## OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

## DISCLAIMER



## FAIR USE POLICY



## CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

Distr.
RESTRICTED

IO/R.47
17 November 1987

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

# MANUFACTURING OF SOLAR WATER HEATER FOR INDUSTRIAL APPLICATIONS

TF/JOR/82/001

JORDAN

## Technical report: Manufacturing and installation of solar hot water system for Coral Beach Hotel in Aqaba*

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

Based on the work of Messrs. Kabariti and Touqan**

Backstopping officer: H. Seidel, Engineering Industries Branch

---

* This document has been reproduced without formal editing.

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

V.87 91778

# TABLE OF CONTENTS

## EXECUTIVE SUMMARY

This is to report the activities carried out in fullfillment of the requirements of the second part of the project "Manufacturing of Solar Water Heater for Industrial Applications". The activities reported which is related to the system at the Coral Beach Hotel in Aqaba are the manufacturing, installation of the system and its associate measurement instrumentation and control.

The activities reported in this report were based on the system design reported by Dr. S. V. Szokolay in January 1987.

## 1. INTRODUCTION

This report includes a description of the installation of the second large solar water heating system where it was conducted at the CORAL BEACH HOTEL IN AQABA, JORDAN. The system is to provide hot water for domestic use of the hotel rooms, kitchen, and laundry.

This work is a second part of the project "MANUFACTURING OF SOLAR WATER HEATER FOR INDUSTRIAL APPLICATIONS", being executed at the Royal Scientific Society (RSS) in Amman - Jordan, with all equipment and materials funded by the UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO).

The Coral Beach Hotel is located at the sea side in Aqaba, south of Jordan. It has 95 rooms, it is low-rise (3-storey) building. It has a boiler that uses 4900 liters of deisel oil per month to produce the needed hot water for hotel uses.

The Coral Beach Hotel was chosen for many reasons:

- Its location in one of the hotest areas in Jordan.
- A reasonable quantity of oil is used for water heating, therefore a significant oil saving could be acheived by installing the solar system.

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

The solar water heater system will be a preheater to the existing boiler system, where a thermostat controls the temperature of hot water inside the existing cylinder which is connected to the boiler through a heat exchanger. The solar system is to provide the hot water from the storage tank (6 $m^3$) to the hotel hot water cylinder (also 6 $m^3$) at a temperature quality of more than 50 °C, otherwise the boiler will operate until reaching that temperature which could only occur in the early mornings and in winter time.

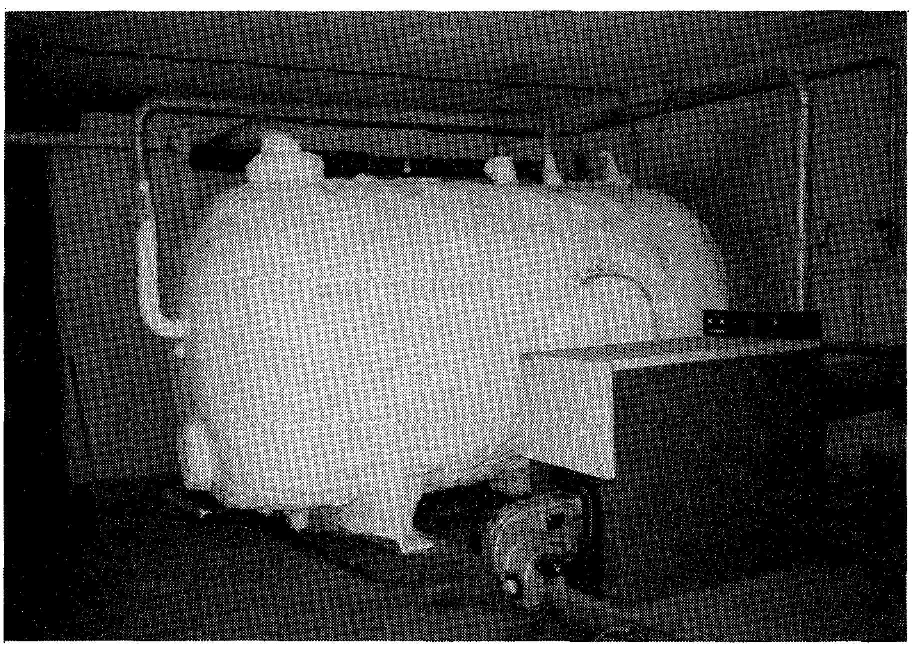
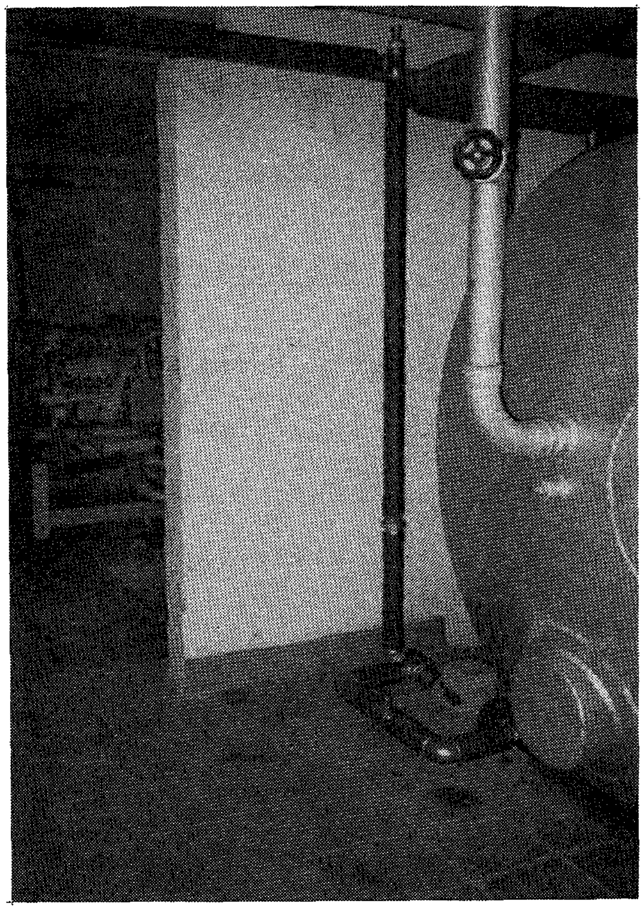


Fig (1.1): Photograph of the Hotel's boiler and hot water cylinder.

Fig (1.2): Photograph showing the solar hot water line connected to Hotel's hot water cylinder.



## 2. PREPERATION AND FABRICATION

### 2.1 Preperation

According to the design which was performed and reported, a quantity survey was carried out to determine the materials needed. The required collecting area was determined to be 180 $m^2$; i.e. 90 new design RSS flat plate collectors (2 $m^2$ each) in order to supply the required amount of hot water; and a storage tank size of 6 $m^3$ was required to keep water at the acceptable temperature taking into consideration the available 6 $m^3$ cylinder, so that the total storage volume is 12 $m^3$.

