TECHNICAL AND ECONOMICAL VALUATION ON THE COUPLING OF A LOW TEMPERATURE MULTIPLE EFFECT (LTME) PLANT TO SOLAR COLLECTOR SYSTEMS

Messrs. GASPARINI, GIUFFRIDA, ZANELLI, MIGLIORINI AND FRANZOSI
S.p.A. TERMOMECCANICA ITALIANA - ANSALDO S.p.A. - S. GIORGIO PRA -
ITALIMPIANTI S.p.A. - CESEN

ABSTRACT

Two solar conversion systems have been considered for supplying thermal energy to a LTME (Low Temperature Multiple Effect) desalination unit having a nominal capacity of 30 cu.mt/day:

1. Heat from heated water using flat-plate collectors
2. Low level enthalpic heat taken from the cooling down of photovoltaic cells for the production of electrical energy

Valuations have been made on each of the foregoing systems in terms of plant reliability, energy saving and economical conveniences.

INTRODUCTION

The economical crisis, caused by the ever decreasing oil reserve and its continuous increase in price, has recently stimulated a considerable interest in the alternative sources of energy.

At the moment the most well known exploitations do not meet with a vast market due to the high production costs involved. It is therefore necessary to make a research on the technologies and applications which will allow for these energy sources to be used at a more convenient cost.

Our research is fundementally based on finding the possibility of a feasible and economical application of solar energy for producing distilled water and if possible, electrical energy. The application would be particularly advantageous for small isolated communities, in hot climates, where there is intensive solar radiation and where water is often scarce.

SOLAR ENERGY

This source of energy is very advantageous; first of all its workin cost is very low, if not any at all, it is a renewable energy and lastly it is an ecological energy which does not cause pollution or damage to the surroundings. Naturally, like all alternative energy sources, solar energy has its disadvantages, like for instance the great dilution, for which considerable extensions are needed for colle ting a notable amount of energy. Another disadvantage is that of the changeableness with which solar energy is available: the availability varies with the latitude, season and in the various hours during the day, for which we require either a great amount of heat or an integrating system partially fed with traditional power and in any case highl flexibility plants.

The efficiency of the solar conversion plates increases when the average temperature of the fluid to be heated is low.

Maintaining a good efficiency means using less conversion surfaces and therefore less investment costs. We therefore have thought of using desalting units working with high performances at relatively low temperatures.

The desalting units of this type may also use low temperature heat obtained from electrical solar plants. These solar plants are nowadays still not used very often because of the low conversion efficienc at high temperatures which involve high investment costs.

The thermal salvage for producing distilled water may increase the total efficiency of the system and also make the electrical energy, produced by the sun, competitive, under particular climate conditions.

MULTI-EFFECT DESALTING PLANTS

There is on the market today the expanding production of the multi-effect type desalting units which are fed with steam at 75°C, and with only nine stages we may have, by means of vapour compression and recirculation on the first stage of the exhausted steam, an economy ratio more than 9 kgs of steam/kg of distilled water produced.

A desalting plant which operates at low temperature brings considerable advantage, both from the investment costs and operating point of view and also as far as the maintenance costs are concerned:

a) The pipe bundle and tube plates may be made in low cost magnesium-aluminium alloy, giving therefore a considerable reduction in the investment costs.

b) With the low temperatures, keeping the brine salinity below 7%, the precipitation of the sulphates is avoided and also that of the carbonates is decreased, with consequent low maintenance costs.

c) The sulphuric dosage may be removed thus allowing for an easy, less dangerous and less expensive operation.

d) The shell and inside parts built in carbon steel may be coated with epoxy paints resistant to the distillate and hot brine up to the temperature of 80-100°C. This gives the plant a longer life and therefore longer amortization periods.

e) The connecting piping may be in polypropylene, plastic material which does not alter itself in any way at working conditions and which is highly corrosion proof against both sea and distilled water.

Description of the desalting unit

The desalting unit in question produces 30 cu.mt/day of distilled water. This amount is sufficient for the demand required for isolated communities of up to 300-750 persons, depending on the average tenor of life, and which also represents, using the integrate solar system, a competitive solution, if compared to today's costs for the distilled water produced by traditional methods.

