE THROUGH UPPER VALVE (WATT.HR)
6) ENERGY TO STORAGE THROUGH LOWER VALVE (WATT.HR)
7) ENERGY TO STORAGE (5+6) (WATT.HR)
8) ENERGY FROM STORAGE TO USER (WATT.HR)
9) HOURLY INCREASE IN STORED ENERGY (WATT.HR)
10) STORAGE HEAT LOSS (7-8-9) (WATT.HR)
11) HOURLY INTEGRATED COLLECTOR EFFECIENCY (3/1)

A) DAILY EFF. OF SOLAR COLLECTOR STORAGE SYSTEM = .12

B) DAILY EFF. OF STORAGE TANK = .85

C) DAILY SOLAR RADIATION (WATT.HR) = 831707

D) DAILY COLLECTED ENERGY (WATT.HR) = 143129

APPENDIX - 3

Two days data and evaluation sheets of the SWH system
at the Coral Beach Hotel

ROYAL SCIENTIFIC SOCIETY
SOLAR ENERGY RESEARCH CENTER
COLLECTOR APPLICATION SECTION
AQABA CORAL BEACH HOTEL SOLAR HOT WATER SYSTEM

TABLE(1-A): HOURLY AVERAGE DATA

DATE: 26/10/87

HOUR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
00	-	-	-	-	-	-	0	0	0	19	0	0	0	-	0	45	44
01	-	-	-	-	-	-	0	0	0	18	0	0	0	-	0	44	44
02	-	-	-	-	-	-	0	0	0	18	0	0	0	-	0	44	44
03	-	-	-	-	-	-	0	0	0	17	0	0	0	-	0	44	44
04	-	-	-	-	-	-	0	0	0	17	0	0	0	-	0	44	44
05	-	-	-	-	-	20	0	0	0	17	0	0	0	60	324	44	41
06	-	-	-	-	-	22	0	0	0	17	0	0	0	61	1166	41	31
07	-	-	-	-	-	22	0	38	19	17	0	0	0	60	601	31	26
08	-	-	-	-	-	23	0	77	52	19	0	0	0	41	1583	26	23
09	24	28	23	-	29	-	146	187	152	20	.17	0	.12	-	0	23	25
10	28	34	28	-	34	25	149	644	549	22	.88	0	.87	28	694	25	31
11	35	41	35	-	41	26	148	864	597	23	1	0	1	35	685	31	39
12	42	49	43	-	49	26	148	992	98	24	1	0	1	42	499	39	48
13	50	57	51	-	57	26	148	1034	92	25	1	0	1	50	457	48	56
14	57	62	57	-	62	-	152	974	826	25	1	0	.55	-	0	56	59
15	58	62	-	-	-	-	158	818	818	26	1	0	0	-	0	59	59
16	57	58	-	-	-	-	158	585	585	25	1	0	0	-	0	59	59
17	53	55	-	-	-	27	154	123	123	24	.2	0	0	60	1207	59	56
18	-	-	-	-	-	27	0	0	0	23	0	0	0	59	855	56	50
19	-	-	-	-	-	26	0	0	0	21	0	0	0	57	657	50	45
20	-	-	-	-	-	25	0	0	0	20	0	0	0	56	352	45	43
21	-	-	-	-	-	25	0	0	0	20	0	0	0	55	1021	43	36
22	-	-	-	-	-	24	0	0	0	19	0	0	0	56	746	36	31
23	-	-	-	-	-	24	0	0	0	19	0	0	0	55	846	31	27
TOTAL								6336	3911						11693		

1) COLLECTOR INLET TEMPERATURE
2) COLLECTOR OUTLET TEMPERATURE
3) BOTTOM STORAGE OUTLET
4) TOP STORAGE INLET
5) MID STORAGE INLET
6) BOTTOM STORAGE INLET FROM COLD WATER SUPPLY
7) COLLECTOR FLOW RATE (LPH)
8) TOTAL RADIATION (WATT/sq. m)
9) DIFFUSE RADIATION (WATT/sq. m)
10) AMBIENT TEMPERATURE
11) PERCENTAGE OF TIME DURING WHICH PUMPS WERE ON
12) PERCENTAGE OF TIME DURING WHICH UPPER VALVE WAS OPEN
13) PERCENTAGE OF TIME DURING WHICH LOWER VALVE WAS OPEN
14) TEMPERATURE OF HOT WATER TO HOTEL
15) HOTEL CONSUMPTION OF HOT WATER (LITER)
16) INITIAL AVE. TEMP. OF STORAGE TANK
17) FINAL AVE. TEMP. OF STORAGE TANK