## 2.2 Fabrication

Fabrication of collectors, Racks, and storage tank was carried out at the mechanical engineering workshop of the Royal Scientific Society as follows:

### 2.2.1 Flat plate collectors:

- Cover: Normal 4 mm glass has been used. In addition, and to protect glass from breakage and to enclose the collector tightly against air and rain, rubber seals between glass and case have been used.

- Case : The case was made of Aluminum frame to form the sides, with the bottom made of 0.7 mm galvanized sheet iron (see fig 2.2).

- Risers, headers, and absorber plate: Risers and headers were made of galvanized seam welded pipes with a diameter of 1/2" and 1" respectively, while the absorber plates were made of 0.9 mm black sheet iron metal.

- Insulation: Fiberglass (rolls) were used to insulate the bottom and sides of the case to decrease amount of heat losses.
- Paint: Simple black paint was applied to treat absorber plates and risers.

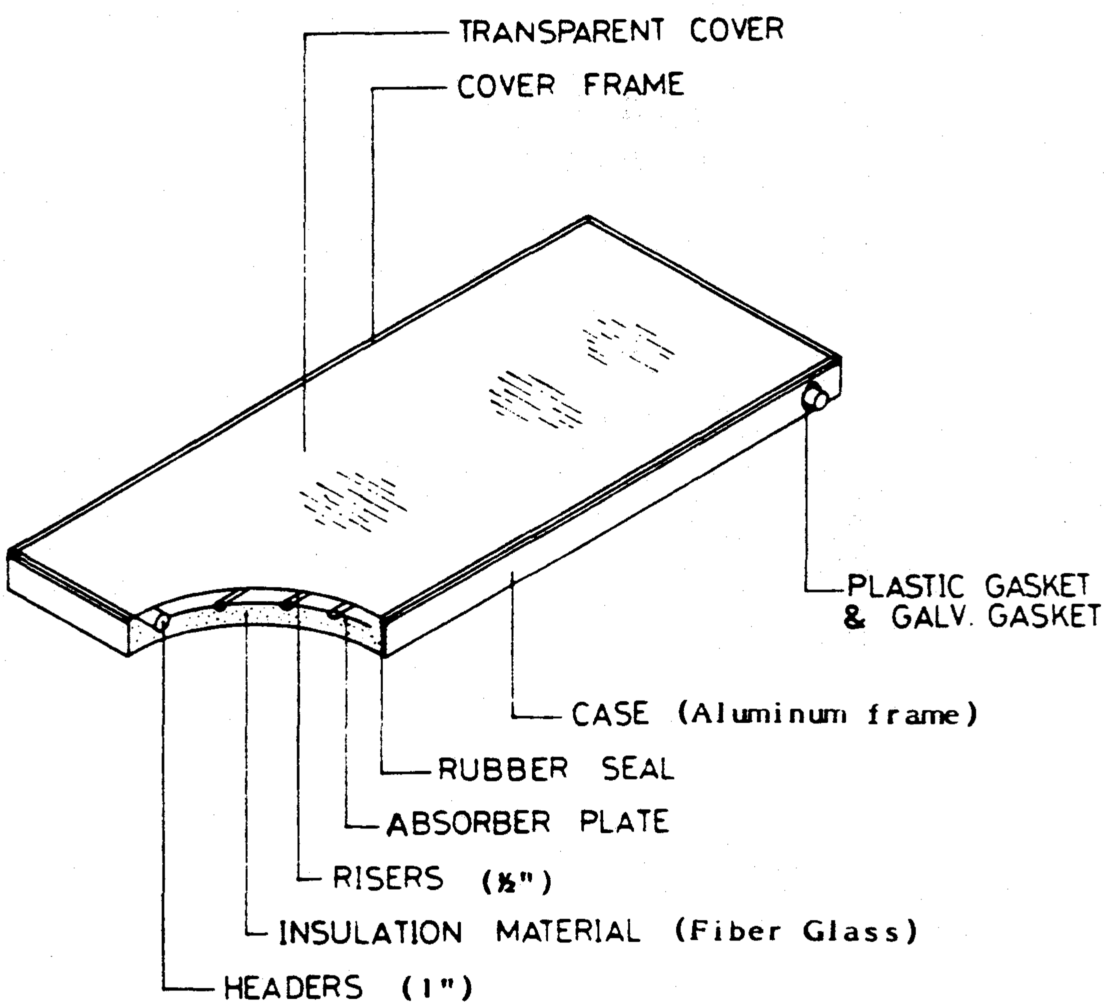



Fig. (2.1): Schematic diagram of a new design RSS collector (2 $m^2$).