- Type	Horizontal tubes
- Design capacity	30 cu.mt/day
- Number of stages	9 (+ condenser)
- Performance ratio	8 kg distillate/kg of steam
- Specific heat consumption	318 KJ/kg
- Max brine temperature	55°C

The plant, in order to operate under full load, needs 95.000 Kcal/hr for preheating 21,6 cu.mt/hr of water from 57,1°C to 61,5°C. The fluid is then sent along to a flash chamber where the steam needed for plant operation is produced (fig.9).

SOLAR CONVERSION SYSTEMS

A desalting unit of this type may be coupled to any type of solar conversion system which produces low temperature heat. In particular we have considered in this study single purpose systems where the heat is partially supplied by solar flat-plates and double purpose plants for the contemporaneous production of electric power and water.

In the latter case, we thought of adopting a photovoltaic cell type solar electric plant using low thermal level heat content recuperated from the cooling of the cells. The desalting unit may, however, conveniently use the heat coming from low temperature condensation of fluids coming from a solar electric plant with collectors of the parabolic-cylinder type.

The dimensioning of the plant was made having taken into account of the installation being carried out in an area having a high grade of insolation and with the necessity of water, like for instance the Arabic peninsula . The main insolation features are referred to 20° parallel north.

In order to limit the solar conversion system from excessively encumbering on the costs of investment, we considered that solar heat would contribute and reduce the consumption of the plant's fuel of 35-45%. In this way the solar plant would always supply a less amount of heat to that required by the desalting plant, even on hotter days: thus expensive heat collecting systems may be avoided.

FLAT-PLATES

Let us now examine a heat-producing system of the Zenasol flat-plate collector type.

These plates are now being manufactured in two versions: the normal series and the selective series, especially suitable for unfavourable insolation conditions, like for instance hazy sun and low day temperatures. The selective type is also conveniently adoptable for reaching high temperatures (80-100°C).

The flat-plates have a sturdy structure in extruded aluminium-alloy bars having a minimum thickness of 2,5 mm for the fluid circulating channels. The covering of the absorbing plate is in 5 mm thick semi-tempered crystal; the outside casing is waterproof and made in anodized aluminium. The entire group is designed and built for a minimum period of 15 to 20 years.

As far as the efficiency is concerned, the Zenasol collector is equipped with a special corrugated profile with a surface which guarantees a considerably higher conversion than that of the other collectors on the market, besides having a back and side insulation in 70 mm thick glass wool padding for reducing thermal dispersion towards the outside (fig.1).

The efficiency of the flat-plates in the considered climate conditions (average insolation intensity: 700 W/m^2, daily mean temperature 35°C) is an average of 67% and 74% respectively for normal and selective collectors (fig.2).

By using 266 m^2 of normal Zenasol flat-plates, 700.000 Kcal/day to 1.000.000 Kcal/day of thermal energy may be recuperated in the span of a year. This means an annual output of about 300.000.000 Kcal equal to 40% of the thermal consumptions of the desalting unit.

The cost of the solar flat-plates is at the moment 160$/$m^2$, for which we have:

<u>Investment Costs</u>

Collectors	$ 42.600
Auxiliary systems (1) and instruments	$ 12.300
Civil works and assembly	$ 7.600
Total investments	$ 62.500

