THE EUROPEAN TEST FACILITY
PLATAFORMA SOLAR DE ALMERIA

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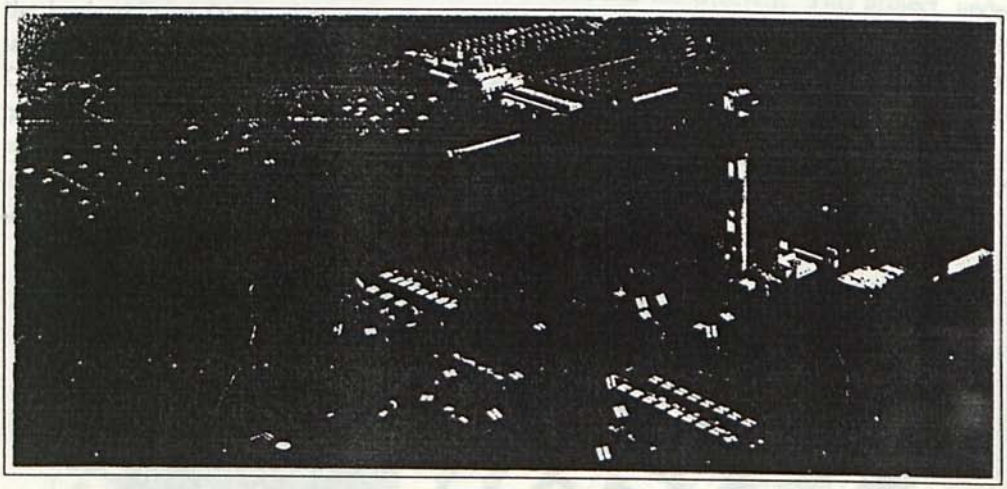


Fig. 1. Plan of the Plataforma Solar

The Plataforma Solar de Almería (PSA) is an installation which belongs to the Spanish Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas of the Ministry of Industry, Commerce and Tourism, (CIEMAT) and is jointly operated by the CIEMAT and the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR), of Germany. It is the largest European test center of solar thermal energy applications. The PSA also participates in European Community scientific research support programs.

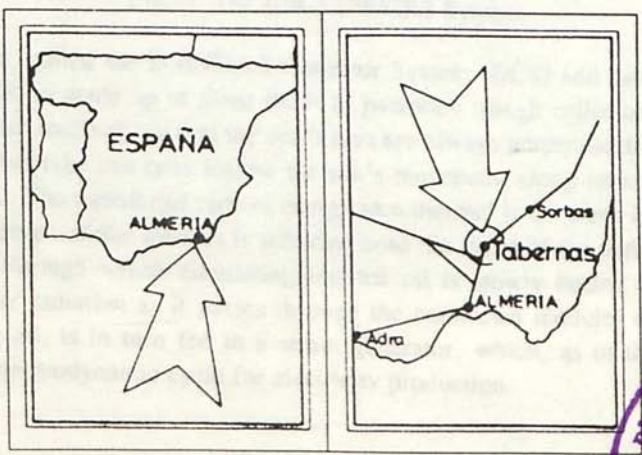


Fig. 2 Location of the PSA

1. BACKGROUND

The Plataforma Solar de Almería initiated its path as a European Test Facility in the desert of Tabernas early in the 80's, with the construction of two large technical feasibility demonstration projects which used concentrated solar energy for electricity production.

The first project, known as the SSPS (Small Solar Power Systems), was a project of the International Energy Agency, with the participation of nine countries (Austria, Belgium, Germany, Italy, Spain, Sweden, Switzerland, Greece and the U.S.A.). This project, under the leadership of DLR, consisted of the design, construction and testing of several plants using different technologies with the same power range of 500 kW_e. The first of these, the CRS or central receiver system, consists of a field of computer controlled mirrors called heliostats, which track the solar radiation and concentrate it on a receiver installed in a central tower, where a working medium, in this case sodium, transforms the radiant energy into thermal energy. This 520°C fluid feeds a steam generator which is hooked up to a thermodynamic cycle for electricity production.

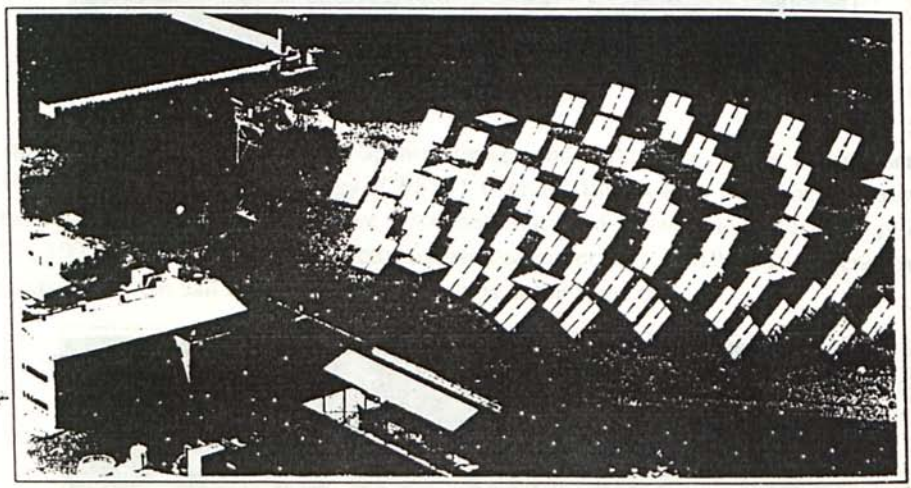


Fig. 3 The IEA-SSPS/CRS System

The other system, called the Distributed Collector System (DCS) and producing the same power as the CRS, is made up of three fields of parabolic trough collectors. Two of these have two-axis solar tracking, so that the sun's rays are always perpendicular to the collector surface. The other type can only follow the sun's movement along its anlgle of elevation over the horizon. The transfer of radiant energy into thermal is the same in both cases: any incident ray on the parabolic mirrors is reflected onto the focus of the parabola where there is a metal tube through which circulating thermal oil is slowly heated to 290°C by the concentrated solar radiation as it passes through the connected modules of the distributed collectors. This oil, is in turn fed to a steam generator, which, as in the case above, is hooked up to a thermodynamic cycle for electricity production.

