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NASA TECHNICAL MEMORANDUM

NASA TM-75369

PROGRAM THEK

ENERGY PRODUCTION UNITS OF AVERAGE POWER AND USING THERMAL CONVERSION OF SOLAR RADIATION

Translation of "Programme Thek, Unités de production d'énergie de moyenne puissance par conversion thermique du rayonnement solaire", Centre National De La Recherche, Marseilles, September, 1977, 6 pp.

(NASA-TM-75369) PROGRAM THEK ENERGY PRODUCTION UNITS OF AVERAGE POWER AND USING THERMAL CONVERSION OF SOLAR RADIATION (National Aeronautics and Space Administration) 16 p HC A02/MF A01 CSCL 10A G3/44

N79-11474

Unclas 36860

NOV 1978
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NASA STI FACILITY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 NOVEMBER 1978

STANDARD TITLE PAGE

1. Report No. NASA TM-75369	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PROGRAM THEK ENERGY PRODUCTION UNITS OF AVERAGE POWER AND USING THERMAL CONVERSION OF SOLAR RADIATION		5. Report Date November 1978
		6. Performing Organization Code
7. Author(s) ----		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address SCITRAN P. O. Box 5456 Santa Barbara, CA 93108		11. Contract or Grant No. NASW-3198
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D. C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Programme Thek, Unités de production d'énergie de moyenne puissance par conversion thermique du rayonnement solaire," Centre National De La Recherche, Marseilles, September, 1977, 6 pages.

16. Abstract

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22.
Unclassified	Unclassified		

NASA-HQ

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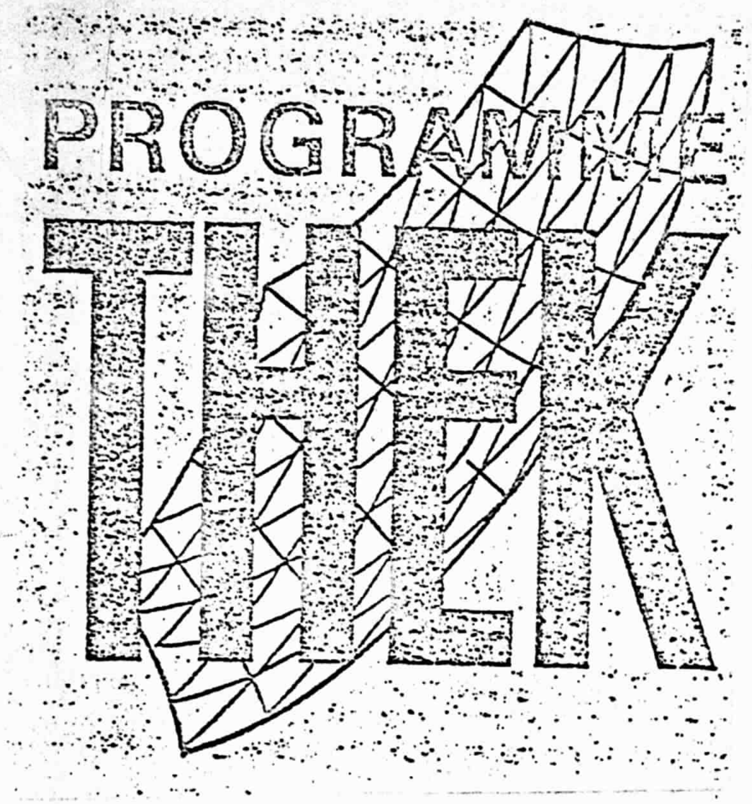