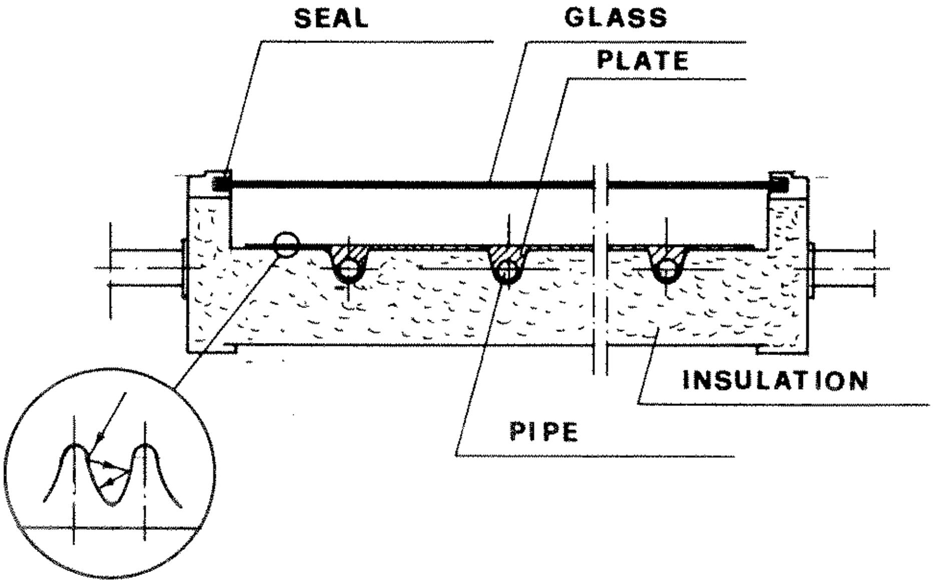

FIG. 1 – FLAT PLATE SECTION

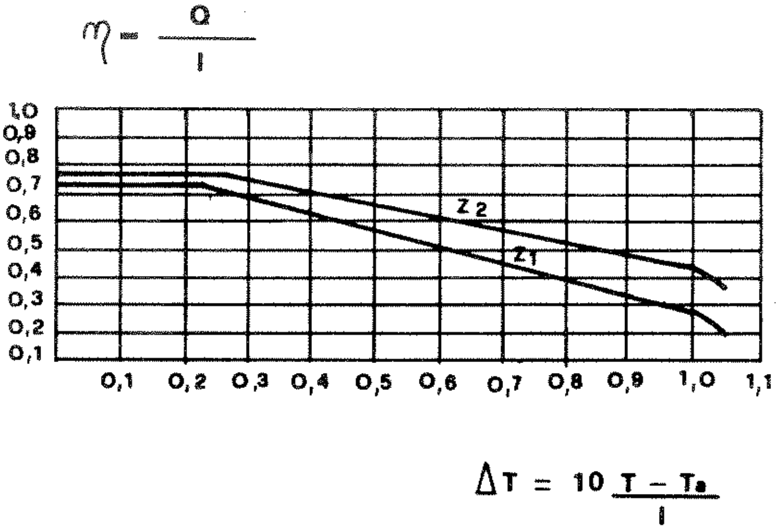

FIG. 2 – EFFICIENCY CURVES OF SOLAR FLAT PLATES

(Calculated from EURATOM research center – ISPRA – following reccomandation of NATIONAL BUREAU OF STANDARDS)

Z1	Normal surface	I	Solar flux density W/m^2
Z2	Selective surface	T	Plate average temperature
Q	Recovered energy W/m^2	Ta	Ambient temperature

Power Savings

Fuel oil (2) 36.800 Kg/year

Free from the electrical energy consumption of the recirculating pump, up to 32.000 kg/year of fuel oil may be saved.

PARABOLIC PHOTOVOLTAIC CELL CONCENTRATORS

The concentrator system consists of parabolic-cylinder collectors, in the focus of which we have the photovoltaic receiver formed up of a certain number of photovoltaic cells electrically connected and cooled by the recirculating water. Figure 3 shows a carrousel of parabolic concentrators, basic unit of the solar plant, with $48 m^2$ of converting surface.

The cooling fluid, in this case recirculated water, is flown along inside the dissipator on which the photovoltaic cells are located. In figure 4 we have illustrated the section of two types of dissipators.

For the particular type of movement used (2 axes alt-azimuthal), the energy absorbed by the collectors corresponds to the insolation curve given in figures 5 and 6.

Thermal balance for a carrousel of parabolic concentrators

- Reflected surface	$48\ m^2$
- Nominal direct insolation	$700\ W/m^2$
- Reflection loss	5.040 W
- Optical loss	1.430 W
- Loss by transparency and by 2nd reflection	1.355 W
- Electrical energy produced	2.935 W
- Thermal outside loss	4.570 W
- Thermal energy to fluid	18.270 W
- Energy impressed on reflected surface	33.600 W

---

(1) Plate supports, recirculation system, flash chamber, connections

(2) Supposing:

Calorific value	9600 Kcal/kg
Boiler efficiency	85%
Operation	8000 hrs/year

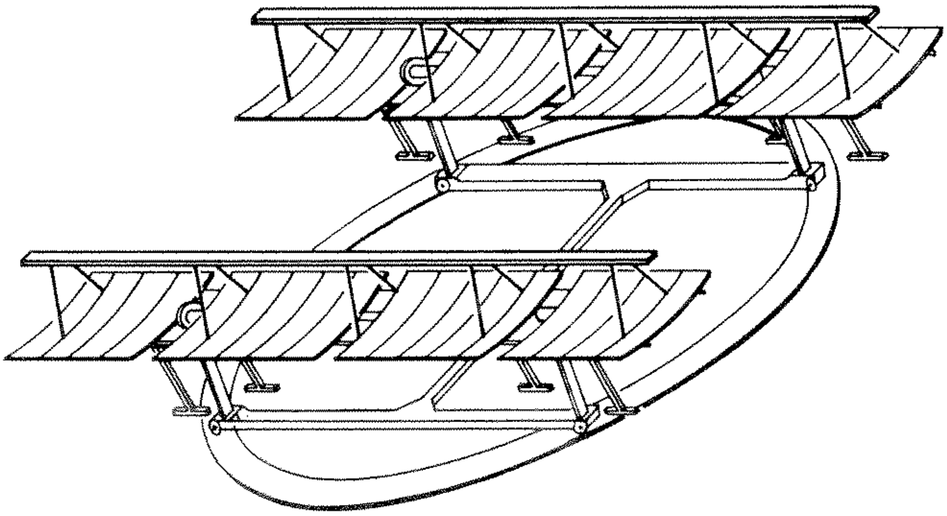

FIG. 3 PHOTOVOLTAIC PARABOLIC CYLINDER CONCENTRATOR

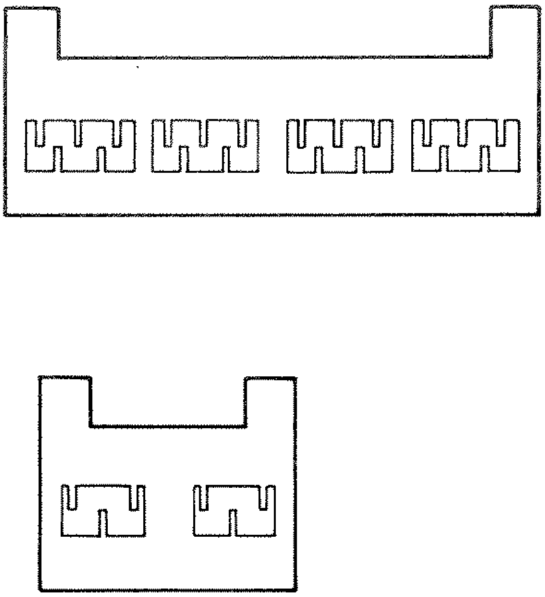

FIG. 4 CELL COOLING CHANNEL

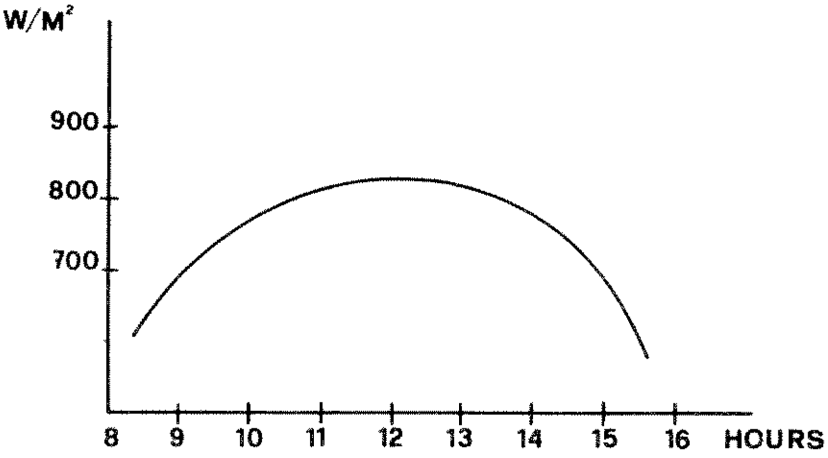

FIG. 5 – DAILY SOLAR FLUX DENSITY

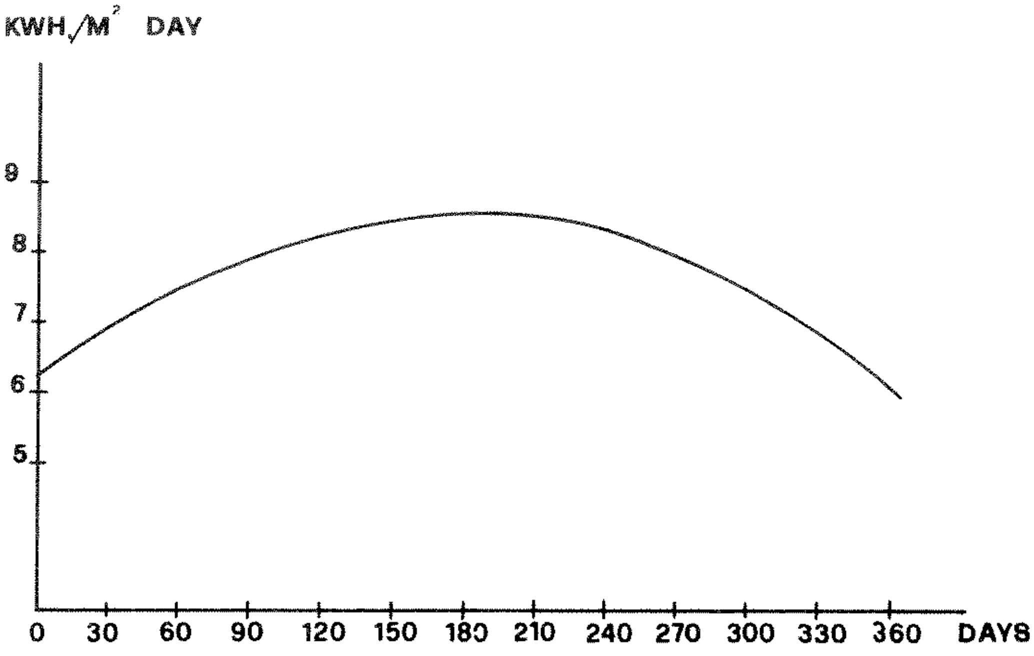

FIG. 6 – YEARLY DIRECT SOLAR FLUX DENSITY

By using five carrousels equal to 240m^2 of reflected surface, 290 x 10^6 Kcal/year will be supplied, equal to approximately 38% of the thermal requirement of the desalting unit. The thermal and electrical outputs of the solar plants are shown in Fig.7 and Fig.8.

Energy saving in terms of unburned fuel oil, may be compared with the efficiency drop of the solar cells. The cells will be kept, infact, at about 64-65°C, instead of the 35°C which would allow us to have amaximum efficiency (η)

η (64,3°C) = 11,4%

η (35°C) = 12,6%

This would correspond to lose about 9,5% of the converters, equal to an investment of 17.700 $.

Investment Costs

- Converters	$ 17.700
- Auxiliary systems and instruments	$ 6.700
- Civil works and assembly	$ 3.600
Total investments	$ 28.000

Energy Savings

Fuel oil	35.500 Kg/year

CONCLUSIONS

Solar power used for producing distilled water is, of course, one of the most interesting applications used as an alternative source of energy, as it may be seen in fig.10 which shows the pay-out of the investment costs of the solar systems taken into account compared to the cost of the fuel oil.

The solar integration is already more convenient to today's fuel oil costs, above all in the "dual purpose" systems which also have the advantage of producing electric energy, both for the desalting unit and for the demands of the communities.

We also wish to point out that in the proposed plants, the pollution level is reduced as they are partially fed by a "clean" and renewable source of energy.