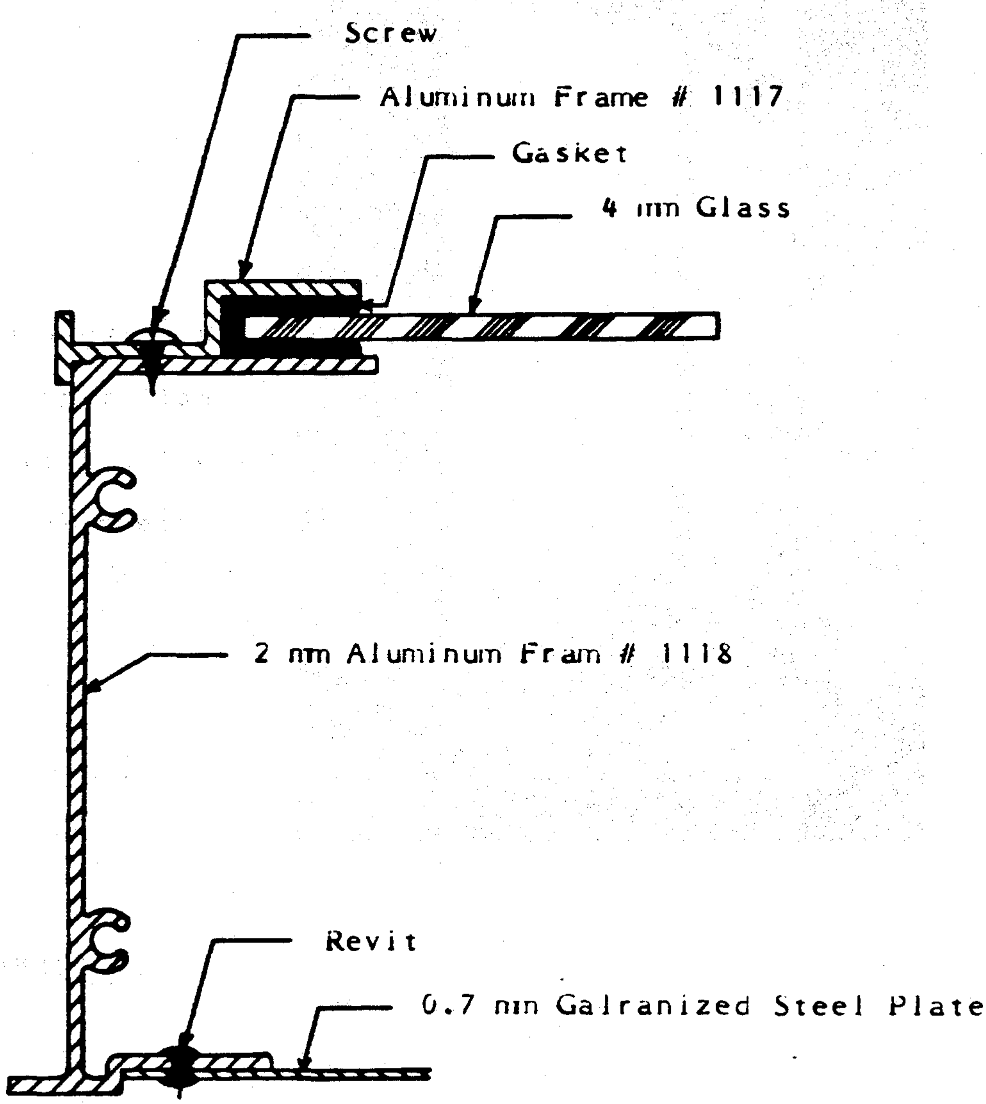



Fig. (2.2): Schematic diagram showing the aluminum frame used to form the sides of the collector.

2.2.2 Racks: Racks were made of 45 x 45 x 3 mm iron angle. They had a 45° tilt angle. The racks were all painted with silver protection paint. The racks were fabricated in a way to be welded on site, so that each rack will hold 5 collectors.

2.2.3 Storage tank: The 6 $m^3$ cylindrical storage tank of 3 mm thickness was made of galvanized sheet metal. Rolled sheets were arc welded to form the sleeve of the tank. The top and bottom of the tank are of the concave type so as to give more rigidity to the tank; stiffeners were welded inside the tank for the same purpose. Internally threaded nipples were welded on the sides bottom and top of the tank. A manhole was put on the side of the tank to allow serviceability. Three legs at the bottom of the tank were provided for stability and the desired spacing for insulation. The tank height was 3.0 meters while it's diameter was 1.6 meter.

## 3. INSTALLATION

All material were hand lifted and transported by trucks to site. The collectors and racks were hand lifted to the roof of installation where each collector (weights about 70 kg) needs 4 men to lift it. The installation of all system parts took place as follows:

3.1 Racks: All racks were welded on site. Racks were directed towards the south and were split into 18 sets, so that each set would hold 5 collectors. The places of welding were all repaintbed again with silver paint.

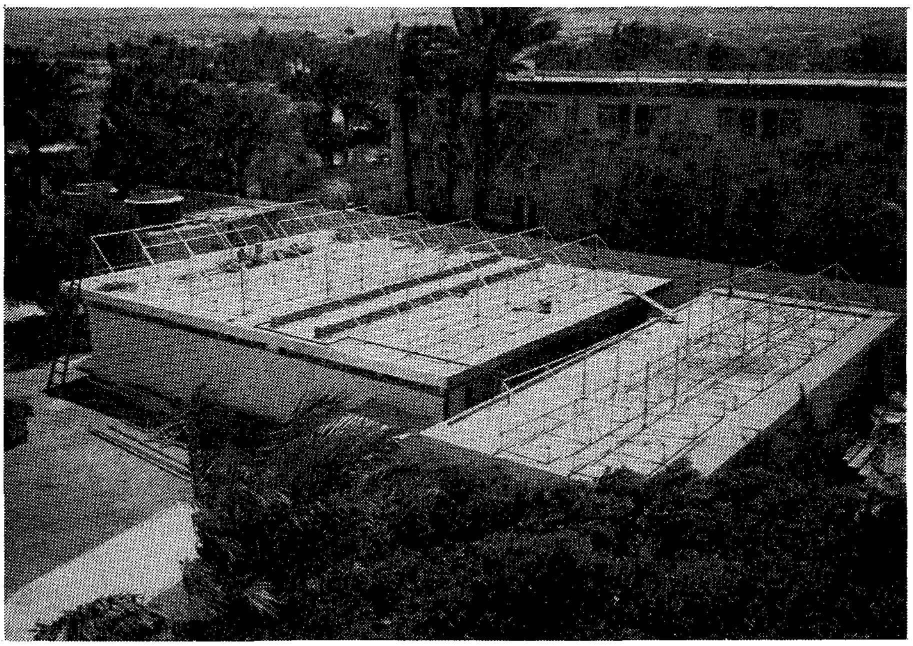


Fig (3.1): Photograph of racks after welding and putting in place.

3.2 Collector array: The collectors were mounted in 8 rows facing south. The basic unit consists of 5 panels. Each of the first two rows consists of 3 units (15 collectors) while each of the other six rows consists of 2 units (10 collectors). Every two of these units share the inlet and outlet connection.

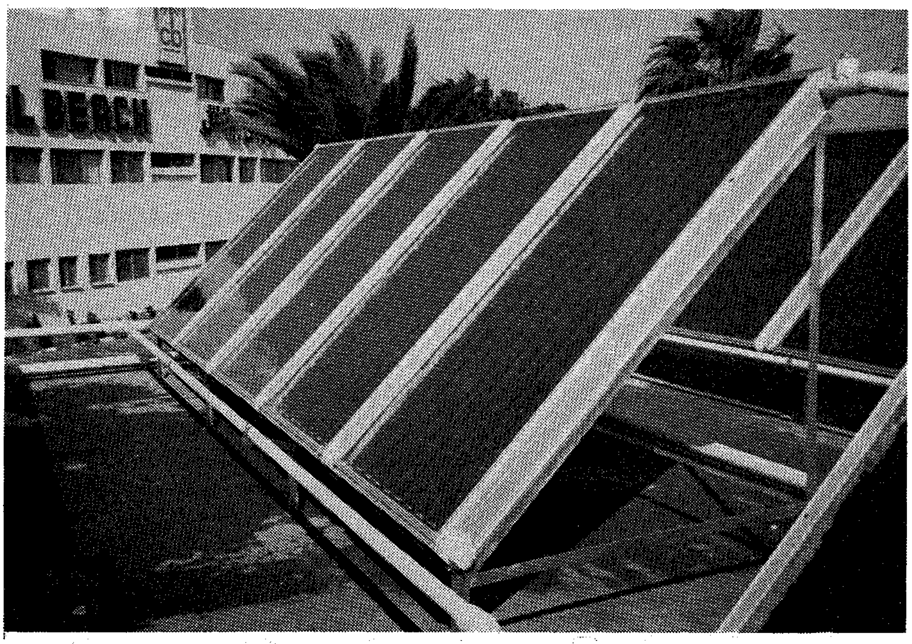



Fig (3.2): Photograph showing the basic unit consisting of 5 collectors.

Fig (3.3): Photograph showing the connection operation of each 5 collectors.

Given the latitude of Aqaba at 29 deg N; the collector set had been tilted at an angle of latitude + 15 deg which gives approximately 45 deg which is better for winter utilization of the system, when the sun is in its lowest positions.

Fig (3.4): A general view of the collector array.