ROYAL SCIENTIFIC SOCIETY
SOLAR ENERGY RESEARCH CENTER
COLLECTOR APPLICATION SECTION
AQABA CORAL BEACH HOTEL SOLAR HOT WATER SYSTEM

TABLE(1-B): HOURLY AVERAGE DATA & ENERGY

DATE: 26/10/87

HOUR	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
00	25	26	27	29	42	60	63	64	64	45	0	0	0	0	0
01	25	26	27	29	41	59	63	64	64	44	0	0	0	0	0
02	25	26	27	29	40	59	63	64	64	44	0	0	0	0	0
03	25	26	27	29	40	58	63	63	63	44	0	0	0	0	0
04	25	26	27	29	40	58	62	63	63	44	0	0	0	0	0
05	25	26	27	28	36	54	62	63	63	43	.23	0	0	0	19202
06	23	24	26	27	29	38	52	61	63	38	.08	0	0	0	53775
07	22	22	22	25	26	27	29	39	56	29	0	0	0	0	27049
08	22	22	22	22	23	24	26	27	31	24	0	0	0	0	20660
09	23	23	23	24	24	24	24	25	26	24	.17	9350	0	8396	0
10	28	28	28	28	28	28	28	28	28	28	.17	51882	0	52723	2201
11	35	35	35	35	35	35	35	35	35	35	.01	63744	0	60756	4795
12	43	44	44	44	44	44	44	44	44	44	.31	73268	0	62443	842
13	51	52	52	52	52	52	52	52	52	52	0	69962	0	53853	1531
14	58	58	58	59	59	59	59	59	59	59	0	57006	0	26802	0
15	60	61	61	61	61	61	61	62	62	61	0	44933	0	0	0
16	60	61	61	61	61	61	61	62	62	61	0	19255	0	0	0
17	51	57	58	58	58	59	59	61	62	58	0	3943	0	0	22003
18	28	34	52	57	58	58	58	59	60	52	0	0	0	0	32309
19	27	28	32	51	57	58	58	58	59	48	0	0	0	0	23954
20	26	27	28	31	52	57	57	58	58	44	.23	0	0	0	12771
21	25	26	27	28	31	41	56	58	58	38	.06	0	0	0	37014
22	25	26	26	26	28	29	41	56	58	34	0	0	0	0	27195
23	24	25	26	26	26	27	28	32	46	28	0	0	0	0	30425
TOTAL												393343	0	264973	311726

18-26) WALL TEMP. OF STORAGE TANK AT 9 POINTS EQUALLY SPACED ALONG VERTICAL LINE, WITH 18 IS TEMP. AT THE LOWEST POINT AND 26 IS AT THE HIGHEST
27) AVE. TEMP. OF STORAGE TANK
28) PERCENTAGE OF TIME DURING WHICH BOILER WAS ON
29) SOLAR ENERGY COLLECTED (WATT.HR)
30) ENERGY TO STORAGE THROUGH UPPER VALVE (WATT.HR)
31) ENERGY TO STORAGE THROUGH LOWER VALVE (WATT.HR)
32) ENERGY FROM STORAGE TO USER (WATT.HR)

ROYAL SCIENTIFIC SOCIETY
SOLAR ENERGY RESEARCH CENTER
COLLECTOR APPLICATION SECTION
AQABA CORAL BEACH HOTEL SOLAR HOT WATER SYSTEM