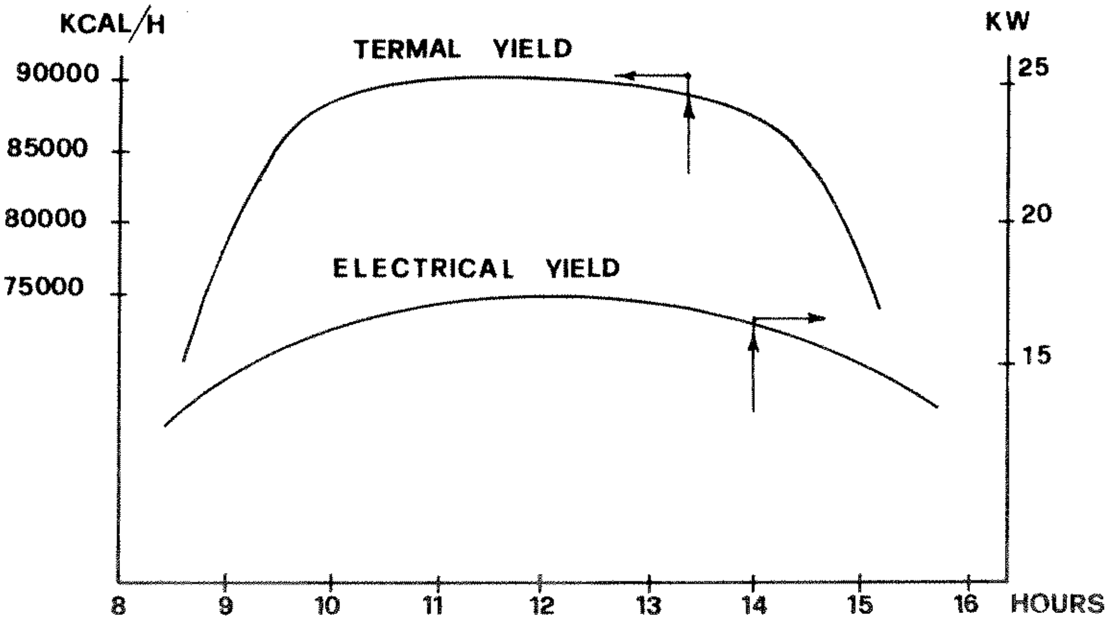

FIG.7 – SOLAR PLANT DAILY YIELDS

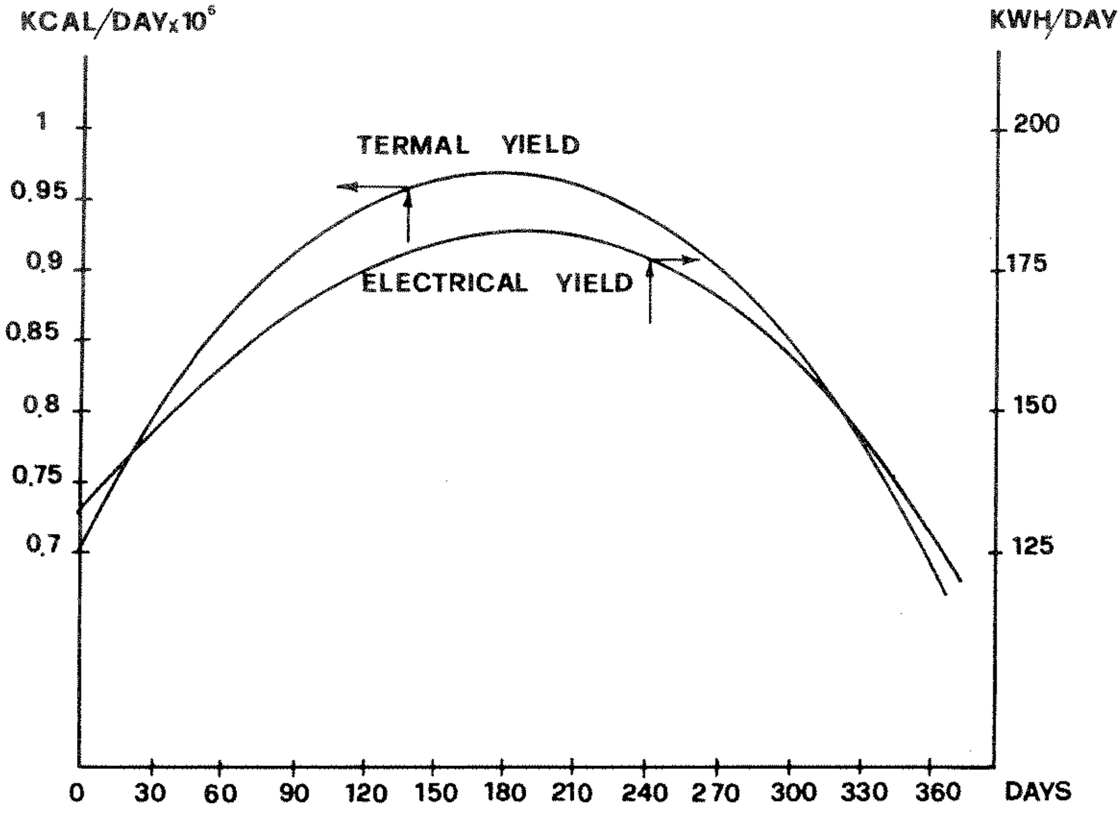

FIG. 8 – SOLAR PLANT YEARLY YIELDS

