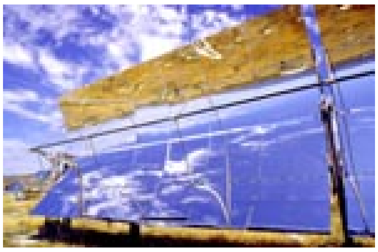
Annual Technical Report 1996

Contents:



Annual Technical Report 1996 Next: 2

1 - Overview of PSA Activities in 1996

Contents:

Manuel Blanco

Michael Geyer

Annual Technical Report 1996 Next: 2
Top: 1 - Overview of PSA Activities in 1996

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We'd like to hear from you.

1.1 - PSA: The European Solar Thermal Test Center

The Plataforma Solar de Almería (PSA), is a dependency of the Spanish Ministry of Industry and Energy's Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), the second largest Spanish research organization. Jointly operated by the CIEMAT and the German DLR Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V., it is today the largest European test center for concentrated solar energy applications.

Fig. 1.1: Aerial view of the Plataforma Solar de Almería

The origins of the PSA go back to the beginning of the 80's. From 1980 to 1984, in the Desert of Tabernas, at what is today the PSA, two large solar thermal technology demonstration projects were built and operated. They were part of a worldwide development effort in the field of solar thermal electricity production technologies promoted, at the time, by the developed countries in response to the high oil prices resulting from the oil crisis of the previous decade.

The first project, known as the SSPS (Small Solar Power Systems), was a project of the International Energy Agency (IEA), built and operated under the leadership of DLR, with the participation of nine countries (Austria, Belgium, Germany, Greece, Italy, Spain, Sweden, Switzerland, and the U.S.A). It consisted of the design, erection and testing of two solar thermal power systems of similar size, 500 kWe, and dissimilar technologies. One of these systems, called CRS or Central Receiver System, consisted of a field of computer-controlled mirrors called heliostats, which track the sun concentrating the reflected solar radiation on a receiver at the top of a tower.

There, the energy of the solar radiation was converted into thermal energy of a working fluid, in this case sodium. The sodium leaving the receiver at 520 ºC was, in turn, used to run a steam generator hooked up to a thermodynamic cycle for electricity production. The other, called the DCS or Distributed Collector System, was made up of a field of parabolic trough collectors, the axis of which was a tube where oil was heated by the concentrated solar radiation as it passed through the connected modules of the distributed collectors. This oil was in turn fed to a steam generator, which, as in the previous case, was hooked up to a thermodynamic cycle for electricity production, producing a similar amount of power.

The second project, known as CESA-1 (Central Electrosolar de Almería-1), was entirely designed and built with Spanish technology under the auspices of the Spanish Ministry of Industry. It consisted of a solar thermal central receiver system of 7 MWth nominal power, with 300 heliostats, a water/steam receiver operating at 520 ºC and 100 bar, and molten salt thermal storage.

Both projects were evaluated through 1984. The CESA-1 Project was also a test bed in 1985 and 1986 for the Spanish-German GAST Technology Program. Within this program, several different types of heliostats and two air-cooled receivers were tested, one metal and the other ceramic, reaching air temperatures of 800ºC and 1000ºC respectively at 10 bar.

By 1985, the collapse of oil prices led some governments and companies participating in the SSPS project to scale back or even withdraw their participation. The International Energy Agency, Germany and Spain initiated negotiations to determine the future use and ownership of the SSPS facilities and to establish a new frame of cooperation in the field of solar thermal technologies.

As a result of these negotiations in 1986 the ownership of all SSPS facilities was transferred to Spain; the "Plataforma Solar de Almería" was created by merging the SSPS facilities and the CESA-1 facility into one large solar thermal research installation and a Cooperation Agreement for long-range utilization of the Plataforma Solar de Almería was signed by DLR and CIEMAT.

From the beginning, PSA R&D activities started to diversify beyond solar thermal power generation. Research projects on new solar applications were initiated and new facilities erected. The diversification of research activities and infrastructures was paralleled by diversification of its sources of funding. Third party funding of PSA activities has grown steadily since 1987; today it represents around one third of the total PSA budget, which amounted to more than seven hundred million pesetas for 1996. The following milestones in the process of diversification and internationalization of the PSA are worth mentioning:

- 1988: The PSA is contracted by The European Space Agency (ESA) for testing of components of its HERMES Space Shuttle, simulating the thermal conditions to which these components would be subjected during reentry in the earth's atmosphere.

- 1990: The PSA earns European Commission (EC) qualification as a "Large-Scale Scientific Installation". Since then, the PSA has been contributing to European research in solar applications within the framework of the EC-DGXII "Large-Scale Scientific Installations", "Human Capital and Mobility" and "Training and Mobility of Researchers", and others related to them.

- 1994: The first important research contracts within the framework of the European Commission JOULE, APAS, and other programs are signed.

- 1996: Funding is obtained from the JOULE Program for the DISS project, an ambitious technology program the objective of which is a substantial reduction in the cost of the parabolic trough technology for solar thermal electricity generation.

- 1997: The PSA participates in two THERMIE projects, Colón Solar y THESEUS. Each of them constitutes in its respective technology (central receiver in Colón Solar and parabolic trough in THESEUS) the most important, serious and ambitious proposal to date for the installation of commercial solar thermal power plants in Europe.