Outlets of all sets of collectors drop into one line in which water goes to the storage tank through 4 selenoid valves (two are normally open which goes to the pumps and two are normally closed which goes to top and mid. inlets of storage tank) which operates depending on temperature difference; or back through 4 pumps (each 2 in series) to the collectors again. An automatic air vents were installed at the outlet of each basic unit and at each drop point to prevent air block in the system.

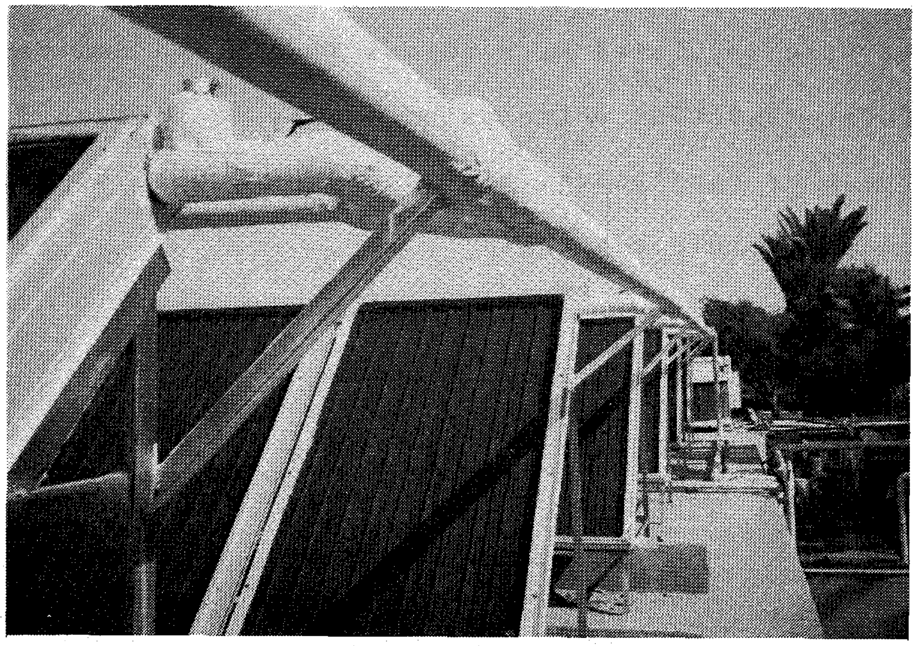


Fig (3.5): Photograph showing the outlet pipe from each row connected to the main header.

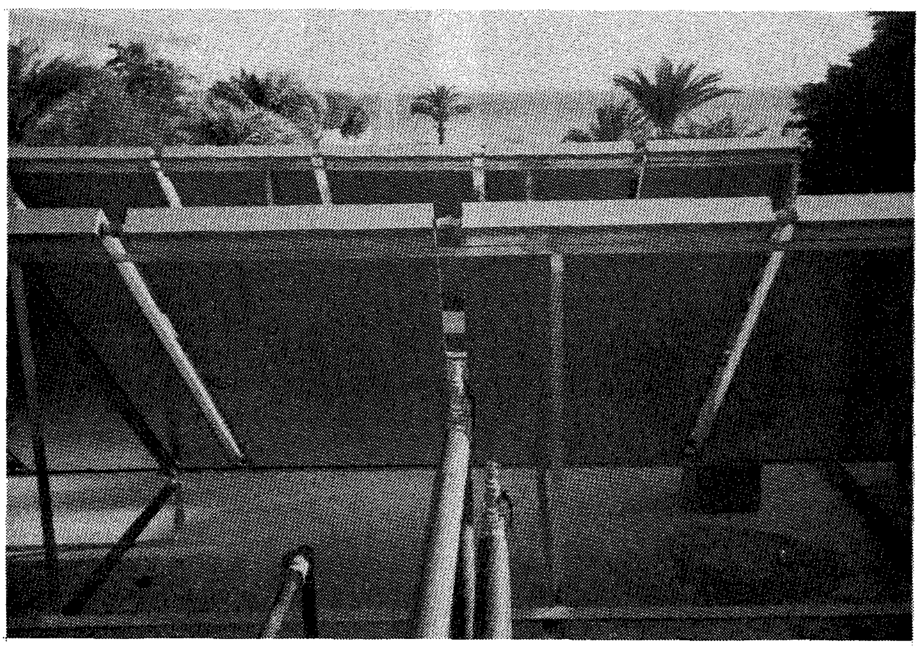


Fig (3.6): Photograph showing the automatic air vents at drop points.

All pipes were insulated with climax insulation and painted by ultra-violet resistant white paint, so as to protect it from adverse weather conditions. The pipes were also supported to prevent any possible bending.