THE THEK PROGRAM

ENERGY PRODUCTION UNITS OF AVERAGE POWER AND USING THERMAL CONVERSION OF SOLAR RADIATION

Marseilles, September 1977

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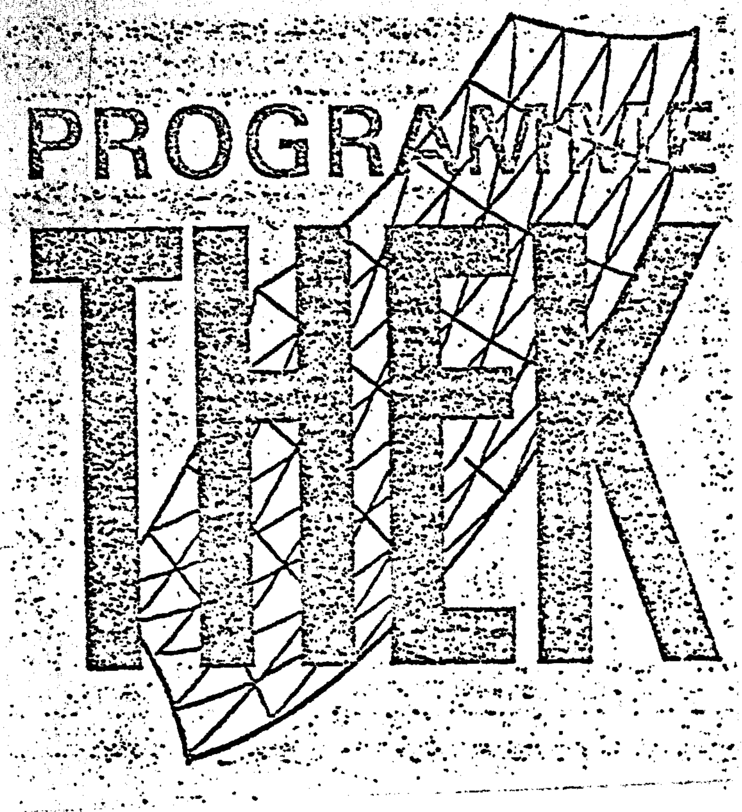

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THE THEK PROGRAM

Marseilles, September 1977

DEFINITION OF THE THEK PROGRAM

General studies undertaken by the C.N.R.S. in the field of "solar power plants" have generated the problem of building energy production units in the medium range of electrical power, in the order of 100 kW.

Among the possible solutions, the principle of the use of "distributed" heliothermal converters has been selected as being, with the current status of things, the most advantageous solution. This principle consists of obtaining the conversion of concentrated radiation into heat by using a series of "heliothermal conversion modules" scattered over the ground; the produced heat is collected by a heat-carrying fluid circulating inside a thermal loop leading to a device for both regulation and storage.

Thermal energy is then available for use:

- either directly (at a temperature level between 30 and 300°C) for heating, air conditioning, soft-water production, steam production, industrial or agricultural conversions, etc.
- or for the production of electrical energy. This production currently involves the standard thermodynamic method (volumetric machine at the low range, turbogenerator for higher power levels) but the use of other methods (thermo-electricity for example) is in no way excluded. In the case of production using the thermodynamic approach, the recovery of heat at a low level, at the condenser, is planned for complementary applications.

The THEK program currently includes three phases.

The first phase, called THEK 1, has as its goal the study, construction and testing of two heliothermal conversion prototype modules to establish specifications for pre-mass production and then for mass-production.