Annual Technical Report 1996
Back: 1 - Overview of PSA Activities in 1996
Top: 1.1 - PSA: The European Solar Thermal Test Center
Next: 2
Next: 1.2

1.2 - General Objectives

Since its beginning, the prime objective of CIEMAT/DLR cooperation at the PSA has been the development of solar thermal concentrating technologies for electricity generation. At present, this objective continues to be a priority, but no longer is it the only one. The evolution of the PSA over the years, the success obtained in the process of diversification of activities and especially success in the development of precisely solar thermal concentrating technologies for electricity production have made it advisable to widen the range and reach of CIEMAT/DLR general objectives at the PSA. These objectives, which inspire the research activities carried out at the PSA are the following:

- Contribute to a clean and sustainable world energy supply.
- Contribute to the conservation of European energy resources and the protection of our climate and environment.
- Promote market introduction of the solar thermal technologies.
- Contribute to the development of a competitive European export solar industry.
- Reinforce cooperation between the electrical sector and scientific institutions in the field of research, development demonstration and marketing of the solar thermal technologies.
- Further cost-reducing innovation leading to market acceptance of solar thermal technologies.
- Promote North-South technological cooperation, especially in the Mediterranean Region.
- Support industry in the identification of solar technology business opportunities.

Annual Technical Report 1996
Last: 1.2 Back: 1 - Overview of PSA Activities in 1996 Next: 2
Next: 1.4

1.3 - Organizational Structure

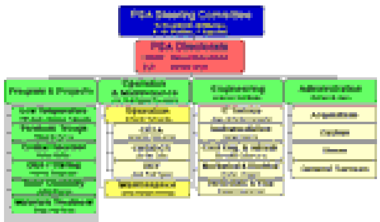


Fig. 1.2: PSA Matrix Management Organization as of 31.12.96

The management of research at the PSA is shared jointly and equally by Spain and Germany. The first is represented by CIEMAT and the second by DLR. The organizational structure adopted to carry out this co-management of research at the PSA is shown in Fig. 1.2.

It may be seen in this figure how the maximum decision-making organ is the "Steering Committee". This Committee, made up of two CIEMAT and two DLR representatives, approves and supervises all joint programs and projects conducted under the Cooperation Agreement. As stipulated in this Cooperation Agreement, the specific responsibilities of the Steering Committee (SC) are:

- Unanimously adopt the Program of Work and Budget of the Plataforma Solar every year, following a proposal by the Department of Renewable Energy of CIEMAT (CIEMAT-DER) that has been prepared in collaboration with DLR Managementdienst Energietechnik (DLR MD-ET).
- Appoint and control Task Leaders for the joint CIEMAT-DLR programs and projects.
- Approve by consensus all important matters concerning the joint programs on the PSA, such as new projects, major investments, external clients, major changes of personnel, etc.
- Make such rules and regulations as may be required to facilitate optimum cooperation at the Plataforma Solar.

Daily management of the PSA is delegated by the SC in a Directorate composed of two directors, one from the CIEMAT-DER and the other from the DLR MD-ET.

Finally, the PSA is organized within a matrix management structure into three service departments:

- Engineering,
- Operation & Maintenance, and
- Administration,

and into six program areas:

- Low Temperature Applications,

- Parabolic Trough Collectors,
- Central Receivers,
- Dish Technology,
- Solar Chemistry, and
- Material Testing.

The highly project-oriented nature of most PSA activities and the ever-increasing involvement of the PSA in international research contracts, has made it necessary to strengthen PSA capacity for project development and monitoring. In this regard, at the end of 1996, a new permanent operational unit was created. This unit, called the "Project Development and Monitoring Unit" is in charge of:

- Assisting the PSA Directors in planning and organizational activities,
- Assisting the PSA Directors and project leaders in the preparation of new project proposals,
- Monitoring the progress of PSA projects, contracts and budget, and
- Assisting the PSA directors and project leaders in keeping the PSA projects within budget and time constraints.

The Unit's two Directorate Staff members, Mr. Andrés López and Mr. Bernhard Milow, report directly to the PSA Directors, as do the Department and Area Heads.

It should be pointed out that the PSA organizational structure was intentionally conceived to completely integrate CIEMAT and DLR personnel. Such effective integration, which is very difficult to find in project cooperation between different countries, confers on the PSA the character of a true international research center and is one of its greatest competitive advantages.

Annual Technical Report 1996
Last: 1.2 Back: 1 - Overview of PSA Activities in 1996 Next: 2
Next: 1.4
Top: 1.3 - Organizational Structure

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Next: 1.5

1.4 - Resources

The PSA resources enabling it to carry out its objectives may be classified as:

- Solar insolation and other site-related resources,
- Facilities and infrastructure,
- Human resources,
- Funding.

The following sections briefly describe these resources

Contents:

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Next: 1.5
Top: 1.4 - Resources

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Next: 1.6

1.5 - Overview of 1996 PSA Projects and Activities

During 1996, projects and research activities were carried out in all PSA program areas (See Fig. 1.9). What follows is only a brief description of the most important. More exhaustive information on 1996 PSA projects and activities can be found in subsequent chapters

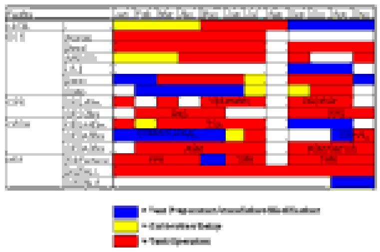


Fig 1.9: 1996 PSA Test Plan

Contents:

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Next: 1.6
Top: 1.5 - Overview of 1996 PSA Projects and Activities

Annual Technical Report 1996
Last: 1.5 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Next: 1.7

1.6 - PSA Milestone Achievements in 1996

- Erection of a new Solar Transmittance System in the LECE.
- Design and erection of a rotating device for the LECE Mediterranean test cells.
- Detailed design of the PSA DISS facility.
- Start of erection of the new third-generation dish/Stirling systems.
- Successful testing of the DLR CorRec ceramic volumetric receiver.
- Comparative testing of two new generation large-area heliostats, the German ASM150 and the Spanish GM100.
- Formation of a new consortium of local authorities and companies in Almería province and the PSA for design and construction of the first commercial solar detoxification plant.
- Thermal testing of the ESA Mars penetrator, STAMP, thermal protection shield.
- New EC Access to Large Scale Facilities Training and Mobility of Researchers Program contract.