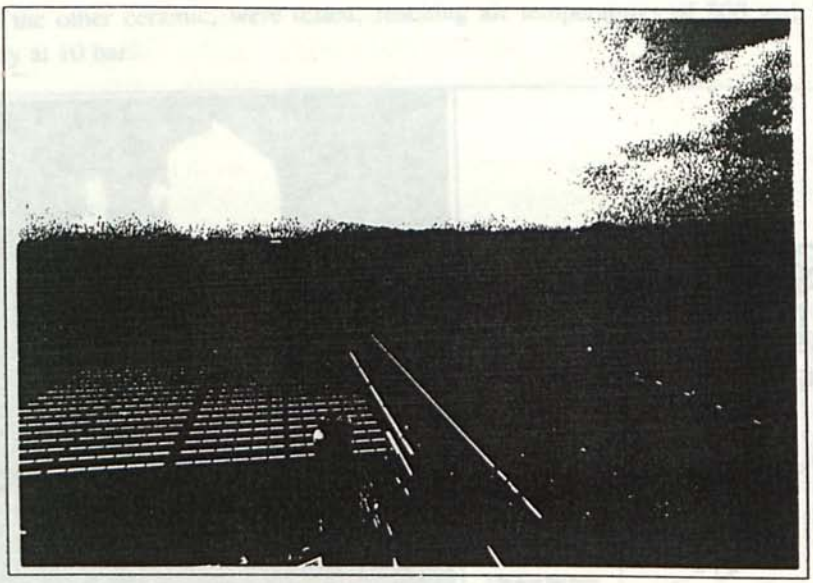


Fig. 4 IEA-SSPS/DCS

The other large project, of entirely Spanish design and technology, under the auspices of the Ministry of Industry and Energy, CESA-1 (Central Electrosolar de Almería), uses the central tower concept described above. 300 heliostats and a water/steam receiver produce 520°C, 100 bar steam which is directly transferred either to a 1 MW_e tubine-generator or to storage in molten salt tanks, or both operations at the same time.

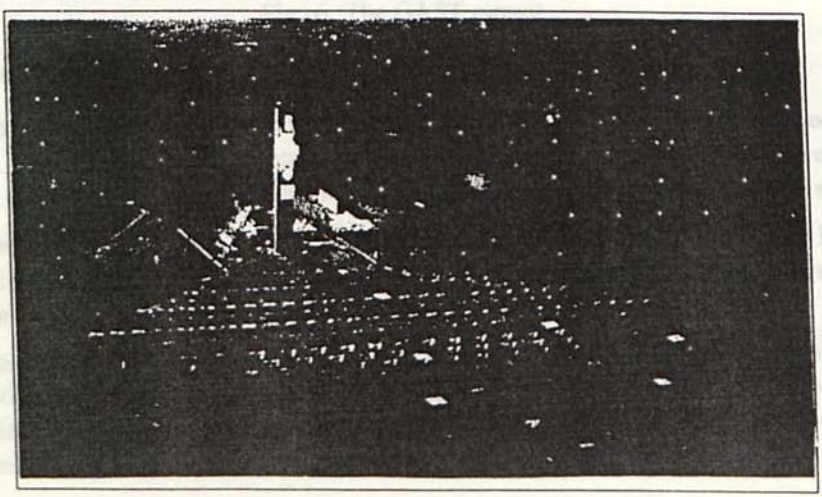


Fig. 5 CESA-1

These two large projects were evaluated through 1984. The CESA-1 Project was also a testbed from 1985 to 1987 for the Spanish-German GAST Technology Program, the which designed, built and evaluated central tower technology components (heliostats and receivers). Within this program, several different types of heliostats and two receivers, one

metal and the other ceramic, were tested, reaching air temperatures of 800 and 1,000°C respectively at 10 bar.