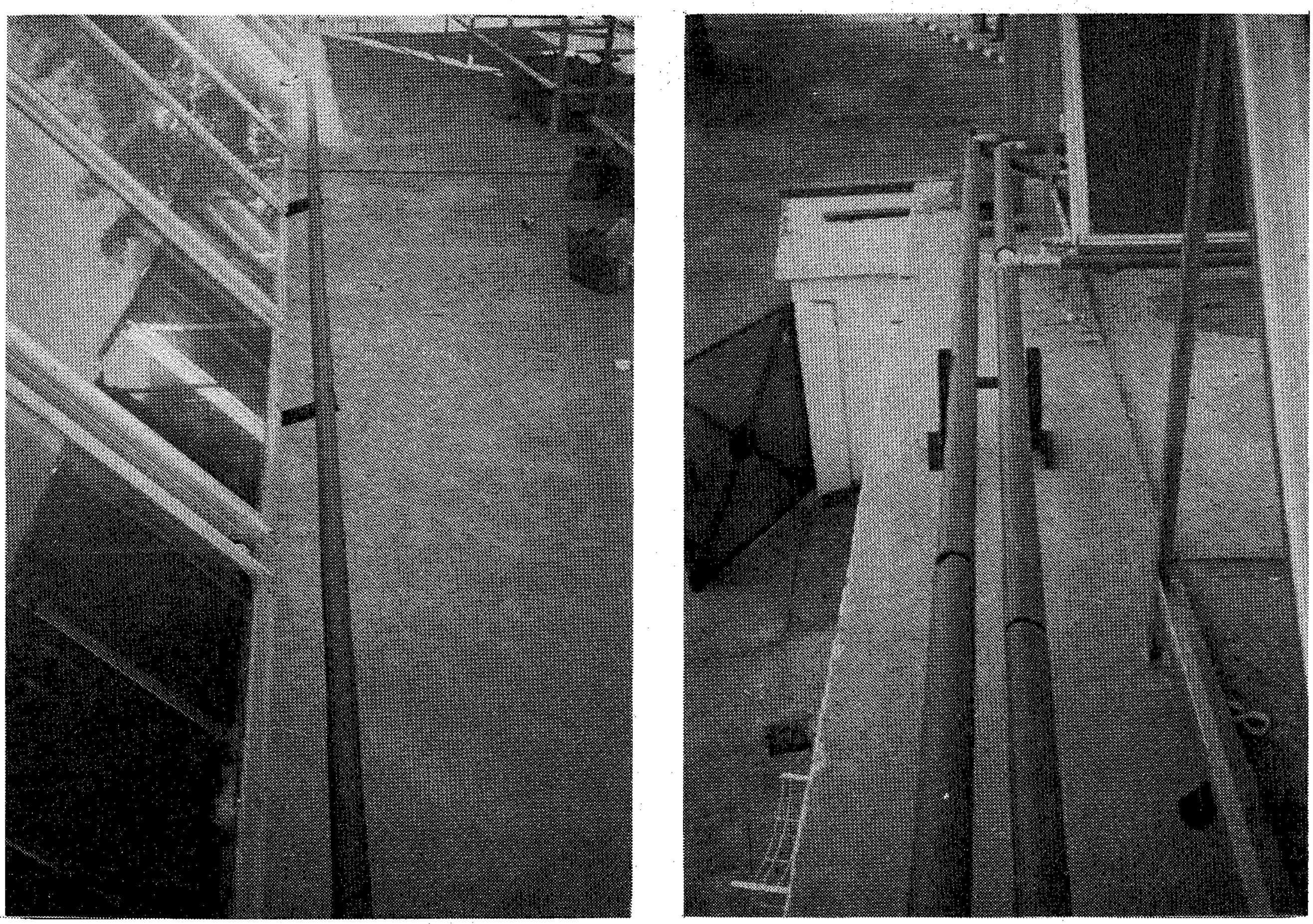


Fig (3.7): Photographs showing the supports of the pipes.

### 3.3 Storage tank

The 6 $m^3$ storage tank which has a cylindrical shape was installed near the boiler room vertically to acheive a better temperature stratification. To prevent overnight cooling, the tank was insulated with 100 mm of polyurethane. The thermocouples for temperature measuring of storage tank wall temperatures were all put in places before insulation took place. The cold water supply to the storage tank comes from tanks at the roof the hotels (about 10 meters high).

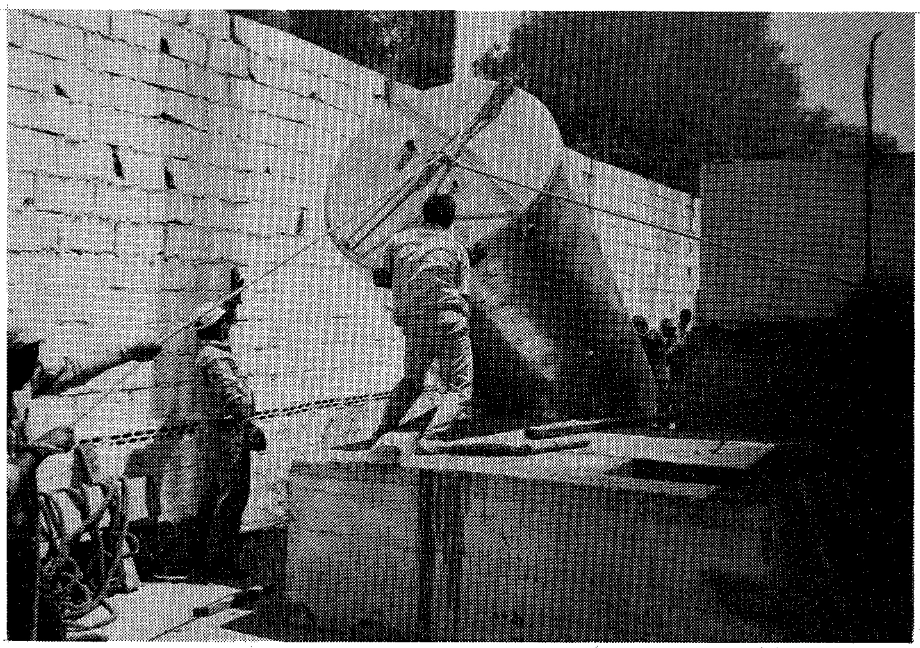


Fig (3.8): Photograph showing the operation of putting the storage in its place.

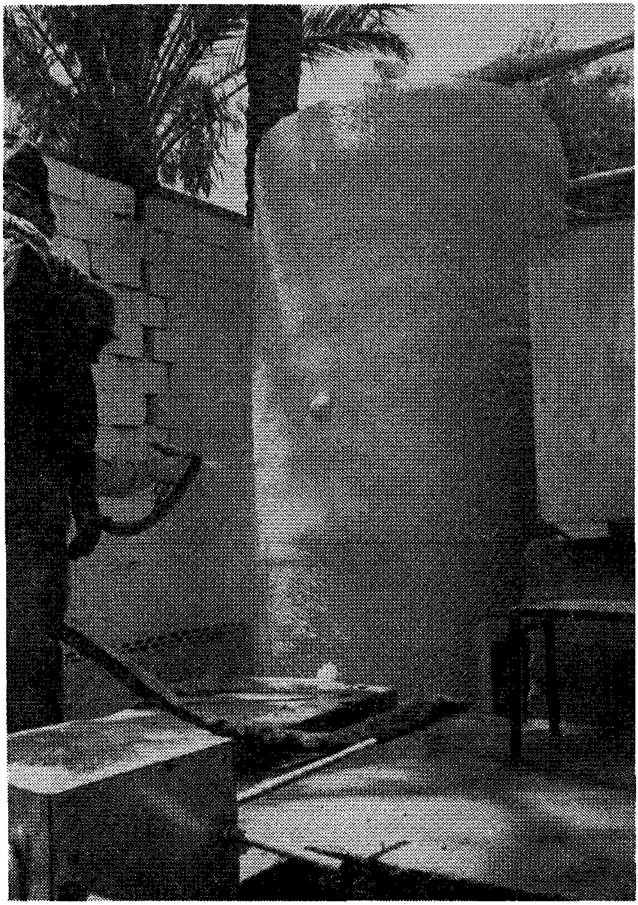


Fig (3.9): Photograph showing the storage tank during insulation.

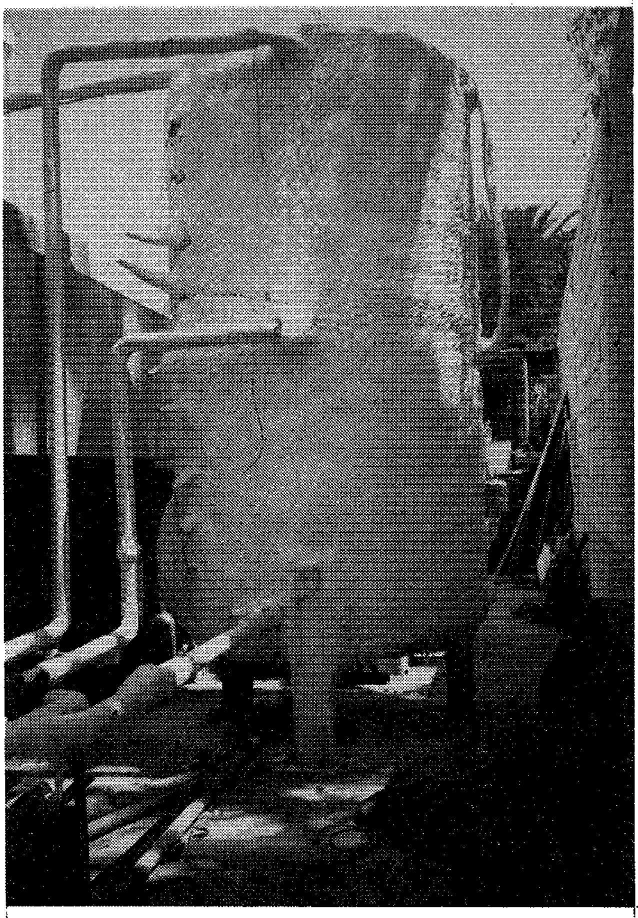


Fig (3.10): Photograph of the insulated storage tank with the mid. and upper inlets.