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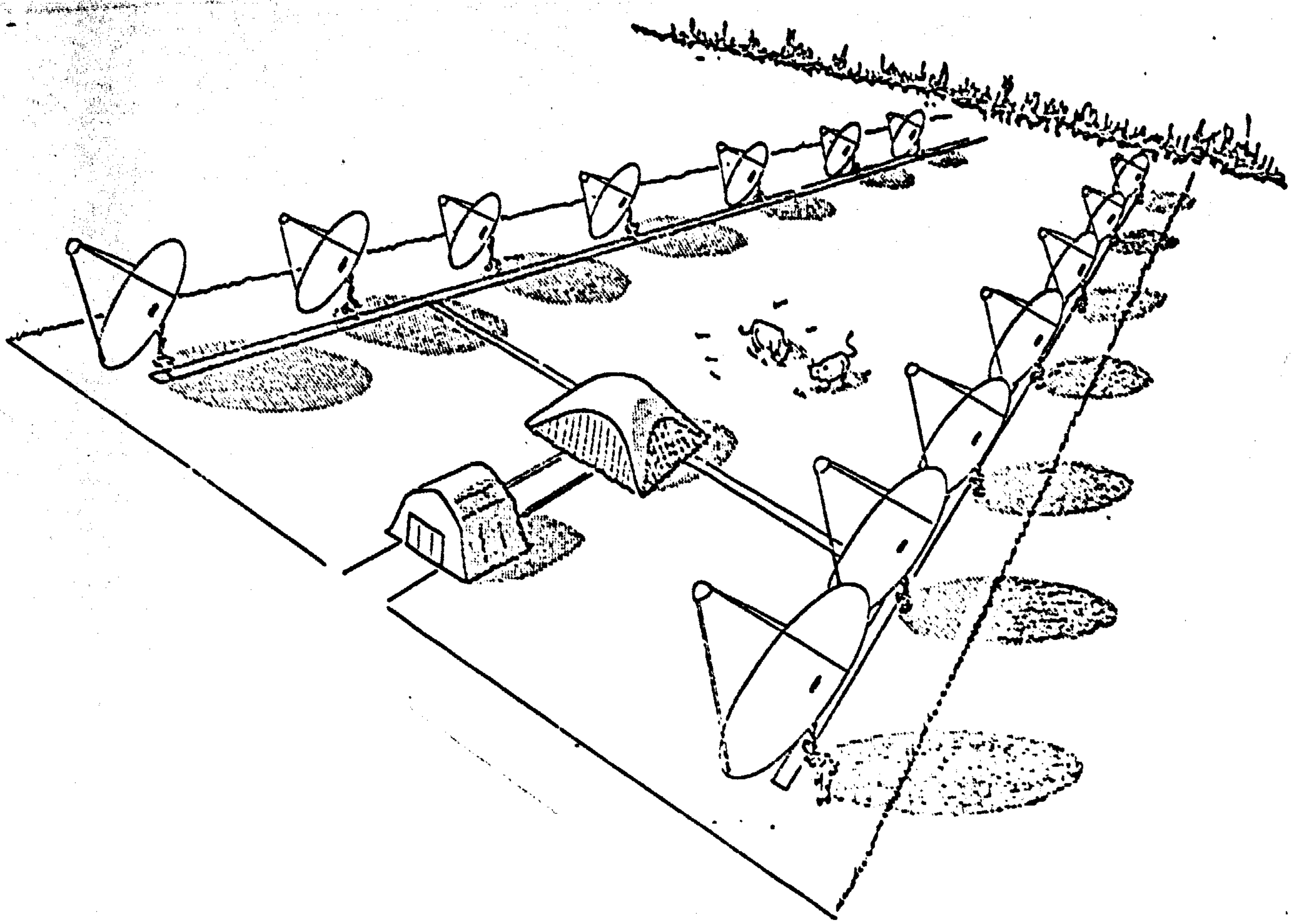

Figure 1 - THEK System for 400/500 Kilowatts.

The second phase, called THEK 2, consists of the study, construction and testing of a field of 26 collectors that will be connected to an existing thermal loop.

The third phase covers the various applications that can be conceived from the heliothermal conversion module perfected for THEK 1.

The technical solutions retained under the THEK program attempt to satisfy, in order of priority, the following constraints primarily dictated by economic reasons:

- the module must be a standard component that can be used regardless of the power and geographical location of the power plant;
- the apparatus must be "rustic" for obvious reasons associated with utilization in isolated regions;
- priority, within the selection criteria, must be given to investment savings and to reliability (in comparison with the performance rate, for example);
- the results of studies conducted under the THEM Project must used to the maximum extent, particularly with respect to the dimensions of the modules, the nature of the heat-carrying fluid, thermal storage, etc...

PROJECT TK 1

Started in March 1976 after a preliminary study that made it possible to define two heliothermal conversion prototype modules, the THEK 1 project will enter the testing phase during the last three months of 1977.

In order to be able to conduct this testing under conditions as close to real operation as possible, a complete elementary system (Figure 2) is being built and it includes:

1) a heliothermal conversion module
2) a storage tank
3) a test exchanger
4) a steam generator
5) a volumetric engine coupled to an alternator
6) a measuring device.