Annual Technical Report 1996
Last: 1.5 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Next: 1.7
Top: 1.6 - PSA Milestone Achievements in 1996

Annual Technical Report 1996
Next: 2
Last: 1.6
Back: 1 - Overview of PSA Activities in 1996

1.7 - Plans for the Future

Reflecting the requirements of electrical equipment manufacturers and utilities, improvement of parabolic-trough technology and development of direct steam generating collectors have been the focus of new European Commission 4th Framework JOULE and THERMIE Program proposals. The effort exerted in these new developments and qualification of the next-generation technology proposed is a fine complement to parallel ongoing efforts in solar plant construction projects using current technology by preserving the technological leadership of the participants. With the inauguration of the first full row of solar direct steam generation collectors at the PSA in 1998, the participants will demonstrate their ability to supply and operate solar fields in upcoming projects.

In the field of central receiver technology, the PSA will work intensively with the Colón Solar consortium, initiating a program to substantially reduce the cost of heliostats and other central receiver components. In the field of receiver technology, an advanced pressurized air receiver concept for the integration in gas turbine cycles will be tested in 1997/98 in the so called REFOS experiment at the CESA-I tower. The TSA receiver system of the PHOEBUS consortium will be run to demonstrate its reliability to generate electricity in routine operation.

In a final step toward marketing of the dish/Stirling concept, participating German industry will test and demonstrate the first three of a pre-series of one hundred such units in the DISTAL II project. The hybridization and fossil/solar interfacing of these systems starts in 1997 under the EC-financed HYPIRE project. In future project proposals the industrial partners will attempt to reduce costs to less than 5 000 ECU/kW.

Future solar power equipment and system testing will focus on the integration of solar power into fossil-energy generation systems and their combination with biomass firing. In this field, the PSA has proposed the combination of solar and biomass gasification technologies for electricity production in a fully renewable power plant.

In 1998 and beyond, the PSA will also offer eight of its facilities for training of European researchers working in applied solar energy.

Contents:

Annual Technical Report 1996

Last: 1.6 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2

Top: 1.7 - Plans for the Future

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Back: 1.4 - Resources | Next: 1.5
Next: 1.4.2

1.4.1 - Solar Insolation and Other Site-Related Resources

The PSA is located in the Southeast of Spain in the Desert of Tabernas at 37º 05' 27.8" Latitude North and 2º 21' 19" Longitude West. With an annual direct insolation of over 1900 kWh/m^2 and average annual temperature of about 17ºC, the PSA is not only one of the sunniest places in Europe, but an exceptional site for the testing of solar systems.

These ideal conditions for a solar concentrating system test center conferred on it by its privileged climate are reinforced by the availability at the PSA and surrounding area of resources and infrastructures appropriate to the requirements of accessibility, supplies and connection to information networks of a research center of its caliber and importance. In spite of being located, as mentioned above, in the middle of a desert, the PSA is well connected, by a main artery of the Andalusian highway system nearby and the Almería airport which is less than 30 minutes away. As part of the IRIS network, it is also perfectly integrated into the world's information systems. This, together with its excellent intranet, structured around optic fiber connections, high-spec servers and a powerful modern personal computer pool, guarantee researchers excellent access to internal and external sources of information.

Thus, while the PSA offers a location with insolation and climatic characteristics similar to the developing and sunbelt countries, where the major market potential for solar thermal electricity generation is found, it has the advantage of installations with materials, infrastructure and computer systems as modern as any found in the most advanced countries of Europe, making it a most privileged site for demonstration and technology transfer.

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Back: 1.4 - Resources | Next: 1.5
Next: 1.4.2
Top: 1.4.1 - Solar Insolation and Other Site-Related Resources

1.4.2 - Facilities and Infrastructure

PSA activities have clearly diversified beyond solar thermal power plant R&D, as seen in the functions of its new and improved facilities, until it has become one of the three centers of its kind in the world and the most versatile in Europe. The infrastructure which it has developed and the technical successes it has obtained in such solar applications as sea-water desalination, water detoxification and the EC-DGXII programs of "Access to Large-Scale Scientific Installations", "Human Capital and Mobility" and "Training and Mobility of Researchers", have enabled the PSA to further offer its services as a test center to the aerospace industry and European Commission research projects within a Plan for Diversification and Services.

Today, the major test installations available on the PSA are:

- 7 MWth CESA-1 Central Receiver Test Facility,
- 2.7 MWth SSPS-CRS Central Receiver Test Facility,
- 1.2 MWth SSPS-DCS Parabolic Trough Test Faciltiy with Storage and Desalination,
- 3 x 33.5 kWth DISTAL I Parabolic Dish Test Facility,
- 0.6 MWth High-Flux Solar Furnace,
- Solar Detoxification Loop (SDL),
- Compound Parabolic Concentrator (CPC) Photoreactor,
- The SOLFIN (Solar Fine Chemicals Synthesis) Test Facility,
- The LECE (Building Components Test Laboratory) Facility.

The following sections describe these major facilities in more detail.

Contents:

Annual Technical Report 1996

Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2

Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5

Next: 1.4.3

Top: 1.4.2 - Facilities and Infrastructure

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.2 | Back: 1.4 - Resources | Next: 1.5
Next: 1.4.4

1.4.3 - Human Resources

The permanent PSA staff is made up of 77 persons, of which 25 are CIEMAT, 14 are DLR, 34 are subcontracted for maintenance and operation and 4 are subcontracted for security. Of this total of 77 persons, 65 are scientists, engineers and technicians, highly specialized and experienced in the field of solar energy.