## 4. SYSTEM OPERATION

The water coming from the collector array may enter the storage tank through the top inlet or the mid inlet, if it is sufficiently warmer than water at the corresponding level of the tank. Four seleniod valves (two normally open and two normally closed) were installed to control the top and mid. entering of water to storage according to the temperature difference. Two ports exist at the bottom level of the tank, one is the outlet to the collector loop and the other is the inlet of supply cold water. Water flowing to the cylinder in the boiler room is discharged through the outlet located at the top of the storage tank.

Four pumps (each two in series) were installed to circulate the water through the collector loop, which operates according to the temperature difference between the inlet and outlet of the collectors.

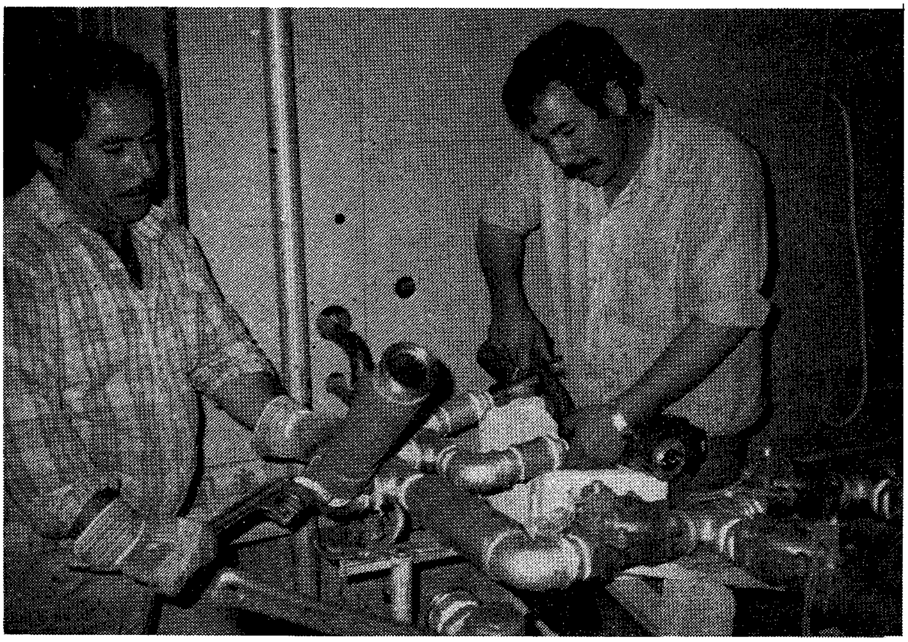


Fig (4.1): Photograph showing the installation of the pumps and valves.

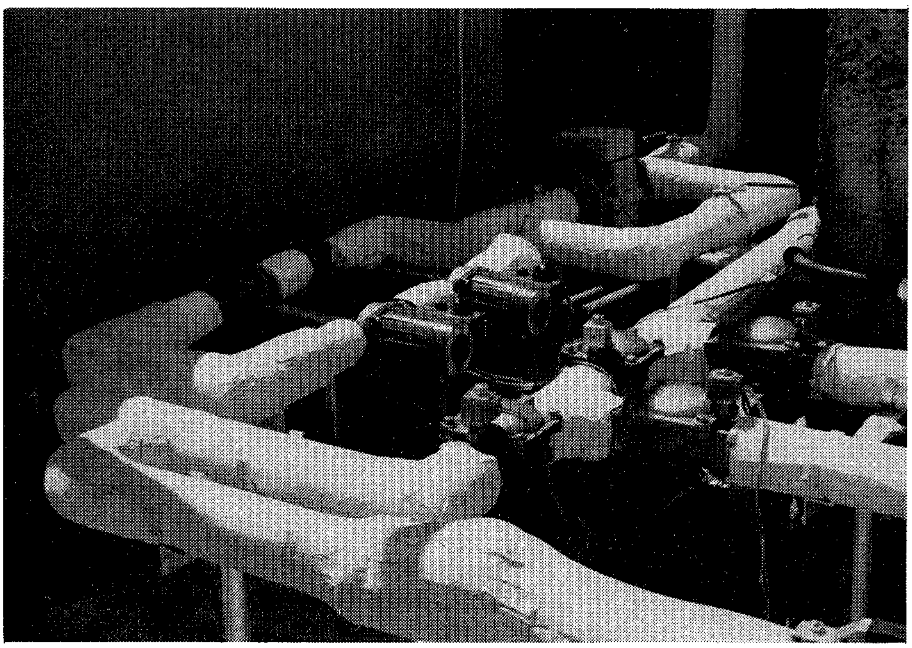


Fig (4.2): Photograph showing the four pumps, four selenoid valves, and collector loop flowmeter.

## 5. INSTRUMENTATION AND CONTROL

A magnatic flowmeter was installed after the pumps to measure the water flowrate through the collector loop, while another flowmetere was installed on the water pipe going from the top of the storage tank to the boiler's cylinder to measure the hotel consumption of hot water from which we could calculate the energy given to the hotel from the solar system.

Two solarimeters with and without a shielding ring are used to measure the diffuse and total radiation. They are held to their bases by screws, and the two bases which are made of angle iron are welded to the collector rack.

Fig (4.3): Photograph of the two solarimeters.

A board hanging on the wall of a room beneath the roof has 3 differential temperature thermostats (delta - T) fixed to it. Those are to control the operation of the selenoid valves and the pumps. Each two selenoid valves (one normally open and one normally closed) are electrically connected together so that if one is closed the other is open and visa versa. The location of their sensors are as follows: (see Figure 4.4).

for the pumps: temperature difference is between the surface of the piping of the main outlet header (collector out), and the surface of piping immediately after the pumps (collectors inlet).

for the two selenoid valves of the upper inlet: temperature difference is between the top level of water inside the storage tank, and the surface of piping immediately before the valves.

For the two selenoid valves of the mid inlet:- temperature difference is between the mid level of water inside the storage tank, and the surface of piping immediately before the valves.