TABLE(1-C): DATA EVALUATION

DATE: 26/10/87

HOUR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
00	0	0	-	-	0	0	0	0	-2018	2018	-	0
01	0	0	-	-	0	0	0	0	-1419	1419	-	0
02	0	0	-	-	0	0	0	0	-1637	1637	-	0
03	0	0	-	-	0	0	0	0	-800	800	-	0
04	0	0	-	-	0	0	0	0	0	0	-	0
05	0	0	-	-	0	0	0	15202	-10823	3621	-	.23
06	0	0	-	-	0	0	0	53725	-69203	15428	-	.08
07	38	19	-	-	0	0	0	27049	-32913	5864	-	0
08	77	25	-	-	0	0	0	20660	-20660	0	-	0
09	187	35	90	137	0	8396	8396	0	8396	0	.27	.17
10	644	95	278	366	0	52723	52723	2201	45850	4672	.43	.17
11	864	267	342	522	0	60756	60756	4795	55961	0	.4	.01
12	992	894	393	599	0	62443	62443	842	61601	0	.4	.31
13	1034	942	375	659	0	53853	53853	1531	52322	0	.36	0
14	974	148	305	669	0	26802	26802	0	26802	0	.31	0
15	818	0	241	577	0	0	0	0	0	0	.29	0
16	585	0	103	482	0	0	0	0	0	0	.18	0
17	123	0	21	102	0	0	0	22003	-22003	0	.17	0
18	0	0	-	-	0	0	0	32309	-43858	11549	-	0
19	0	0	-	-	0	0	0	23954	-33372	9418	-	0
20	0	0	-	-	0	0	0	12771	-15335	2564	-	.23
21	0	0	-	-	0	0	0	37014	-52125	15111	-	.06
22	0	0	-	-	0	0	0	27195	-29942	2747	-	0
23	0	0	-	-	0	0	0	30425	-32122	1697	-	0
TOTAL	6336	2425	2108	4113	0	264973	264973	311726	-125298	78545		1.26

1) TOTAL SOLAR INCIDENT (WATT.HR/sq.m)
2) DIRECT SOLAR INCIDENT (WATT.HR/sq.m)
3) SOLAR ENERGY COLLECTED (WATT.HR/sq.m)
4) COLLECTOR HEAT LOSS (1-3) (WATT.HR/sq.m)
5) ENERSY TO STORAGE THROUGH UPPER VALVE (WATT.HR)
6) ENERGY TO STORAGE THROUGH LOWER VALVE (WATT.HR)
7) ENERGY TO STORAGE (5+6) (WATT.HR)
8) ENERGY FROM STORAGE TO USER (WATT.HR)
9) HOURLY INCREASE IN STORED ENERGY (WATT.HR)
10) STORAGE HEAT LOSS (7-8-9) (WATT.HR)
11) HOURLY INTEGRATED COLLECTOR EFFECIENCY (3/1)
12) PERCENTAGE OF TIME DURING WHICH AUXILIARY BOILER WAS ON

A) DAILY EFF. OF SOLAR COLLECTOR STORAGE SYSTEM = .16
B) DAILY EFF. OF STORAGE TANK = .7
C) DAILY SOLAR RADIATION (WATT.HR) = 1180396
D) DAILY COLLECTED ENERGY (WATT.HR) = 392720

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SOLAR ENERGY RESEARCH CENTER
COLLECTOR APPLICATION SECTION
AQABA CORAL BEACH HOTEL SOLAR HOT WATER SYSTEM