Throughout its years of operation, the PSA has continuously added to and improved the education and training of its staff, its human capital, who have become worldwide experts in the solar field.

This dedicated team of scientist and engineers, experienced solar power technicians and highly skilled craftsmen, many of whom have been dedicating their skills and expertise to solar thermal activities since the late 1970s are one of the most valuable assets of the PSA.

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.2 | Back: 1.4 - Resources | Next: 1.5
Next: 1.4.4
Top: 1.4.3 - Human Resources

Annual Technical Report 1996
Last: 1.3 Back: 1 - Overview of PSA Activities in 1996 Next: 2
Last: 1.4.3 Back: 1.4 - Resources Next: 1.5

1.4.4 - Funding

The financial resources to carry out PSA research activities and projects and to maintain in optimum condition all its facilities and infrastructures come from three sources: the contributions of the Spanish and German governments made within the frame of their Cooperation Agreement and third party contributions. The first two, due to their institutional nature and according to this agreement are always equal, although the amount may vary from year to year depending on the state of the Spanish and German national budgets and the requirements of the PSA. The third is intrinsically variable and the amount depends on third party contracts signed by the PSA. This third party share has grown continually since the creation of the PSA until in recent years it is comparable to the contributions of Spain and Germany.

Specifically, in 1996, the PSA budget amounted to 710 million pesetas. The two partners of the Spanish-German Agreement each contributed 220 million pesetas. A total of 247 million pesetas was received in contributions to projects from the European Commission and 23 million pesetas was received from industrial clients.

Annual Technical Report 1996
Last: 1.3 Back: 1 - Overview of PSA Activities in 1996 Next: 2
Last: 1.4.3 Back: 1.4 - Resources Next: 1.5
Top: 1.4.4 - Funding

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6
Next: 1.5.2

1.5.1 - Low Temperature Application Projects

Industrial Thermal Processes

Although at present there is not very much research activity at the PSA in this field, the potential of solar thermal technologies for cost-effective driving of industrial thermal processes makes it likely that in the immediate future the situation will change.

A particularly promising and important application is Solar Thermal Water Desalination. Previous research projects carried out in the PSA Desalination Facility have demonstrated the feasibility of such systems to produce drinking water. Future activities address the installation of pilot plants in countries with plenty of sunlight but scarce water resources through European Commission programs. Additionally, the PSA Desalination Facility is being offered for training of European researchers within the EC Program of Access to Large-Scale Scientific Installations.

Testing of Building Materials and Solar Passive Components

Strictly speaking, this is not a project, but a service offered by the PSA on a continuous basis. Most testing is done in the LECE cells. Their purpose is to evaluate the reliability and efficiency of building materials and components as energy saving elements, and characterize their thermal and optical behavior. Access to the LECE Facility is also being offered within the EC Program of Access to Large-Scale Scientific Installations.

Furthermore, there are several short-term projects directly involving private companies and Spanish and other European research centers in this field of activity, among which the following may be named:

- ROOFSOL, for the study of roofing as an insulating element.
- MEDUCA, for the installation and monitoring of a bioclimatic system on the University of Almería campus.

Both projects are partially supported by the European Commission.

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6
Next: 1.5.2

1.5.2 - Parabolic Trough Collector Projects

Reflecting the interest of equipment manufacturers and electrical utilities, the PSA research activity in this field presently centers on the improvement of the parabolic-trough technology for electricity production and the development of direct steam generating collectors. A large fraction of PSA resources are dedicated to such projects as:

Direct Steam Generation (DISS)

This is the most important project now underway using this technology. It is partially financed by the European Commission-DGXII under the Joule III program (2 million ECUs) and has a total first phase project budget of 6.3 million ECUs. The objective is to erect a parabolic-trough test loop capable of feeding a turbine with steam produced in the collectors, to demonstrate the technical feasibility of direct steam generation in parabolic trough collectors and assess the cost reduction potential of this technology.

ARDISS

The objective is to develop advanced receivers appropriate for use in direct steam generation. A test bench has been erected at the PSA for this project.

Testing of Advanced Control Algorithms

Now in the third phase of this project, begun in 1990 and continued through successive EC-DGXII Access to Large Scientific Installations Programs, ten institutes from different European Union member countries have developed advanced control applications for DCS systems, using these collector fields as a test bed. Five doctoral theses have come out of it and three more are in process. The control schemes developed within this project have also been used to control other systems, such as conventional thermal power plants.

THESEUS Project

The objective of the THESEUS project is to implement a solar plant with parabolic trough collectors with an installed power of 50 MWe on the island of Crete in Greece. The PSA participates in the engineering of the solar field, in the determination of the techno-economical performances and environmental and social impact study. In continuation of the experience obtained with this technology in the nine SEGS solar plants in California, with a total capacity of 354 MW and accumulated solar generation of more than 5 GWh, the THESEUS project attempts to introduce the parabolic trough collector technology in the Mediterranean Region electrical sector.

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.5.1 | Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6
Next: 1.5.3
Top: 1.5.2 - Parabolic Trough Collector Projects

Annual Technical Report 1996
Last: 1.4 Back: 1 - Overview of PSA Activities in 1996 Next: 2
Last: 1.5.2 Back: 1.5 - Overview of 1996 PSA Projects and Activities Next: 1.6
Next: 1.5.4

1.5.3 - Central Receiver Projects

The CRS projects and research activities underway are:

Development of Low-Cost Heliostats

Since the cost of the heliostat field represents a considerable share of the total cost of a tower system (approximately 40% of the total), this line of research is of strategic importance for the market introduction of the tower technology. Since the beginning of the PSA, this activity has been attributed great importance, as much in the technological development initiatives of DLR, as those of CIEMAT and equipment manufacturers in the electrical sector of various countries.