The board has also a watt meter to measure the system parasitic consumption of electricity. It is also possible to override the delta-T's and turn on the pumps together or individually and the valves by pressing the appropriate switch(es).

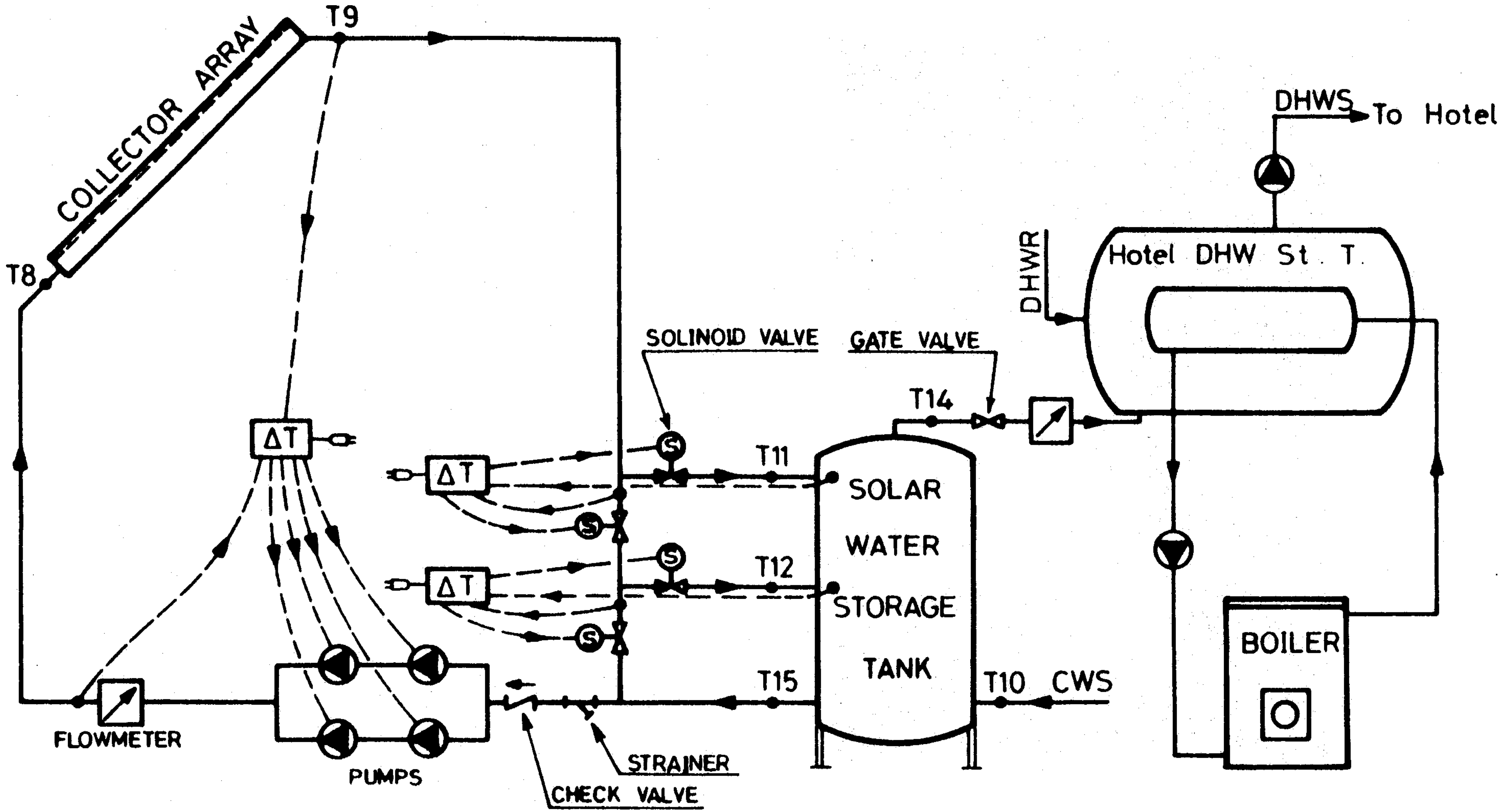
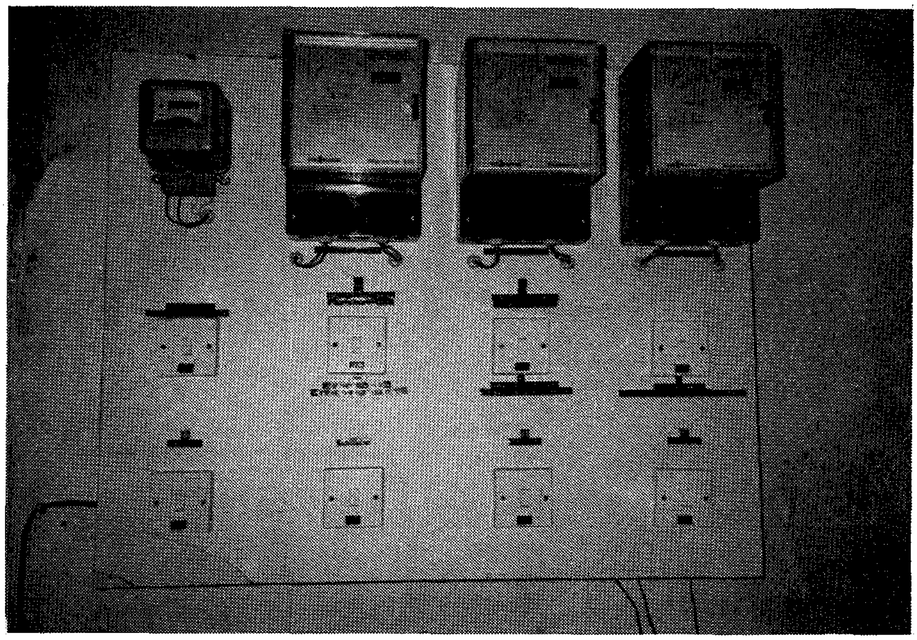



Fig. (4.4): Schematic diagram of the system showing the location of the sensors.



Fig(4.5): photograph of the control board showing the temperature differential controllers, Watt-meter, and electrical switches.

Four small AC/DC transformers whose output voltages are about 5 volts were installed. Three of them were connected to the delta-T's, in order to record through a computer programme the pumps and the valves are on or off. The fourth transformer was connected to the boiler to record through the computer programme the operational time of the boiler. A data acquisition unit is used to record the various readings for the voltage of the thermocouples, the two solarimeters, the two flowmeters and the four small transformers.

## 5.1 THERMOCOUPLES

Copper/constantan thermocouples (17 thermocouples) were connected to measure the temperature at different parts of system. Nine of them are fixed to the cylindrical wall of the storage tank by special welded joints, which are uniformly spaced on a vertical line to measure the temperature variation of water inside the tank in the vertical direction. Two thermocouples are at the collector loop inlet and outlet.

One thermocouple is housed on a well ventilated white wooden box to measure the ambient temperature. The final five thermocouples are at the 3 inlets and 2 outlets of the storage tank.