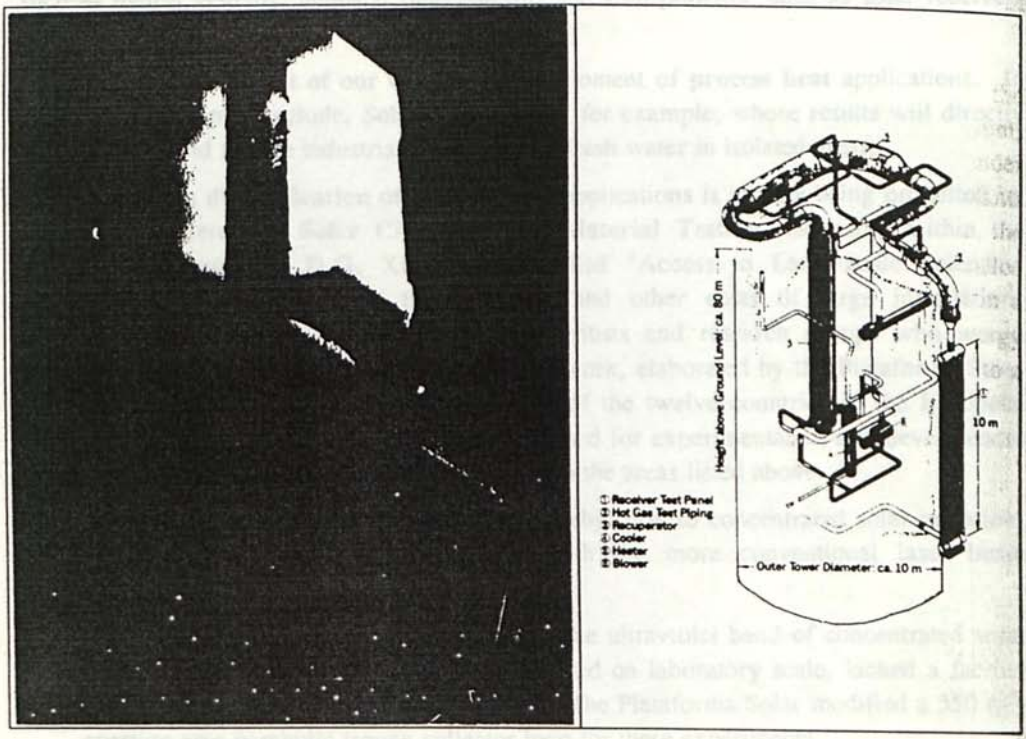


Fig. 6 The GAST circuit

2. AREAS OF INVESTIGATION

The goals outlined for the construction of the CESA-1 and SSPS plants, which constitute the basic infrastructure of the Plataforma Solar, were the comparison of the several then available technologies for the production of electrical energy within the same MW range

At the end of this period in 1986, the Plataforma Solar was converted into a Research Center directed toward the improvement of components and systems and the diversification of solar energy applications.

This reorientation of objectives coincides with the signing of the Spanish-German Cooperation Agreement and a creation of the Steering Committee, made up of two membes from each country, which grouped all future activities of the Plataforma into five general categories:

I. Electricity generation
II Industrial thermal processes
III Solar Chemistry
IV Materials testing
V Education and publication of experience

The first of these is **Electricity Production**, the activity which has longest held our attention at the Plataforma Solar. Current efforts concentrate on **development of Systems**, such as hybrid systems, heliostat field control, and **Components**, such as solar receivers and heliostats.

Another important aspect of our work is the develoment of **process heat** applications. In this category we may include, Solar Desalination, for example, whose results will directly affect the demand for the industrial production of fresh water in isolated areas.

Our work in the **diversification** of solar thermal applications is rapidly being propelled by international interest in **Solar Chemistry** and **Material Testing**, especially within the European Community's D.G. XII program called "Access to Large-Scale Scientific Installations", which subsidizes the operating and other costs of large installations originating in the their use by Community scientists and research groups who would otherwise not have access to them. The plan of work, elaborated by the Plataforma Solar with four groups of scientists representing nine of the twelve countries in the European Community, enables the Plataforma Solar to be used for experimentation and development projects within four lines of research coherent with the areas listed above:

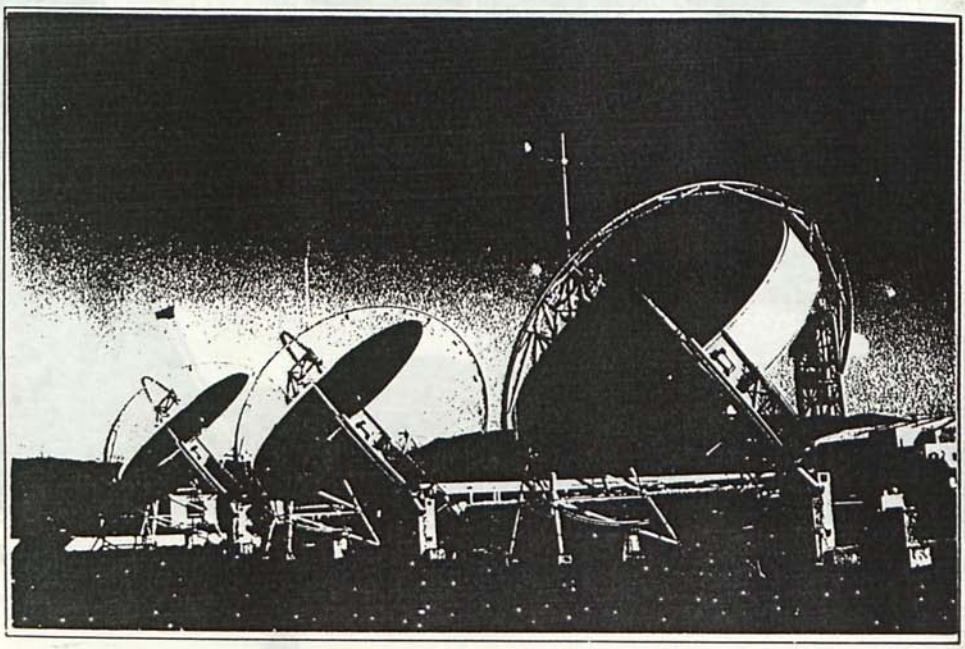
- Metallurgical thermal shock treatments by subjection to concentrated solar radiation, and comparison with results obtained with the more conventional laser beam methods.
- Industrial waste-water detoxification using the ultraviolet band of concentrated solar radiation. This process, already demonstrated on laboratory scale, lacked a facility for its semi-industrial-scale demonstration. The Plataforma Solar modified a 350 m^2-aperture-area parabolic trough collector loop for these experiments.
- Adaptative control systems. The Plataforma Solar facilities constitute the perfect test bed for investigation in this field, especcially for a good understanding of the mathematical models, the dynmamics and the stability of new strategies for industrial control processes.
- Production and characterization of zircon ceramic fibers. The production of this fiber requires clean melting of the zirconium which occurs at 2800°C. The Plataforma Solar has built a 60 kW solar furnace capable of concentrating to 8000 suns (about 8 MW/m^2) for the experiments required by this work group.