Volumetric Receivers

This activity continues the development of volumetric receivers which use air as the cooling fluid. Within this line of work several test campaigns and complementary developments are going to be carried out in the immediate future. At present, 200 kWth volumetric receivers are being tested to obtain conclusive data on the feasibility, capacity for scale-up to high thermal efficiencies, validation of flow models and information on the lifetimes of materials. From the end of 1997, three different 400 kWth models of a pressurized air receiver will be tested.

RAS Project

This project has as its objectives exploration of possible advantages that a new concept of Advanced Salt Receiver developed by CIEMAT might have in comparison with other tubular receiver or direct absorption concepts. The project includes construction and evaluation of this type of receiver and comparison of its behavior to other more conventional receivers.

TSA (Technology Program Solar Air Receiver) Program

A 2.5 MWth air receiver with steam generator and energy storage has been built and tested within the 30 MWe PHOEBUS project. It represents an indispensable intermediate step toward 115 MWth capacity planned for the PHOEBUS concept receiver. The system already has accumulated more than 1000 hours of operation and is functioning perfectly.

THERMIE Colón Solar Project

This project, promoted by three important electrical utility companies (SEVILLANA, ENDESA y ELECTRICIDADE DE PORTUGAL), has as its main objectives:

- Demonstrate the feasibility of integrating solar energy into a conventional power plant.
- Evaluate the benefits that can be derived from its integration (increased efficiency, reduction in pollution, etc.)
- Take a first step toward market introduction of the CRS technology.
- Acquire experience in the commercial industrial operation of a central receiver system that can be used for the future development of this technology.

The PSA participates in this activity as general coordinator of the solar system engineering project and as technical consultant for the electric companies leading the project.

Annual Technical Report 1996
Last: 1.4 Back: 1 - Overview of PSA Activities in 1996 Next: 2
Last: 1.5.2 Back: 1.5 - Overview of 1996 PSA Projects and Activities Next: 1.6
Next: 1.5.4
Top: 1.5.3 - Central Receiver Projects

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.5.3 | Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6
Next: 1.5.5

1.5.4 - Dish Technology Projects

The PSA has actively participated in the development of the parabolic dish technology since 1991. The objective of these small to medium size units is their use as autonomous power generators in isolated areas. The projects currently ongoing at the PSA are:

DISTAL

This project is a feasibility and operability study of this type of systems based on the seven-day-week, sunrise-to-sunset routine operation of three 7.5 kWe units installed at the PSA. During this time an attempt is being made to identify and solve any possible problems before they are marketed. A data base with all this information will later serve as a basis for development of larger capacity units.

This project is also one of the EC Access to Large Scientific Installations Program activities.

DISTAL II

Three new and improved, larger capacity units, each able to generate up to 9 kWe, are now being erected.

25 kW Study

In continuation of the above projects, a new test program is about to begin, based on the design of a 25 kWe generating unit recently accepted as a project with possible subsidy from the European Commission, within the Joule-II Program.

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.5.3 | Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6
Next: 1.5.5
Top: 1.5.4 - Dish Technology Projects

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.5.4 | Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6
Next: 1.5.6

1.5.5 - Solar Chemistry Projects

Solar Detoxification of Industrial Effluents

The solar detoxification of aromatic organic components and heavy metals has been demonstrated with more than satisfactory results. Several environmental consultants and chemical companies have shown their interest in this application. The PSA has begun to experiment with their samples and has made studies of future pilot plants. The activities of the PSA during the coming years will focus on the installation of the first commercial plants for the solar photocatalytic treatment of water. At the same time the PSA attempts to become the main European center for applied solar photocatalysis, taking advantage of projects financed by the EC which involve detoxification.

High Temperature Detoxification Applications

A proposal is being elaborated to define a project for high temperature detoxification in the Solar Furnace following the line of current research projects being carried out at CIEMAT (Madrid) and DLR (Cologne).

Solaris II

The results obtained by DLR and RWTH (Aachen, Germany), in their joint project "Solaris I", tested at the PSA has encouraged a growing number of chemists and chemical engineers to continue to develop the production of fine chemicals with solar radiation.

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.5.4 | Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6
Next: 1.5.6
Top: 1.5.5 - Solar Chemistry Projects

1.5.6 - Thermal Treatment of Materials Activities

At present there are two thermal materials treatment facilities at the PSA: the Solar Furnace and the ESA test room in the CESA-1 Tower. The following projects and research activities are currently underway:

Advanced Materials Treatments in the Solar Furnace

Carried out under the European Commission's Access to Large Installations Programs (currently the TMR program) since 1991, several groups of European researchers have studied possibilities for using highly concentrated sunlight in the thermal treatment of metals and ceramics for industry. This may be approached from two viewpoints.

- Making existing industrial treatments more environment-friendly and energy-saving, and even, due to the peculiarities of the solar spectrum, improving the characteristics of the material.

- Experimenting with treatments which, using the extremely high density of the solar energy applied instantly to the surface of the material, are impossible with conventional means. The path followed is marked by laser treatments, which can apply very high energy densities, but only to very small areas at a time.

The short range goal is to develop, with the support of various European research groups, a new optimized unit, with greater concentrating capacity and better optical quality, so that the following step toward the implementation of industrial demonstration units can be taken.

Cooperation with IVTAN in the Solar Furnace

The Institute of High Temperatures of the Russian Academy of Sciences in Moscow, has had a Cooperation Agreement with the Plataforma Solar for several years. Through this Agreement, materials for Russian satellites have been tested since 1994. They have also installed a vacuum chamber in the furnace which permits treatment under controlled atmospheres (inert or vacuum).