TABLE(2-A): HOURLY AVERAGE DATA

DATE: 27/10/87

HOUR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
00	-	-	-	-	-	23	0	0	0	19	0	0	0	52	158	27	26
01	-	-	-	-	-	-	0	0	0	18	0	0	0	-	0	26	26
02	-	-	-	-	-	-	0	0	0	18	0	0	0	-	0	26	26
03	-	-	-	-	-	-	0	0	0	17	0	0	0	-	0	26	26
04	-	-	-	-	-	20	0	0	0	17	0	0	0	42	145	26	26
05	-	-	-	-	-	20	0	0	0	16	0	0	0	38	246	26	26
06	-	-	-	-	-	21	0	0	0	16	0	0	0	30	1238	26	24
07	-	-	-	-	-	21	0	37	18	16	0	0	0	26	1588	24	23
08	-	-	-	-	-	22	0	81	54	17	0	0	0	25	1763	23	22
09	23	27	23	-	27	23	149	219	155	19	.51	0	.49	23	1151	22	25
10	27	32	27	-	32	25	150	652	544	21	1	0	1	27	561	25	31
11	34	40	34	-	40	26	149	858	539	24	1	0	1	33	489	31	39
12	42	49	42	-	49	27	149	963	116	25	1	0	1	42	364	39	47
13	49	56	50	-	56	-	150	999	119	26	1	0	.89	-	0	47	54
14	56	61	57	-	61	27	148	956	848	26	1	0	1	56	336	54	60
15	62	65	61	-	64	-	154	815	815	27	1	0	.36	-	0	60	62
16	61	63	-	-	-	-	158	583	583	27	1	0	0	-	0	62	62
17	55	57	-	-	-	27	151	116	116	25	.12	0	0	62	540	62	62
18	-	-	-	-	-	27	0	0	0	23	0	0	0	62	1771	62	51
19	-	-	-	-	-	26	0	0	0	22	0	0	0	61	942	51	43
20	-	-	-	-	-	25	0	0	0	21	0	0	0	60	602	43	38
21	-	-	-	-	-	25	0	0	0	21	0	0	0	59	388	38	35
22	-	-	-	-	-	25	0	0	0	19	0	0	0	59	975	35	28
23	-	-	-	-	-	24	0	0	0	18	0	0	0	56	777	28	27
TOTAL								6279	3907						14036		

1) COLLECTOR INLET TEMPERATURE
2) COLLECTOR OUTLET TEMPERATURE
3) BOTTOM STORAGE OUTLET
4) TOP STORAGE INLET
5) MID STORAGE INLET
6) BOTTOM STORAGE INLET FROM COLD WATER SUPPLY
7) COLLECTOR FLOW RATE (LPM)
8) TOTAL RADIATION (WATT/sq. m)
9) DIFFUSE RADIATION (WATT/sq. m)
10) AMBIENT TEMPERATURE
11) PERCENTAGE OF TIME DURING WHICH PUMPS WERE ON
12) PERCENTAGE OF TIME DURING WHICH UPPER VALVE WAS OPEN
13) PERCENTAGE OF TIME DURING WHICH LOWER VALVE WAS OPEN
14) TEMPERATURE OF HOT WATER TO HOTEL
15) HOTEL CONSUMPTION OF HOT WATER (LITER)
16) INITIAL AVE. TEMP. OF STORAGE TANK
17) FINAL AVE. TEMP. OF STORAGE TANK

ROYAL SCIENTIFIC SOCIETY
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COLLECTOR APPLICATION SECTION
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TABLE(2-B): HOURLY AVERAGE DATA & ENERGY

DATE: 27/10/87

HOUR	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
00	25	25	25	26	26	26	27	29	33	27	0	0	0	0	1948
01	25	25	25	26	26	26	27	28	31	26	0	0	0	0	0
02	25	25	25	26	26	26	27	28	31	26	0	0	0	0	0
03	25	25	25	26	26	26	27	28	31	26	0	0	0	0	0
04	25	25	25	26	26	26	26	28	30	26	0	0	0	0	1896
05	24	25	25	25	26	26	26	27	29	26	.28	0	0	0	2718
06	22	24	25	25	26	26	26	26	28	25	.12	0	0	0	9024
07	21	22	22	22	24	25	25	26	26	24	.18	0	0	0	8076
08	22	22	22	22	22	22	22	23	25	23	.39	0	0	0	6218
09	22	23	23	23	23	23	23	23	23	23	.27	19573	0	20579	27
10	27	27	27	27	27	27	27	27	28	27	.06	44736	0	46165	1369
11	34	34	34	34	35	35	34	35	35	34	.35	61225	0	61919	3999
12	42	43	43	43	43	43	43	43	43	43	0	69042	0	62787	3404
13	50	51	51	51	51	51	51	51	51	51	.22	71028	0	49778	0
14	57	57	57	58	58	57	57	58	58	57	.05	52309	0	49551	7828
15	62	62	62	62	63	63	62	63	63	62	0	37822	0	13585	0
16	64	64	64	64	64	64	64	64	64	64	0	18464	0	0	0
17	60	62	62	62	62	63	63	64	64	63	0	1962	0	0	2089
18	32	44	54	61	62	62	62	63	64	57	0	0	0	0	72050
19	27	28	28	33	52	61	61	62	62	46	0	0	0	0	38044
20	26	27	28	28	29	48	61	62	62	41	0	0	0	0	24119
21	26	27	27	28	28	30	53	61	62	37	0	0	0	0	15714
22	25	26	26	27	28	28	31	44	60	31	0	0	0	0	39202
23	25	25	25	26	27	27	28	28	38	27	0	0	0	0	11925
TOTAL												381161	0	304364	249646