Other projects at the PSA include experiments in **solar convection drying** and **bioclimatic architecture**. Finally, but still an important aspect of our activities, is the **education** of future solar engineers and technicians and the diffusion of newly acquired technologies.

3. MOST IMPORTANT PRESENT AND FUTURE PROJECTS

There are two basic types of solar thermal systems for **electricity production**: high and low concentration. High concentration systems may be either parabolic dish or central tower (CRS). The dish systems use a mirror surface mounted on a revolving parabola which focus the sun's rays on a point at which the receiver is located. They can generate

electricity either with a small Stirling motor installed in the focal point, or they can be grouped together in medium power systems. The German company Schlaich Bergermann und Partner (SBP), in a Project cofinanced by the German Ministry of Technology and Research (BMFT) has installed three 10 kW_e parabolic dish/Stirling motor arrangements at the Plataforma Solar.



The Schlaich Bergermann und Partner parabolic dishes

Low concentration systems employ distributed parabolic collectors to concentrate the irradiated solar energy up to 100 times with parabolic mirrors onto a tube receiver situated along the focal axis. Temperatures obtained can vary from 100 to 400°C are used for industrial process applications or for electricity production. This parabolic trough technology has by now been well proven. Besides the IEA-SSPS project experiments, in southern California (USA) there are 300 MW_e of such collectors in electrical cogeneration plants generating 75% of the electricity from solar energy and 25% from gas.

Recent studies have shown that improved efficiency of these plants would imply eliminating oil as the thermal transfer fluid and producing steam directly in the tube receiver which would then go directly to the turbine. European companies have indicated their desire to install such a direct steam generation technology demonstration project at the Plataforma Solar in order to evaluate the economic competitiveness of the concept.

Within the area of solar power plant component development, CIEMAT is a pioneer in the development of low-cost heliostats. The most innovative materials, such as stretched metallic membranes, glass fiber reinforced polyester sandwiches and holographic concentrators are being tested for forthcoming plants and future applications. In recent years at the Plataforma Solar eight different types of heliostats have been tested. The resulting improvements have attained a satisfactory quality/cost relationship.

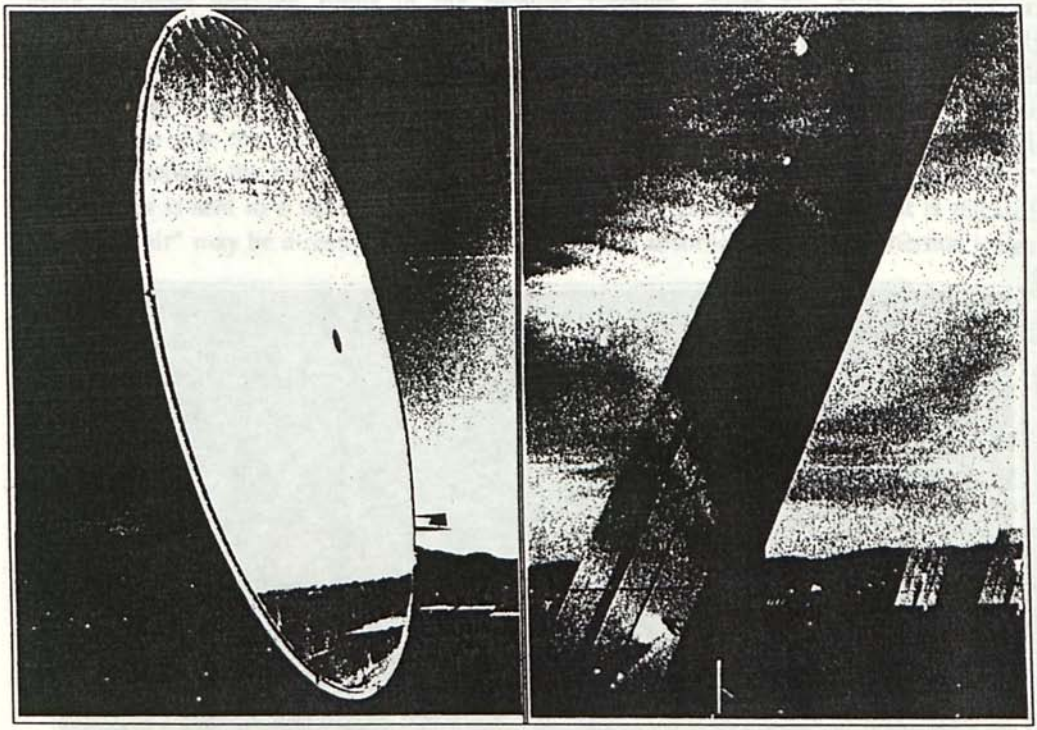


Fig. 7 New heliostats: On the left stretched-membrane helisotat, on the right glass-mirror.