Treatments on Aerospace Materials for the ESA

The object of these tests is to validate the various concepts of composite ceramics for use as thermal protection of the European Space Agency's space vehicles. At present there are two test rooms in the CESA-1 tower, both equipped with the infrastructure necessary to expose the test pieces to solar concentrated radiation supplied by the 300-heliostat field of the CESA-1 Project. These prototypes are supplied by the companies contracted by the ESA to develop the materials (Dassault Aviation, Dornier, Aerospatiale, SEP). In 1996, a reduced-scale probe for depositing scientific instruments on the surface of Mars was tested. In 1997, Dornier is planning to test several different components of a capsule now under development.

Annual Technical Report 1996
Last: 1.4 Back: 1 - Overview of PSA Activities in 1996 Next: 2
Last: 1.5.5 Back: 1.5 - Overview of 1996 PSA Projects and Activities Next: 1.6
Next: 1.5.7
Top: 1.5.6 - Thermal Treatment of Materials Activities

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.5.6 | Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6

1.5.7 - Scientific Cooperation, Training and Education

As a partner in the European Commission's DGXII research program Training and Mobility of Researchers (TMR) under its "Access to Large-Scale Facilities" (LSF) program, PSA involvement in this activity has been of growing importance. EC support is intended operating and other costs to subsidize originating from the use of PSA facilities by groups of Community scientists who would otherwise not have access to them.

During recent years, the TMR contribution to the PSA provided access to user groups from all over Europe. From 1996 to 1998, fifty researchers of fifteen European member countries have applied for 256 weeks of access to the various PSA facilities within the TMR program.

During 1996 the PSA has continued to successfully cooperate with research institutions and industry from Europe, USA, Russia, Australia and other countries under the International Energy Agency's SolarPACES program.

In the area of training and education, the PSA student program has played a very important role, allowing a large number of Spanish, German and other international students access to the PSA.

Annual Technical Report 1996
Last: 1.4 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.5.6 | Back: 1.5 - Overview of 1996 PSA Projects and Activities | Next: 1.6
Top: 1.5.7 - Scientific Cooperation, Training and Education

Annual Technical Report 1996
Last: 1.6 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Back: 1.7 - Plans for the Future | Next: 1.7.2

1.7.1 - Cooperation with Industry and Electric Utilities

The major Spanish electric utility companies, ENDESA, IBERDROLA and SEVILLANA are active partners of the PSA in the DISS (Direct Solar Steam generation in parabolic troughs) and COLON SOLAR (Commercial solar tower and fossil fuel combined-cycle plant) projects. The Colon Solar group, coordinated by the Andalusian utility, SEVILLANA, has contracted the PSA for engineering support, testing of heliostats and other new Colon Solar equipment. Six German electric utilities are also committed to sponsor the DISS project in 1997. In the THESEUS Project, Preussen Elektra of Germany and ENEL of Italy are the electrical utility partners of Pilkington Solar International in the development of a 50 MW solar parabolic trough plant on the island of Crete. In the southern Mediterranean, the Egyptian Electric Authority (EEA), the Jordanian National Electricity Company (NEPCO) and the Office Nationale d'Electricité (ONE) of Morocco are currently developing solar thermal projects in close contact with industry and the PSA. In India, the German KfW and the World Bank have secured financing for an integrated solar combined-cycle plant, for which an RFP is now being prepared.

Annual Technical Report 1996
Last: 1.6 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Back: 1.7 - Plans for the Future | Next: 1.7.2
Top: 1.7.1 - Cooperation with Industry and Electric Utilities

Annual Technical Report 1996
Next: 2
Last: 1.6
Back: 1 - Overview of PSA Activities in 1996
Last: 1.7.1
Back: 1.7 - Plans for the Future
Next: 1.7.3

1.7.2 - Education,Training and Scientific Cooperation

The PSA will continue to ensure the scientific quality users require in the most important PSA vehicle for scientific cooperation with European partners by allocating appropriate budget and personnel. Special emphasis will be placed on its support of European industry and research groups in research networks.

For the tutoring of academic thesis work, the PSA shares laboratories and facilities and exchanges teaching personnel with the University of Almería (UAL), for which CIEMAT and DLR both signed agreements in 1996. Based on these agreements, a new cooperative student program, including doctoral courses and a new expert course, will start in 1997.

The successful ongoing cooperation with research institutions and industry from Europe, USA, Russia, Australia and other countries within the SolarPACES program of the International Energy Agency makes newest results of the PSA research work directly available to other solar energy research teams and their achievements can be used for further planning at the PSA.

Annual Technical Report 1996
Next: 2
Last: 1.6
Back: 1 - Overview of PSA Activities in 1996
Last: 1.7.1
Back: 1.7 - Plans for the Future
Next: 1.7.3
Top: 1.7.2 - Education,Training and Scientific Cooperation

Annual Technical Report 1996
Next: 2
Last: 1.6
Back: 1 - Overview of PSA Activities in 1996
Last: 1.7.2
Back: 1.7 - Plans for the Future

1.7.3 - PSA as a Bridge to Cooperation with Mediterranean Neighbors

In the heart of the growing Mediterranean market for electricity generation, industrial energy needs and increasing air conditioning demands for individual comfort, the PSA offers German, Spanish and other European manufacturers and developers an ideal, and as yet unused, strategic bridge to the rising Mediterranean solar markets with favorable connections to local authorities, consumer, industry, trade and tourist associations on one hand and experienced bilingual engineers and technicians, technological infrastructure and communications on the other.