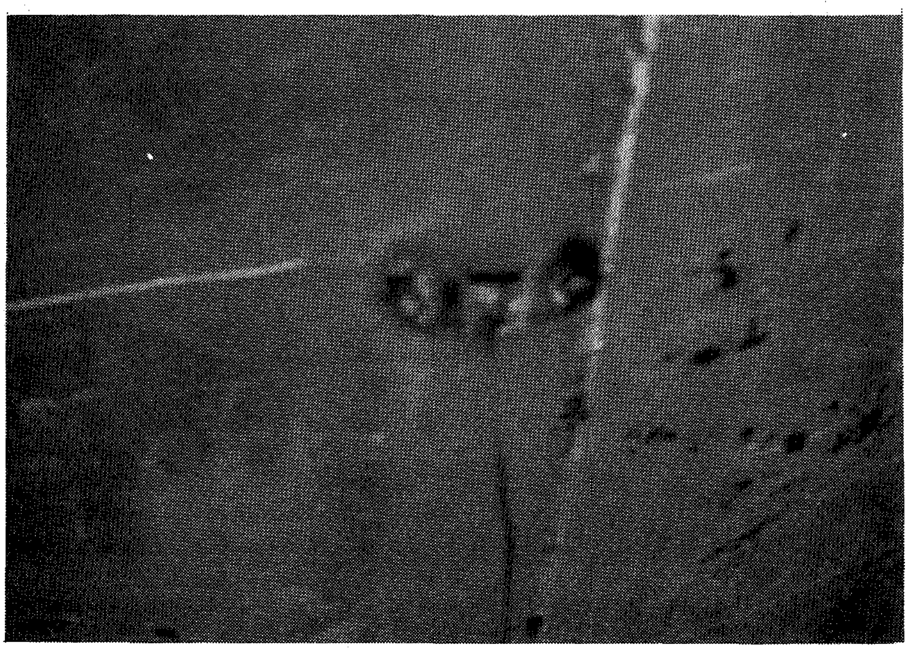


Fig (5.1): Photograph showing the connection of a thermocouple to storage tank wall.

Flexible plastic rigid conduits were used to house the thermocouples, signal wires and cables.

All thermocouples and output wires from flowmeters and transformers are connected to a data acquisition where the readings are taken through a computer software and changed into appropriate units (Temperatures in deg C, and flowrates in liters per minute) and then it is stored in discs to be evaluated later.

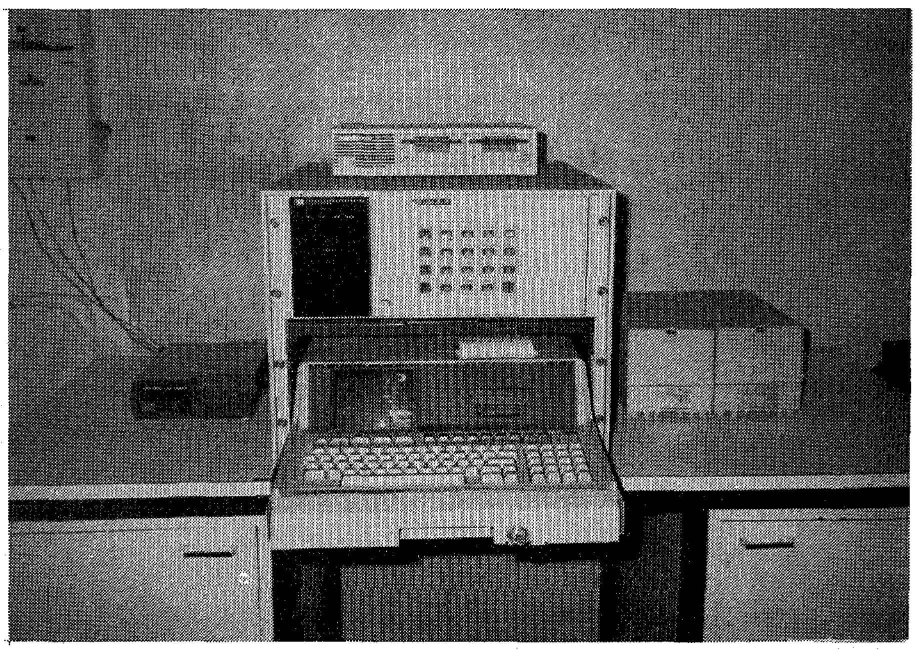


Fig (5.2): Photograph of the data acquistion unit, disc drive, and computer used for data collection to determine system performance.

A test is now conducted on the system, as well as some visits to the hotel so as to check systems operation.

The aim of the data recording and evaluation is to determine the performance of the system, where in order to achieve this aim, different parameters are measured and recorded which includes the following:

- Temperature at different locations on wall of storage tank.
- Temperature difference accross the collector loop.
- Temperature of cold supply water.
- Water flow rate in collector loop and pipe feeding the hotel's cylinder.
- Global and diffuse radiation.
- Ambient temperature.

All previous measured parameters are used in appropriate energy equations to check system effeciency.

## 6. PROBLEMS FACED

The installation of the system took place in a short time and according to work schedule, whereas all the experience gained from the first pilot plant at the Jordan Dairy Company has it's effect in improving the way of work, time spent , and avoiding all problems that occurs before.

Taking in-to our minds that this is a large system, some small problems occured during and after installation which are:

- The pumps were not working properly at first which may be due to storing them for a long time, but afterwords and since installation, they are operating in a good way.
- The sight-glass of the pumps were all broken and resulting in water leakage from the four pumps, this occurs due to high temp. reached (more than 90) where the pumps are domestic hot water circulators, so the glass was changed into plastic gaskets which prevents all the water leakage and resist high temperatures.

- The selenoid valves ( normally closed) were not operating due to damage in the membrane that opens and closes inside the valve where it was changed, and the valves were again operating.

- The thermocouples connection from storage and other places to the data-acquisition was a little hard to do, but it was executed in a good way where all the readings checked were reasonable.

- One collector glass was broken after two weeks of operation which may be due to certain stresses, and it was changed.

- The piping system was filled with water and tested three days before complete insulation where all leak points were retightened again.

## 7. CONCLUSIONS:

The SWH system installed for the hotel is expected to show higher effeciency than that installed at the dairy company, which may be due to higher consumption of hot water which allows for more energy collection which means higher effeciency. Also because the solar system is a preheater to the existing system which allows for complete utilization of the solar system not only in summar, but also in winter.

It was noted from the first two weeks of operation that the consumption is during all hours from early morning until midnight (about 21 hours daily) and the control valves open because of the temperature difference between the collectors outlet water and water inside the storage tank while the pumps are off (which means valves are off), so the temperature differential controller of the pumps was set to operate the pumps at small temperature diffence ($\Delta T$ = 5 °C) so that when any of the valves is open, the pumps are on to circulate the water, which means that cold water would come out from the bottom of the tank to the collector loop, and this means more energy collection and higher effeciency.

Another report concerning system evaluation which includes a listing of some of the data obtained will follow later.