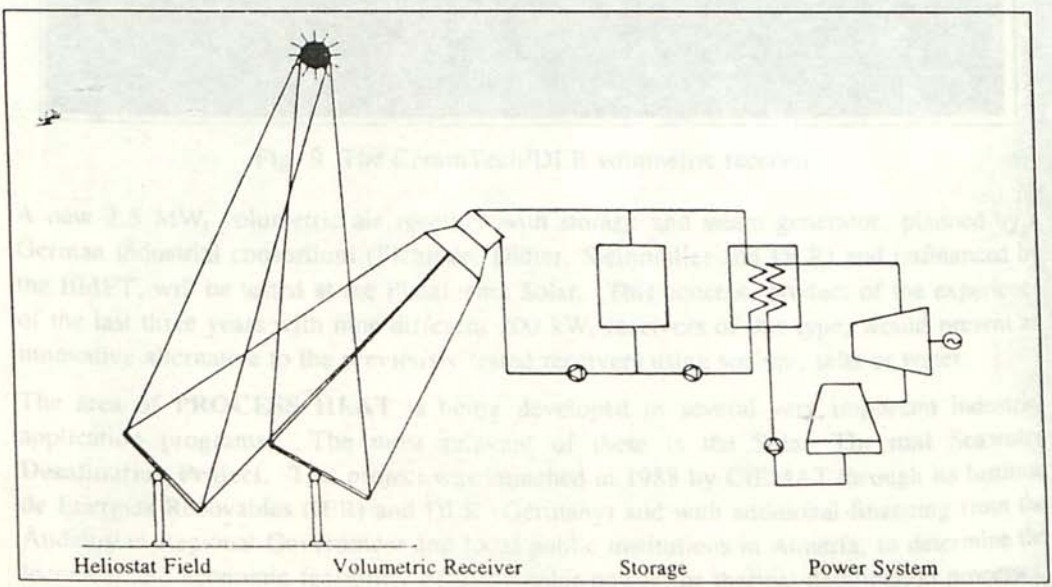


Fig. 8 Schematic drawing of the volumetric receivers

Solar receivers have been tested in various places around the world during the last decade. A total of eight solar central power plants have been designed, constructed and operated

using different working fluids in the receiver (sodium, water and salts). However, recently, a new concept using air, called the Volumetric Receiver, is being intensively developed. The working principle behind the volumetric receiver is actually ratehr simple (see drawing below): the solar radiation is concentrated on a surface made up of porous material, so that the receiver is heated in three dimensions. At the same time, air is absorbed through the pores convectively heating up to temperatures of 700°C to 1200°C. This hot air is sent to a steam generator or a storage subsystem where the heat is released. The "cold air" may be directed to area surrounding the absorber to diminish thermal losses.

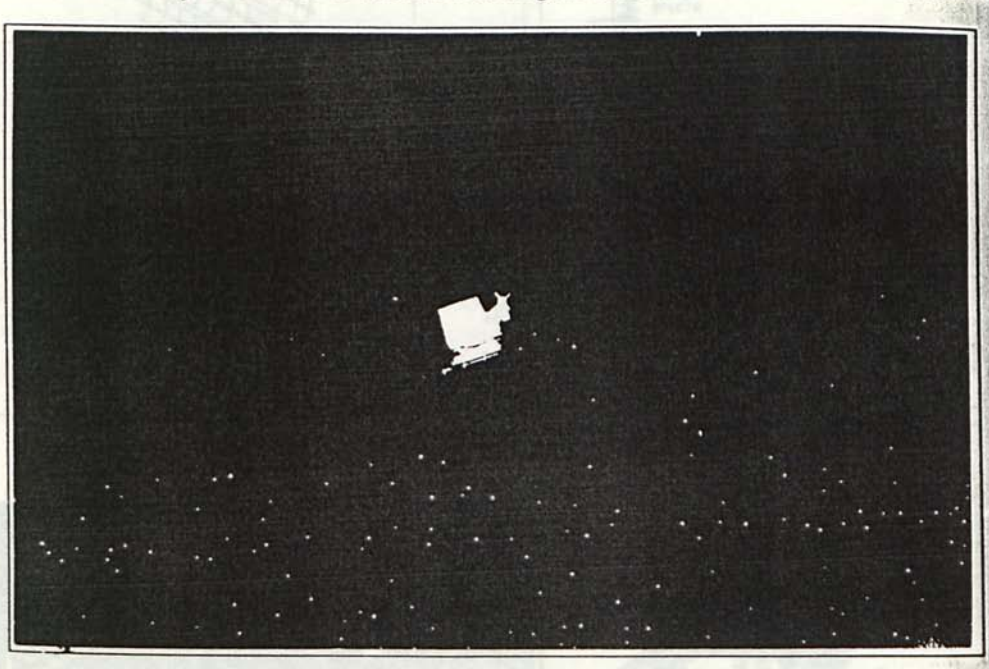


Fig. 9 The CeramTech/DLR volumetric receiver

A new 2.5 MW_t volumetric air receiver with storage and steam generator, planned by a German industrial consortium (Fichtner, Didier, Steinmüller and DLR) and cofinanced by the BMFT, will be tested at the Plataforma Solar. This concept, product of the experience of the last three years with nine different 200 kW_t receivers of this type, would present an innovative alternative to the previously tested receivers using sodium, salts or water.

The area of **PROCESS HEAT** is being developed in several very important industrial application programs. The most relevant of these is the **Solar Thermal Seawater Desalination Project**. This project was launched in 1988 by CIEMAT through its Instituto de Energías Renovables (IER) and DLR (Germany) and with additional financing from the Andalusian Regional Government and local public institutions in Almería, to determine the technical and economic feasibility of using solar power for thermal desalination processes, and to optimize this combination by introducing and evaluating improvements. The two-phase project is based on a multi-effect (ME) desalination plant. The pilot system has been improved by coupling an absorption heat pump to the existing ME plant and the replacing

the hydroejector vacuum system with a steam-ejector. A production cost of about 325 Ptas. or 5 DM per cubic meter of fresh water for commercial plants is expected as a result.