1) THE HELIOTHERMAL PROTOTYPE CONVERSION MODULES

The principle used for the two prototype modules consists of building in the same equipment oriented (words illegible) toward the sun the functions

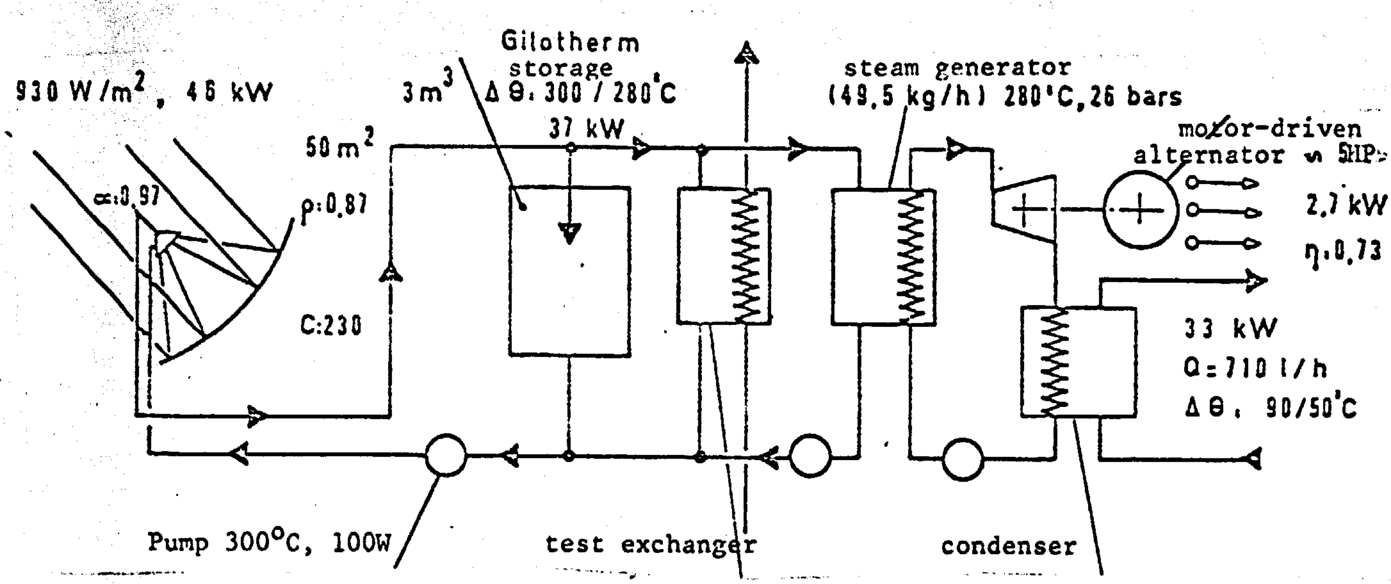

Figure 2 - THEORY OF OPERATION DIAGRAM FOR THE THEK 1 PROJECT TEST FACILITY.

for collecting, concentrating and thermally converting solar radiation.

The primary components of these two modules are:

a - the concentrator

b - the exchanger furnace

c - a mount

d - an automatic sun tracking system.

a) the concentrator

Formed by placing flat triangular mirrors next to each other so as to approximate a paraboloid of revolution, the function of the concentrator is to concentrate the incident solar radiation onto the exchanger furnace.