18-26) WALL TEMP. OF STORAGE TANK AT 9 POINTS EQUALLY SPACED ALONG VERTICAL LINE, WITH 18 IS TEMP. AT THE LOWEST POINT AND 26 IS AT THE HIGHEST
27) AVE. TEMP. OF STORAGE TANK
28) PERCENTAGE OF TIME DURING WHICH BOILER WAS ON
29) SOLAR ENERGY COLLECTED (WATT.HR)
30) ENERGY TO STORAGE THROUGH UPPER VALVE (WATT.HR)
31) ENERGY TO STORAGE THROUGH LOWER VALVE (WATT.HR)
32) ENERGY FROM STORAGE TO USER (WATT.HR)

ROYAL SCIENTIFIC SOCIETY
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TABLE(2-C): DATA EVALUATION

DATE: 27/10/87

HOUR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
00	0	0	-	-	0	0	0	1948	-1948	0	-	0
01	0	0	-	-	0	0	0	0	-500	500	-	0
02	0	0	-	-	0	0	0	0	0	0	-	0
03	0	0	-	-	0	0	0	0	-274	274	-	0
04	0	0	-	-	0	0	0	1896	-1896	0	-	0
05	0	0	-	-	0	0	0	2718	-2718	0	-	.28
06	0	0	-	-	0	0	0	9024	-9024	0	-	.12
07	37	19	-	-	0	0	0	8076	-9064	988	-	.18
08	81	27	-	-	0	0	0	6218	-9489	3271	-	.35
09	219	64	105	114	0	20579	20579	27	20592	0	.48	.27
10	652	108	240	412	0	46165	46165	1369	41514	3282	.37	.06
11	858	319	328	530	0	61919	61919	3999	56952	968	.38	.35
12	963	847	378	593	0	62787	62787	3404	59383	0	.36	0
13	999	880	381	618	0	49778	49778	0	49778	0	.38	.22
14	956	108	307	649	0	49551	49551	7828	41723	0	.32	.05
15	815	0	203	612	0	13585	13585	0	13585	0	.25	0
16	583	0	99	484	0	0	0	0	0	0	.17	0
17	116	0	10	106	0	0	0	2089	-2089	0	.09	0
18	0	0	-	-	0	0	0	72050	-79096	7046	-	0
19	0	0	-	-	0	0	0	38044	-51227	13183	-	0
20	0	0	-	-	0	0	0	24115	-37326	13211	-	0
21	0	0	-	-	0	0	0	15714	-18239	2525	-	0
22	0	0	-	-	0	0	0	39202	-49823	10621	-	0
23	0	0	-	-	0	0	0	11925	-11925	0	-	0
TOTAL	6279	2372	2043	4118	0	304364	304364	249646	-1151	55869		1.00