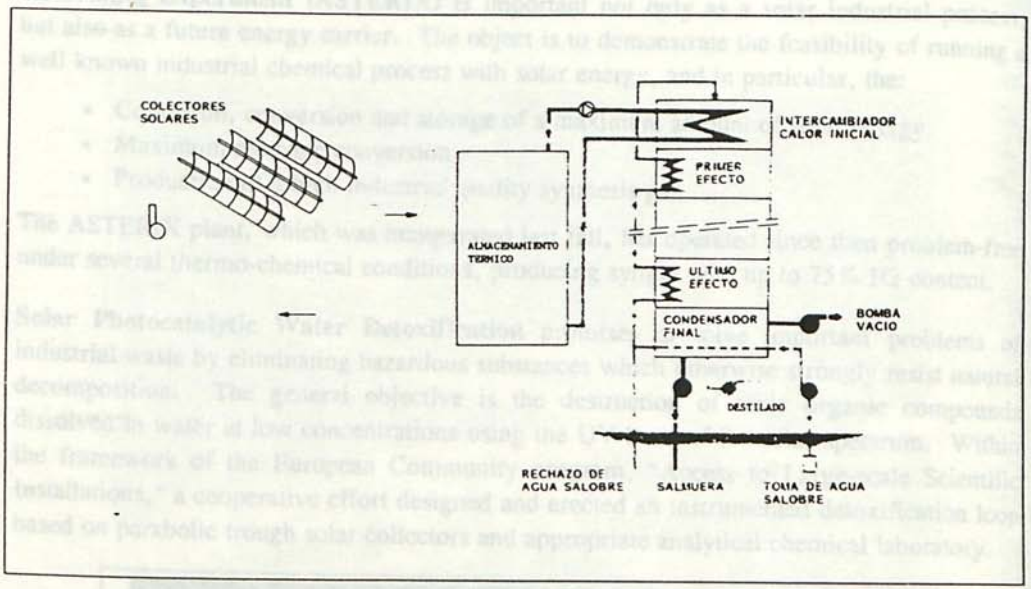


Fig. 10 The Solar Desalination Loop at the PSA

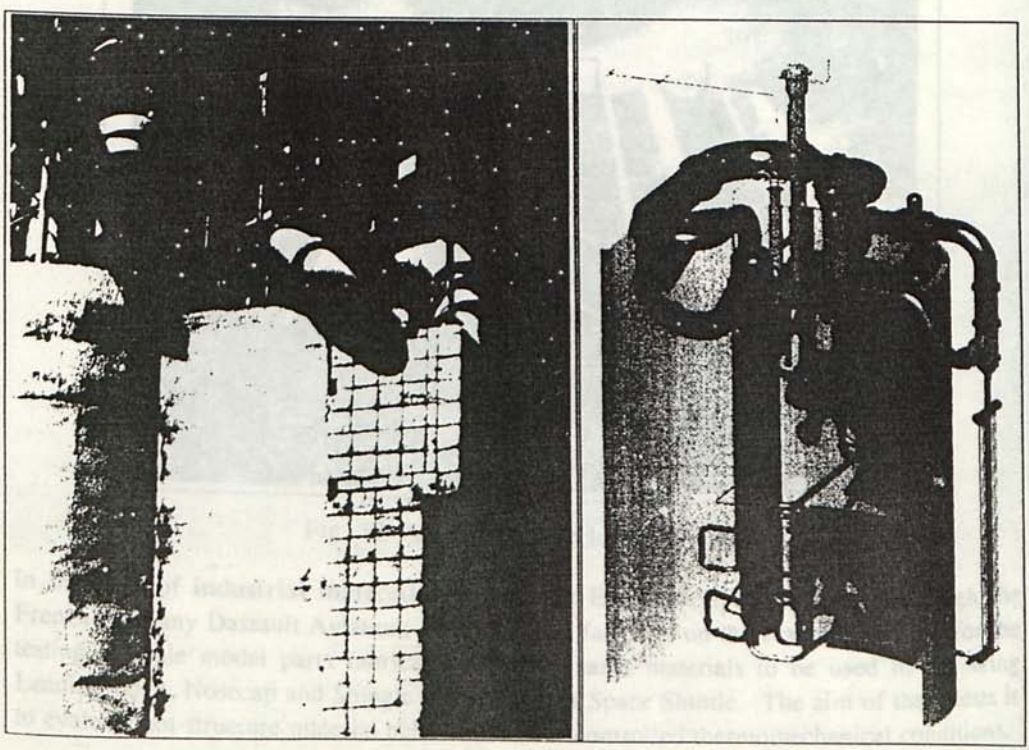


Fig. 11 The ASTERIX Project

SOLAR CHEMISTRY is one of the newest fields in which solar energy has begun to diversify. At the PSA there are several ongoing projects in this area. The **Solar Steam Reforming Experiment (ASTERIX)** is important not only as a solar industrial process, but also as a future energy carrier. The object is to demonstrate the feasibility of running a well known industrial chemical process with solar energy, and in particular, the:

- Collection, conversion and storage of a maximum amount of solar energy
- Maximum methane conversion
- Production of a high industrial quality synthesis gas

The ASTERIX plant, which was inaugurated last fall, has operated since then problem-free under several thermo-chemical conditions, producing syngas with up to 75% H2 content.

Solar Photocatalytic Water Detoxification promises to solve important problems of industrial waste by eliminating hazardous substances which otherwise strongly resist natural decomposition. The general objective is the destruction of toxic organic compounds dissolved in water at low concentrations using the UV band of the solar spectrum. Within the framework of the European Community program, "Access to Large-scale Scientific Installations," a cooperative effort designed and erected an instrumented detoxification loop based on parabolic trough solar collectors and appropriate analytical chemical laboratory.