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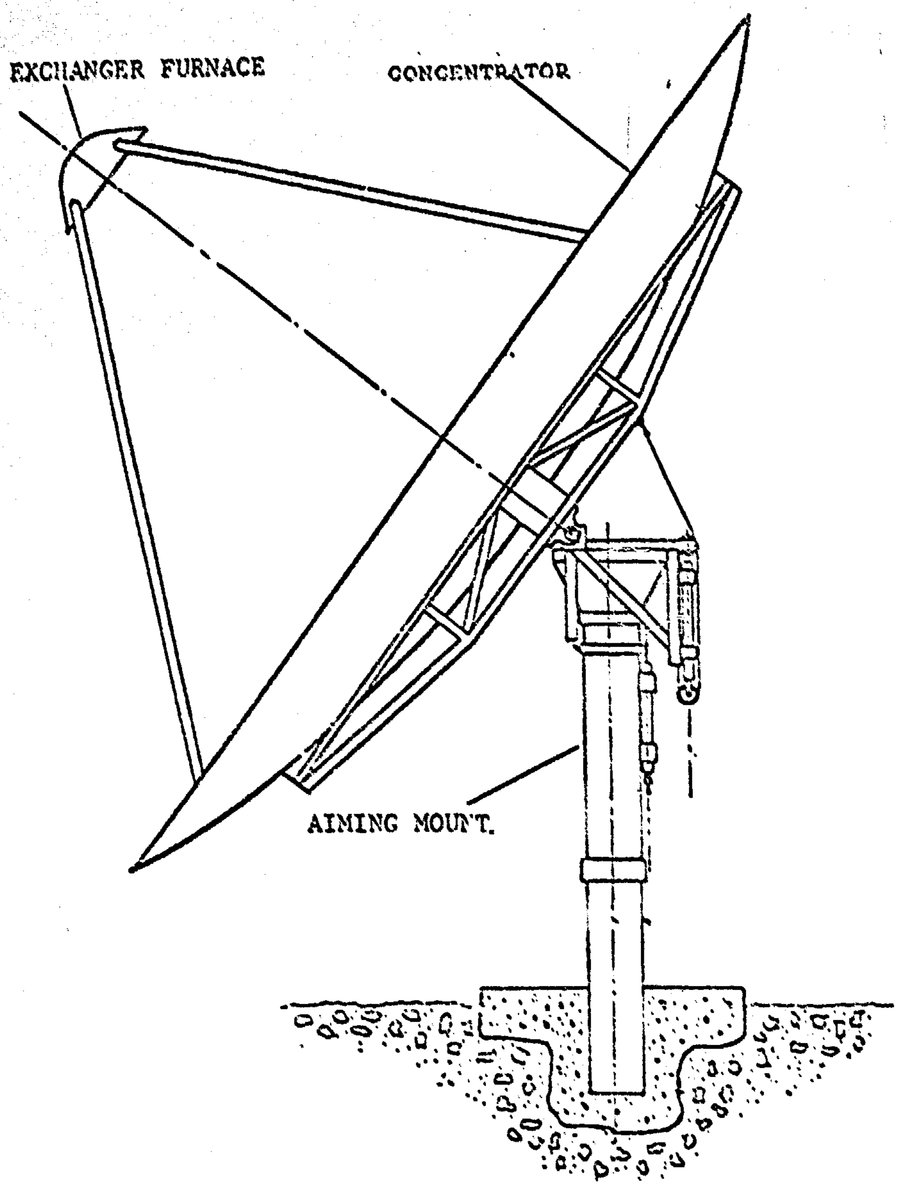

Figure 3 - Heliothermal Conversion Module of the Department of Heliophysics.

The half-angle of aperture of this parabolic pseudo-mirror is 45° which corresponds to a focal distance of 4.8 meters when the diameter is 8 meters.

The geometric concentration factor is close to 250 for a system composed

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of 750 basic equilateral mirrors measuring 40 cm on the side and made from clear glass silvered on the back and protected by an external varnish. The reflection coefficient of the mirrors is 0.87.

b) the exchanger furnace

It is composed of a single tubular boiler made of copper tubing with an inside diameter of 12mm and covered with a special coating (α=0.97; ε=0.90 at the operating temperature). This furnace is placed at the focal point of the concentrator; its function is to convert the concentrated solar radiation into heat and to transmit this heat to the heat-carrying fluid (Gilotherm TH).

The aperture section of the furnace is a circle with a diameter of 0.5m. The geometry of the boiler was studied by taking into consideration the distribution of the light inside the focal volume of the concentrator.

The boiler is equipped with standard thermal insulation on its back side.

c) the mount

This is the area where there is a main difference between the two prototype modules.

The first module, studied by the Department of Heliophysics of the University of Provence, uses an "all-direction" mount composed of a center post on which rests a one-piece plastic cupola turning about a vertical axis and a horizontal axis (see Figure 3).