By participating with other institutions in numerous research networks, the PSA extends its capacity for transferring solar technology from the research lab to the regional and Mediterranean marketplace with other participating Spanish, German and other European developers of industry and technology, supporting the growing regional authority, equipment manufacturer, vendor and end user efforts by supplying them with information on project opportunities and new European/Mediterranean solar technology ventures as well as providing solar testing, engineering and O&M support. For this goal, the PSA is constantly strengthening its engineering capacity with personnel, tools and training as required by the growing solar market demand in:

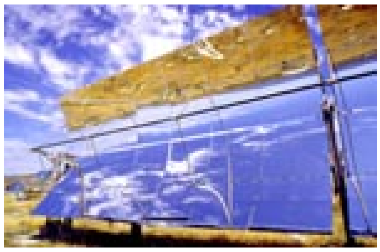
- Integration of solar power with fossil energy generation.
- Combination of solar power and biomass.
- Solar-aided desalination and cogeneration.
- Solar-aided heating and cooling of large Mediterranean building complexes.
- Solar-aided agricultural applications in the Mediterranean.
- Integration of solar technologies in Mediterranean industrial processes.
- Solar detoxification of industrial and agricultural effluents in waste water and air.
- Participation in solar exhibitions and industrial fairs.
- Operation and maintenance of pilot facilities.
- Solar engineering and consulting services.
- Education and training.

In upcoming years, the PSA will set a new focus on optimizing its services to such market needs and actively develop cooperation and technology transfer projects involving German, Spanish and Mediterranean industry.

Annual Technical Report 1996
Next: 2
Last: 1.6
Back: 1 - Overview of PSA Activities in 1996
Last: 1.7.2
Back: 1.7 - Plans for the Future
Top: 1.7.3 - PSA as a Bridge to Cooperation with Mediterranean Neighbors

Annual Technical Report 1996

Contents:

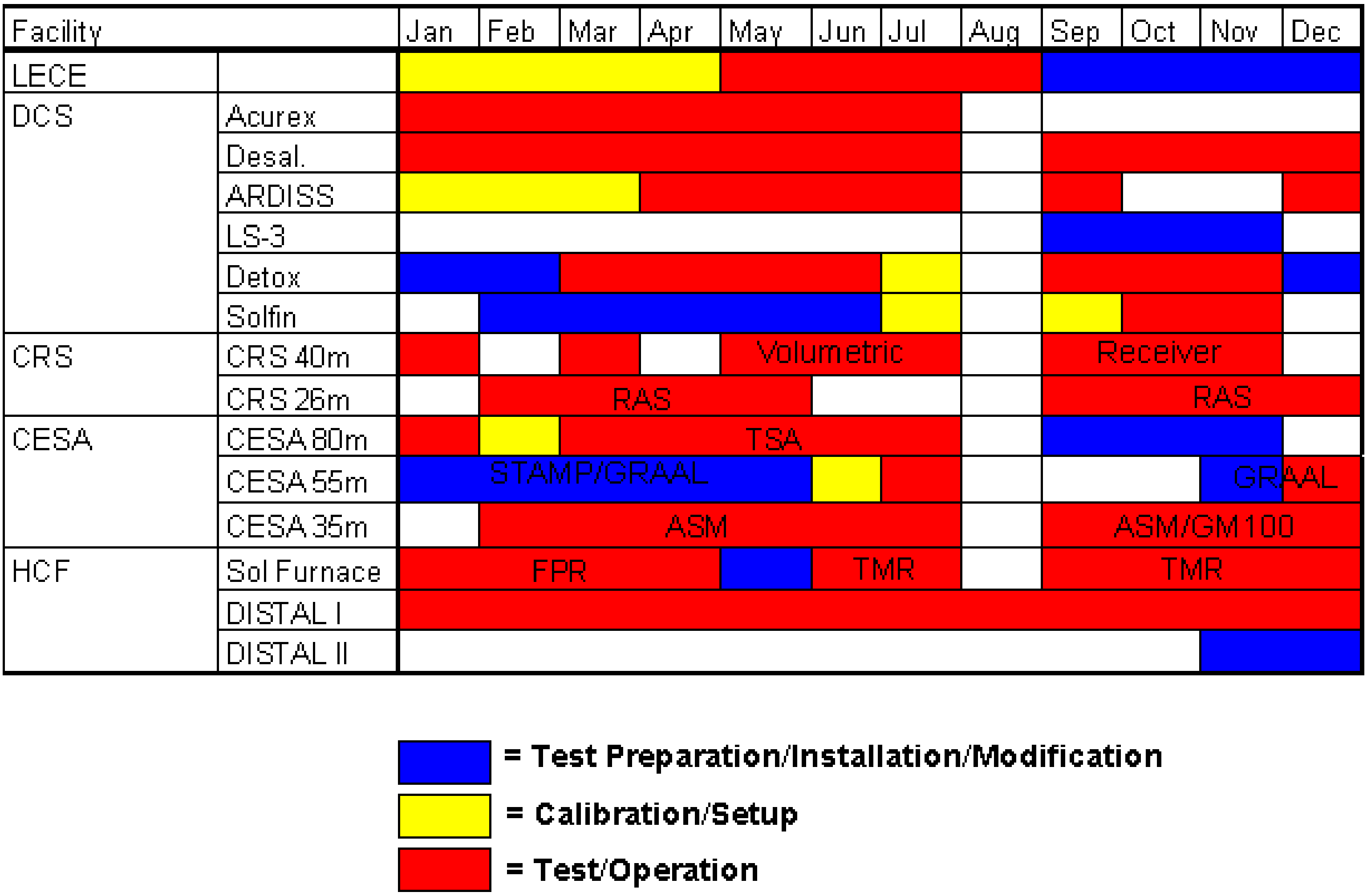


Last: 1 Annual Technical Report 1996 Next: 3

2 - Technical Description and Project Achievements

Contents:

Last: 1 Annual Technical Report 1996 Next: 3
Top: 2 - Technical Description and Project Achievements


Facility
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
LECE
DCS
Acurex
Desal.
ARDISS
LS-3
Detox
Solfin
CRS
CRS 40m
Volumetric
Receiver
CRS 26m
RAS
RAS
CESA
CESA 80m
TSA
CESA 55m
STAMP/GRAAL
GRAAL
CESA 35m
ASM
ASM/GM100
HCF
Sol Furnace
FPR
TMR
TMR
DISTAL I
DISTAL II
= Test Preparation/Installation/Modification
= Calibration/Setup
= Test/Operation

1.4.2.1 - 7 MWth CESA-1 Central Receiver Test Facility

The CESA-1 central receiver test facility heliostat field has 300 individual-tracking 39.6 m^2 heliostat units with an average (clean) reflectivity of 90%, tracking error per axis of 1.5 mrad and beam quality characterized by 3.0 mrad. Maximum field power is 7 MWth. At design insolation of 950 W/m^2, a peak flux of 3.3 MW/m^2 can be achieved on the aperture plane with 99% of the power concentrated within a 4 m-diameter circle and 90% within a 2.8 m-diameter circle.