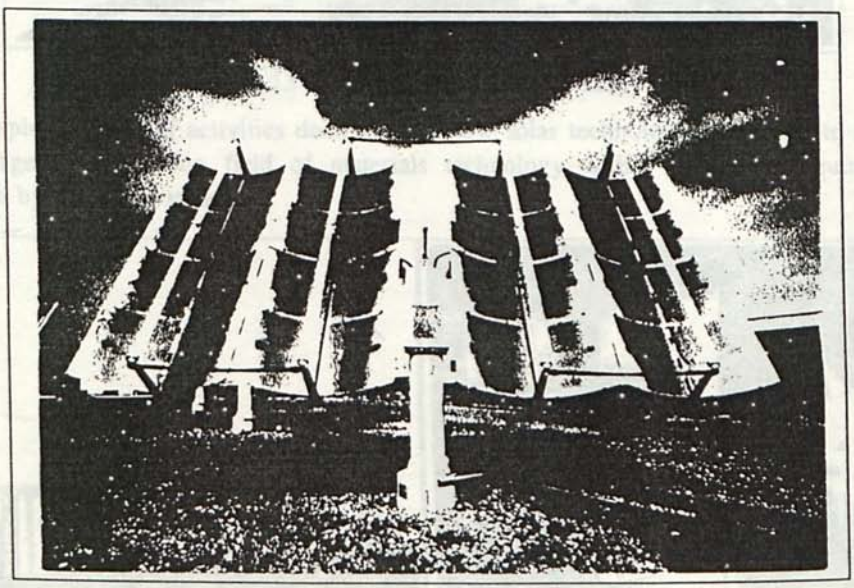


Fig. 12 A detoxification loop collector

In the field of **industrial materials testing,** the European Space Agency's through the French company Dassault Aviation, maintains test facilities on the Plataforma Solar for the testing of scale model parts fabricated with the same materials to be used in the Wing Leading Edge, Nosecap and Shingle of the Hermes Space Shuttle. The aim of these tests is to evaluate hot-structure material behaviour under controlled thermomechanical conditions.

They include:
- Testing under atmosphere thermomechanical reentry conditions
- Reentry test cycles on W.L.E. samples at 1550°C and 1700°C.
- Construction of a new nosecap testing facility and definition of test procedures for the 0.6 scale model of the shuttle nosecap.

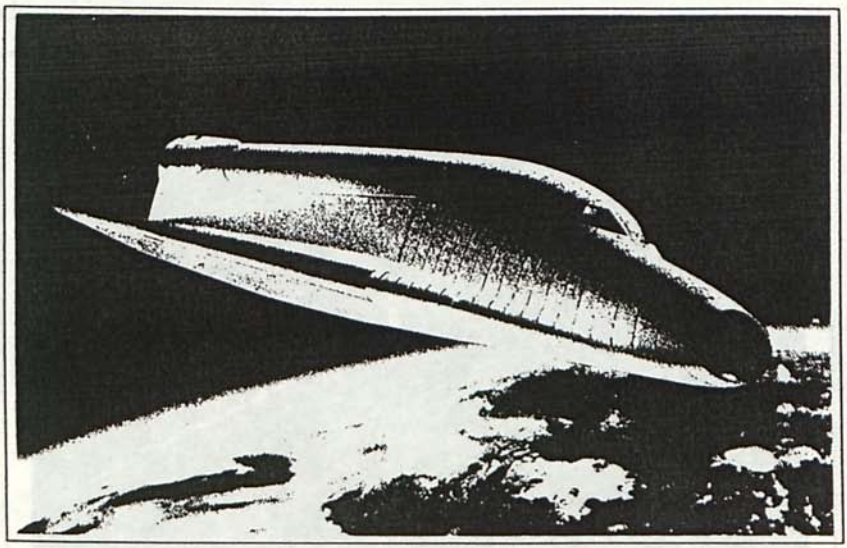


Fig. 13 The HERMES Space Shuttle

This ample program of activities demonstrates how solar technology is helping to expand knowledge of the young field of materials technology within the strict requirements imposed by aerospace standards.

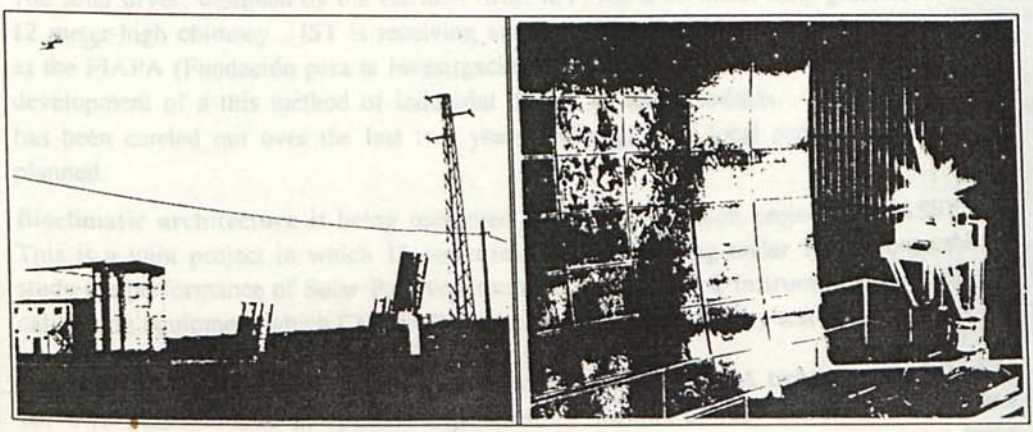


Fig. 14 The Solar Furnace Facility

The recently inaugurated **Solar Furnace**, now offers the scientific and engineering community a powerful tool for Physics, Chemistry and Materials Technology research experiments at very high controllable temperatures produced by concentrated radiation, as well as developing new furnace techniques. Initial Solar Furnace activities form part of the European Community's "Access to Large Scientific Installations Program". Experiments

with the PSA Solar Furnace will be in the area of high-temperature ZrO_2 research and metallurgical surface treatments, in collaboration with 6 different European research centers.