The second module also uses an "all-direction" mount directly derived from the heliostatic mount studied for the THEM Project by the Basic Technology Team of PIRDES. This mount is composed of a welded mechanical structure that moves on a rail about a vertical axis (motion in azimuth) and that can be inclined with a sloping support and a system of chains (motion in elevation) (see Figure 4).

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1 - Roller Track
2 - Carrier Wheels
3 - Drive Wheel
4 - Pivot
5 - Boiler
6 - Tracking System
7 - Control Mechanisms
8 - Sloping Support
9 - Reflecting Surface

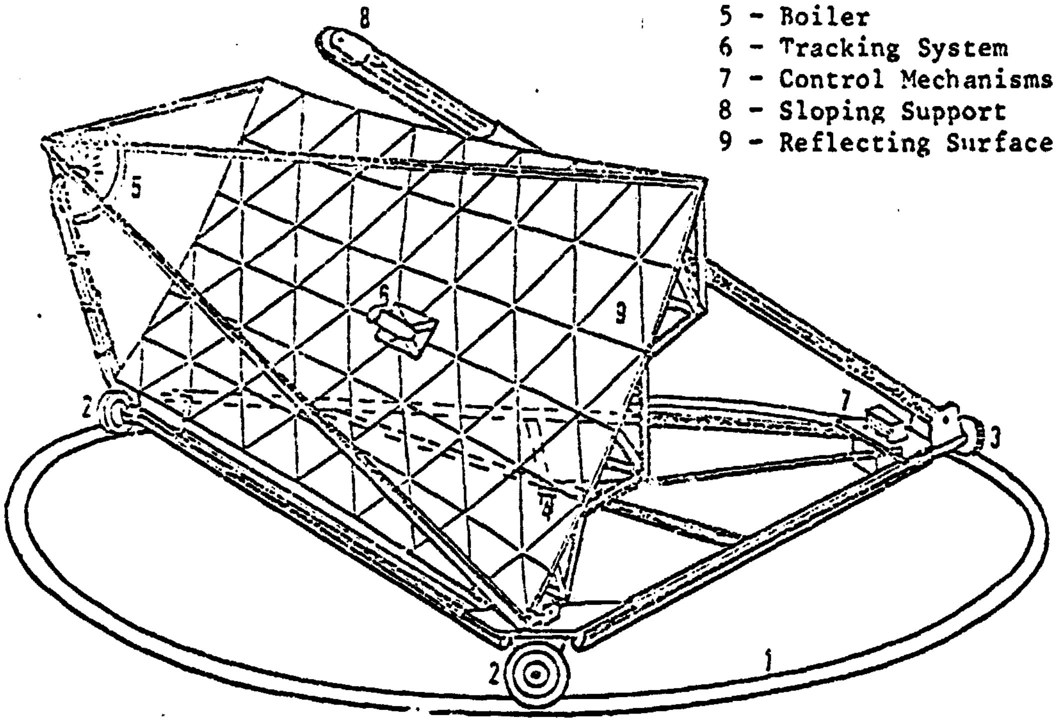

Figure 4 - E.T.B. Heliothermal Conversion Module.

d) the automatic sun-tracking system

The orientation of the modules is automatically controlled by two systems in parallel, one programming the necessary motions independently of the presence of the sun while the other corrects the orientation, as needed, as a fonction of the actual position of the sun.

The first uses a clock movement connected to a mechanical coordinate generator and operates continuously. The second system uses a solar sensor with four photoresistive cells and intervenes on a priority basis when the sun is present. These two systems provide the mount driving mechanisms with the data needed for aiming the mounts.

2) THE STORAGE TANK

It is a Gilotherm tank of 3 m^3 (2400 kg) integrated in the thermal loop and that is to operate at a temperature between 320 and 280°C. It was designed to regulate the operation of the converter, taking into consideration the possibility of clouds passing for periods of time not exceeding several hours.

3) THE TEST EXCHANGER

Necessary for determining the thermal output of the system, a Gilotherm-to-water exchanger is planned to provide an average flow rate of 530 liters/hour.

4 and 5) STEAM GENERATOR AND VOLUMETRIC ENGINE COUPLED TO AN ALTERNATOR

In order to resolve interface problems, the system is completed with the addition of a standard (word illegible) electric converter which we did not try to optimize.