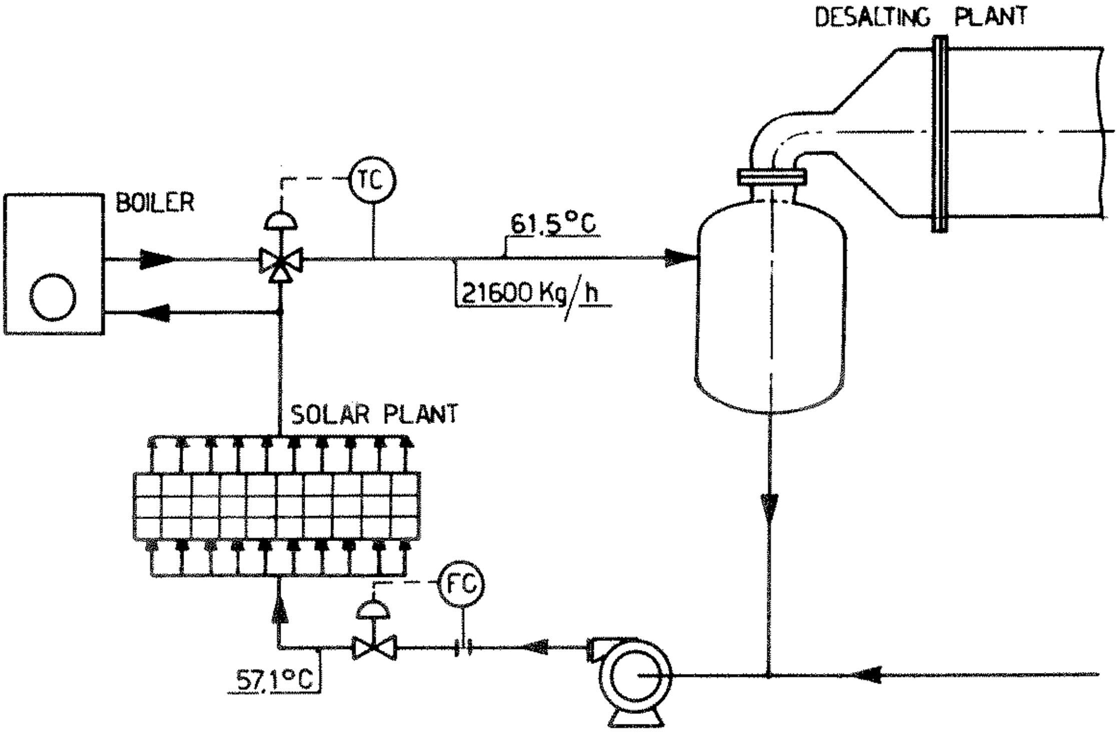

FIG. 9 - HEAT GENERATION SYSTEM FOR DESALTING PLANT (30 m³/DAY)

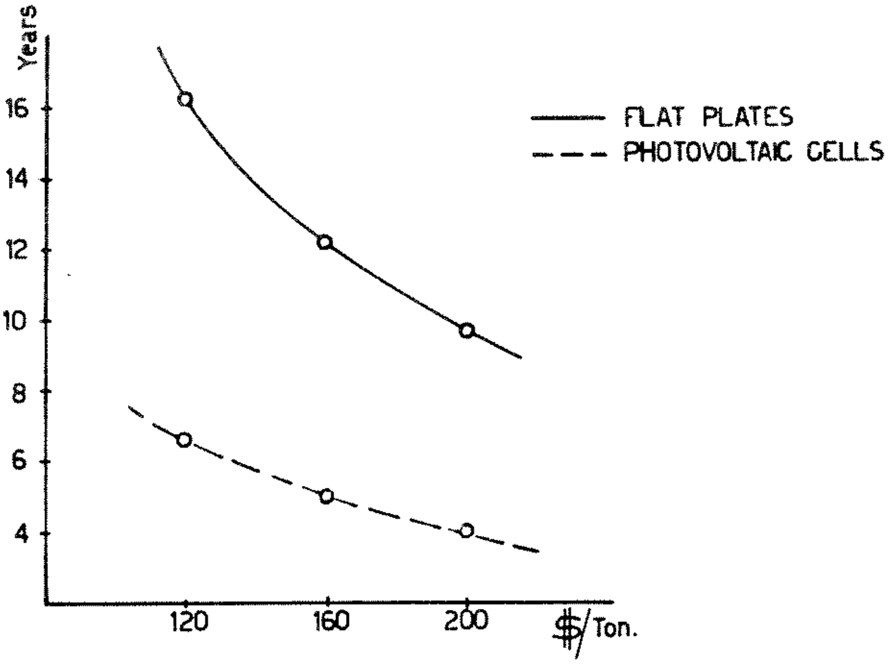

FIG.10 - PAY-OUT OF THE SOLAR PLANT