And finally, among other programs at the PSA, are the **solar convection dryer** and bioclimatic architecture.

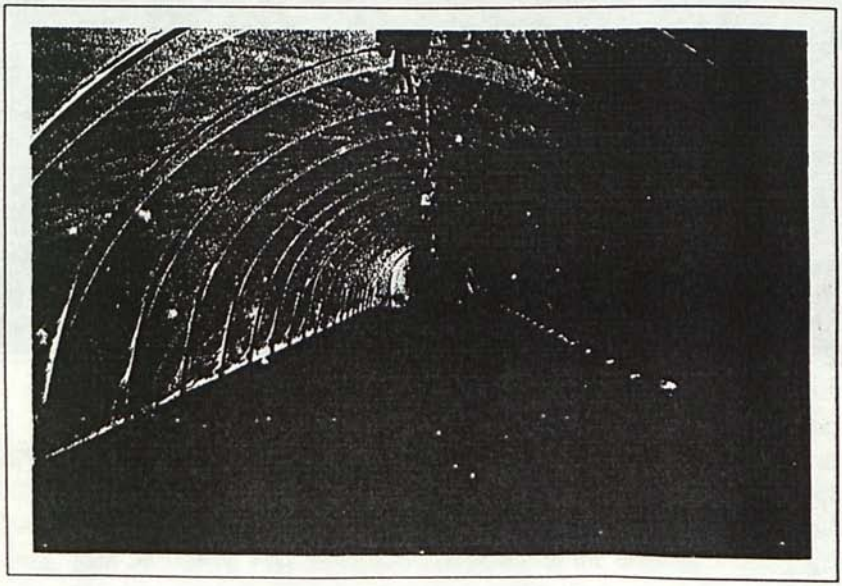


Fig. 15 The IST solar dryer

The solar dryer, designed by the German firm, IST, has a 20 meter-long greenhouse and a 12 meter-high chimney. IST is receiving ample collaboration from local institutions such as the FIAPA (Fundación para la Investigación Agraria de la Provincia de Almería), in the development of a this method of industrial drying of food products. Preliminary testing has been carried out over the last two years and drying of local produce is now being planned.

Bioclimatic architecture is being promoted at the PSA in such projects as **PASSYS II.** This is a joint project in which 11 countries are collaborating under EEC sponsorship to study the performance of Solar Passive Components using the 2 instrumented test cells and calibrating equipment which CIEMAT has set up at this high quality test site.

CIEMAT has also designed, erected and now operates at the PSA two test cells **(CESPA)** for own passsive solar component experiments. Results of roof component design and software control features are now being obtained. The experimentrs which are being carried out at the Plataforma Solar incorporate the new lines of research being investigated en Europe, such as natural cooling and conditioning of interiors in the Mediterranean summer climate. With these new installations, the activities at the Plataforma Solar de Almería broaden and diversify into other areas of research where the sun is the source of energy.

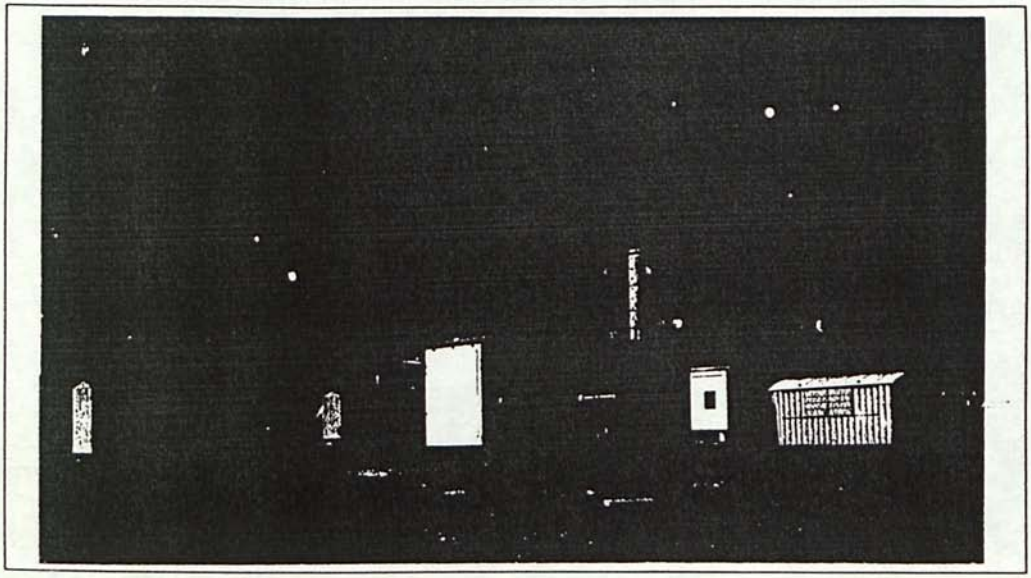


Fig. 16 The bioclimatic test cells

TRAINING AND EDUCATION have always played an important role in PSA activities. Students of engineering, physics, ecology, chemistry, etc., principally from Germany and Spain, but also from other countries, participate in the performance and evaluation of experiments, gain invaluable experience and contribute to the ongoing work. Our periodic courses in different aspects of solar energy applications and technology are also increasingly popular with management and engineers in the power industry who are interested in updating their knowledge of renewable energy.

In conclusion, we may say that in addition to this significant program, the outstanding and even unique Plataforma Solar facilities are available upon request to academic and industrial research centers for sophisticated test requirements in the fields of solar energy, space, materials, optics, etc.

We at the Plataforma Solar de Almería believe that this very ambitious program will demonstrate that solar thermal technology has numerous applications which even the most optimistic could not have expected a short time ago, and we are convinced that exciting results will be forthcoming for the international scientific, industrial and energy communities.