6) THE MEASURING DEVICE

The measuring device designed to continuously record the data necessary for the study of the operation of the various components and particularly of the protoype modules provides the capability of measuring the following parameters:

- direct solar radiation
- velocity and direction of the wind
- temperature of the heat-carrying fluid at the inlet and outlet of the exchanger furnace, of threstorage tank and of the test exchanger
- temperature control of the flow of the heat-carrying fluid
- flow rates in the various circuits
- etc.

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7) PRODUCTION UNITS

The connection of several modules to a single thermal loop represent a specific development; the study phase of this development is covered in the next chapter entitled "Project THEK 2".

PROJECT THEK 2

Project THEK 2 is the logical sequence to Project THEK 1. Its goal is the study, construction and test of a field of 26 collectors resulting from this project. It will make it possible to study the technical problems caused by the parallel emplacement of several modules as well as the management problems associated with a field of distributed heliothermal collectors.

The field could be connected to an existing thermal loop such as the one installed by C.N.R.S. at Odeillo within the framework of Project THEM.

The study of the collector field began during the first six months of 1977 and the main characteristics are given below.

Request for proposals to build these modules, their assembly in the field and civil engineering work will begin in early 1978 after the first series of tests with the two prototype modules of Project THEK 1. The installation of the field should be completed at the end of the first six months of 1979.