1) TOTAL SOLAR INCIDENT (WATT.HR/sq.m)
2) DIRECT SOLAR INCIDENT (WATT.HR/sq.m)
3) SOLAR ENERGY COLLECTED (WATT.HR/sq.m)
4) COLLECTOR HEAT LOSS (1-3) (WATT.HR/sq.m)
5) ENERGY TO STORAGE THROUGH UPPER VALVE (WATT.HR)
6) ENERGY TO STORAGE THROUGH LOWER VALVE (WATT.HR)
7) ENERGY TO STORAGE (5+6) (WATT.HR)
8) ENERGY FROM STORAGE TO USER (WATT.HR)
9) HOURLY INCREASE IN STORED ENERGY (WATT.HR)
10) STORAGE HEAT LOSS (7-8-9) (WATT.HR)
11) HOURLY INTEGRATED COLLECTOR EFFECIENCY (3/1)
12) PERCENTAGE OF TIME DURING WHICH AUXILIARY BOILER WAS ON

A) DAILY EFF. OF SOLAR COLLECTOR STORAGE SYSTEM = .21

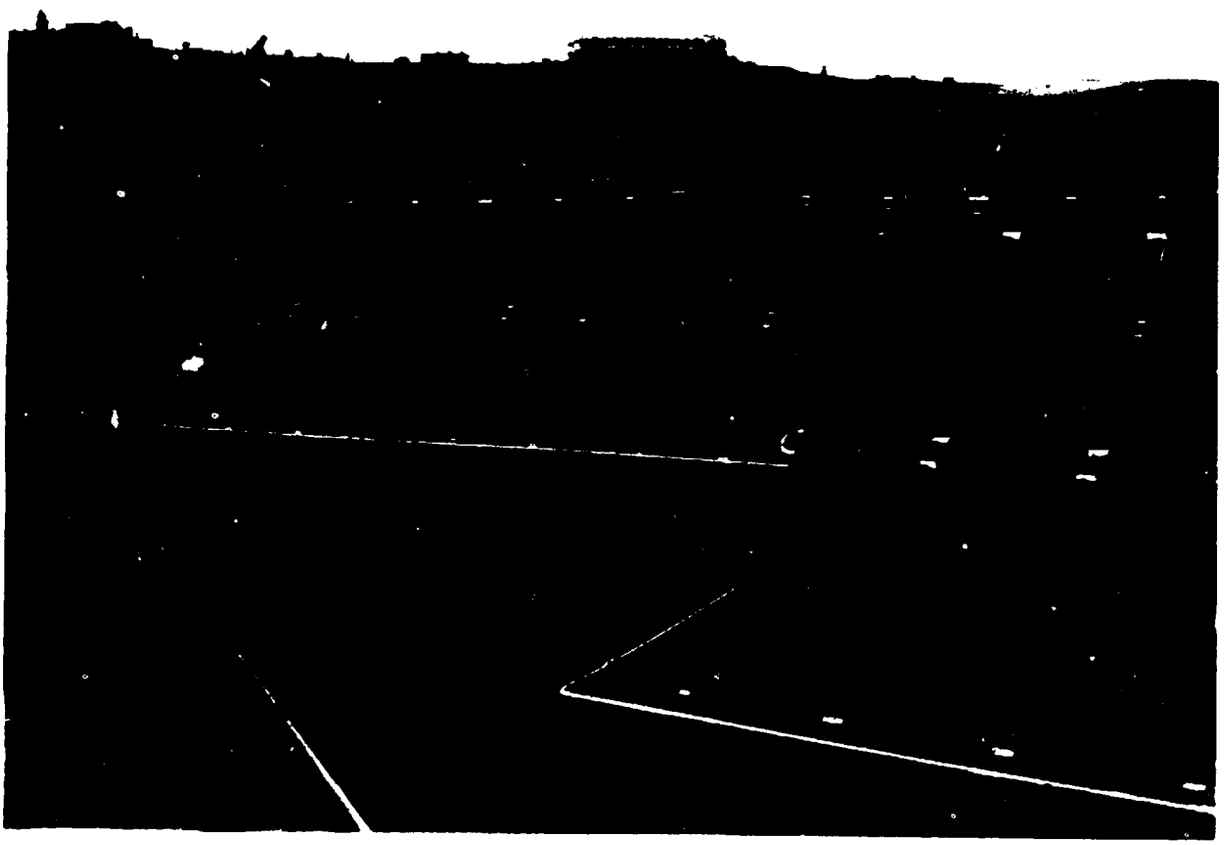
B) DAILY EFF. OF STORAGE TANK = .82

C) DAILY SOLAR RADIATION (WATT.HR) = 1169777

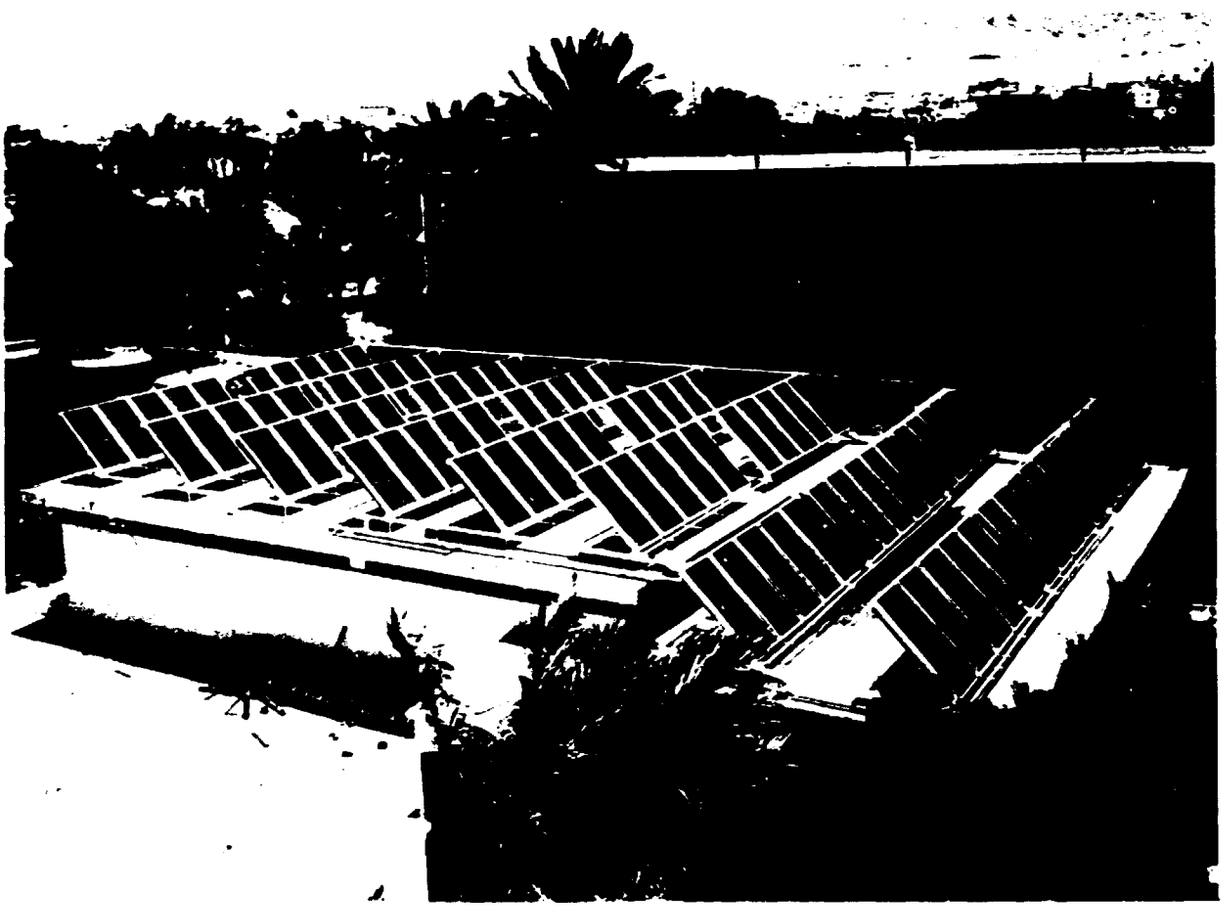
D) DAILY COLLECTED ENERGY (WATT.HR) = 380610

APPENDIX - 4

External view of solar array arrangements



JORDAN DAIRY COMPANY SWH SYSTEM



CORAL BEACH HOTEL SWH SYSTEM