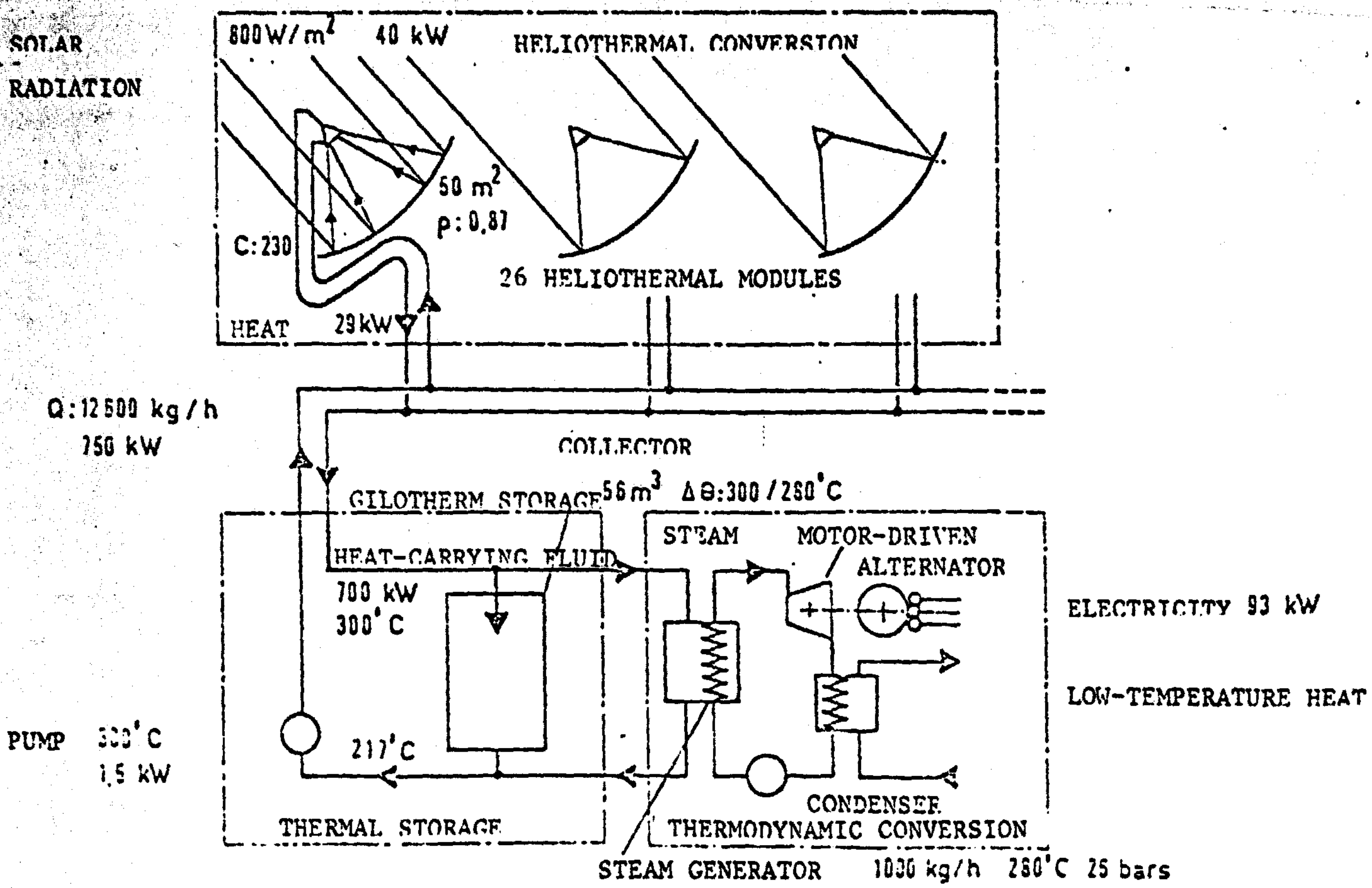

Figure 5 - Theory of Operation Diagram of the THEK 2 Collector Field.

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GENERAL SPECIFICATIONS OF THE THEK 2 COLLECTOR FIELD

SYSTEM:

Number of collector modules: 26

Distribution of the collectors over the field: quincincial pattern

Length of one side of a link: 12 meters

Ground surface covered: 6000 m^2

Mirror surface: 1300 m^2

Length of the main collector: 790 meters

Fluid flow velocity: 1 meter/sec.

Inner diameter of the collector tubing: 75 mm

Mass flow rate of the heat-carrying fluid (12,600 kg/hr): 3.5 kg/sec.

Reynolds Number: 143,000

Weight of the fluid in the pipes (Gilotherm H): 2,900 kg

Pressure drop: 1.7 bars

Power of the circulation pump: 1.5 Kilowatt

Thermal losses in the pipes: 55 Kilowatts (thermal)

Power captured and converted into electrical power: 750 kilowatts (thermal)

STORAGE UNIT:

Type: temperature-sensitive; nebular

Volume stored: 56 m^3

Volume of the expansion chamber: 19 m^3

Thickness of the thermal insulation: 0.40 meters

Loading time: 2 days

Power available to the storage unit: 700 kW (thermal)

THERMODYNAMIC LOOP

Characteristics of the superheated steam: 280°C at 28 bars; 2,700 kJ/kg

Type of exchangers: counterflow

Specific consumption of the exchangers (Gilo for 1 kg/hr of steam): 0.75 kW (th)

Specific consumption of the motor (for 1 kW electrical): 10 kg/hr

Power available to the condenser: 600 kW (thermal)

Available electrical power: 93 kW.

COLLECTOR MODULE:

Type of collector: pseudo-paraboloid

Focal length: 4.83 meters

Collector surface area: 50m^2

Geometric concentration factor: 230

Number of triangular facets: 750

Surface area of one facet (equilateral triangle): 0.069 m^2

Reflectivity of the mirrors: 0.87

Effectiveness of the mirrors: 0.95

Average normal energy impacting: 800 W/m^2

Type of boiler: single-tube type

Boiler inlet diameter: 0.53 meter

Apparent area of the converter inlet: 0.22m^2

Absorptivity of the absorber: 0.97

Fluid temperature at the module inlet: 217^{o}C

Fluid temperature at the module outlet: 300^{o}C

Inner diameter of the exchanger tubing: 12 mm

Fluid flow velocity: 1.5 meter/second

Mass flow rate of the heat-carrying fluid (490kg/hr): 0.135 kg/second

Reynolds number: 34,400

Apparent exchange surface area of the exchanger furnace: 0.55m^2

Exchange coefficient: 2.3 kW/m^2 ^{o}C

Pressure drop: 1 bar

Thermal efficiency of the boiler: 0.91

Type of checking system: closed loop

Acceptable angular error for the reflected rays: 5 milliradians

Available power: 29 kilowatts (thermal)