Fig. 1.3: Aerial view of CESA-1 and SSPS-CRS Facilities

The top of the central concrete tower has a capacity of approx. 100 t. Major test locations are:

- A 10-m-diameter platform on the roof 80 m above ground.
- An area in front just below the top.
- A 4.5 m x 4.5 m test room 60 m above ground.
- A 0.5 m x 0.5 m test room 45 m above ground.

The tower has a 5-t crane on top and a 250-kg-capacity elevator for personnel and equipment.

Annual Technical Report 1996
Back: 1 - Overview of PSA Activities in 1996
Back: 1.4 - Resources
Back: 1.4.2 - Facilities and Infrastructure
Last: 1.3
Last: 1.4.1
Last: 1.4.2.1
Next: 2
Next: 1.5
Next: 1.4.3
Next: 1.4.2.3

1.4.2.2 - 2.7 MWth SSPS-CRS Central Receiver Test Facility

The SSPS-CRS central receiver test facility has 93 first-generation 39.3 m^2 and 20 second-generation 52 m^2 and 65 m^2 individual-tracking heliostat units. Their average (clean) reflectivity is 87%, tracking accuracy 1.2 mrad error per axis and beam quality characterized by 1.5 mrad. At design insolation of 950 W/m^2 a peak flux of 2.5 MW/m^2 can be achieved, with 99% of the power concentrated within a 2.5 m diameter circle and 90% within a 1.8 m diameter circle.

Fig. 1.4: Aerial view of SSPS-DCS facility

The 20-t-capacity steel tower provides two test platforms, one on the tower top at 43 m above ground and another at an intermediate 24 m level. The tower has a 600 kg capacity crane on the top and a 1000 kg capacity elevator for personnel and equipment.

Annual Technical Report 1996
Back: 1 - Overview of PSA Activities in 1996
Back: 1.4 - Resources
Back: 1.4.2 - Facilities and Infrastructure
Last: 1.3
Last: 1.4.1
Last: 1.4.2.1
Next: 2
Next: 1.5
Next: 1.4.3
Next: 1.4.2.3
Top: 1.4.2.2 - 2.7 MWth SSPS-CRS Central Receiver Test Facility

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.2 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.4

1.4.2.3 - 1.2 MWth SSPS-DCS Parabolic Trough Test Facility with Storage and Desalination

This SSPS-DCS first-generation parabolic-trough collector field consists of 40 Acurex 3001 collectors grouped in 10 East-West oriented loops with two rows per loop and two collectors per row. The total collector field aperture area is 2 672 m^2 with an average (clean) mirror reflectivity of 92% and tracking error of less than 0.25º. The collector absorber tubes are black chrome-coated steel and use synthetic thermal oil as the operating fluid. The operating range is between 180 ºC and 290 ºC. At 950 W/m^2 design insolation, a peak thermal output of 1.3 MWth can be reached at noon. The 114 m^3 thermocline tank stores approximately 5 MW thermal energy between 225 ºC and 295 ºC hot oil temperatures. The daily thermal energy delivered by the collector field is about 6.5 MWh.

A 14-cell Multi-effect Distillation (MED) plant for sea-water desalination, which consumes 190 kWth, is connected to the parabolic trough field and has a nominal output of 3 m^3/h of desalinated water. The performance ratio is 9 kg distillate per 2 300 kJ heat input. The output salinity is 50 ppm total dissolved solids.

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.2 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.4
Top: 1.4.2.3 - 1.2 MWth SSPS-DCS Parabolic Trough Test Facility with Storage and Desalination

Annual Technical Report 1996
Back: 1 - Overview of PSA Activities in 1996
Back: 1.4 - Resources
Back: 1.4.2 - Facilities and Infrastructure

Last: 1.3
Last: 1.4.1
Last: 1.4.2.3

Next: 2
Next: 1.5
Next: 1.4.3
Next: 1.4.2.5

1.4.2.4 - 3 x 33.5 kWth DISTAL I Parabolic Dish Test Facility

This facility provides three individual-tracking polar-mounted parabolic dishes. Each dish consists of a 7.5 m diameter, single-facet stretched-membrane concentrator with an average (clean) reflectivity of 94%. At design insolation of 950 W/m^2 a peak flux of 850 W/cm^2 can be achieved with 90% of the power concentrated within a 9 cm diameter circle. The focal length of each dish is 4.5 m.

View of the DISTAL I Parabolic Dish Test Facility

Annual Technical Report 1996
Back: 1 - Overview of PSA Activities in 1996
Back: 1.4 - Resources
Back: 1.4.2 - Facilities and Infrastructure

Last: 1.3
Last: 1.4.1
Last: 1.4.2.3

Next: 2
Next: 1.5
Next: 1.4.3
Next: 1.4.2.5

Top: 1.4.2.4 - 3 x 33.5 kWth DISTAL I Parabolic Dish Test Facility

1.4.2.5 - 0.6 MWth High-Flux Solar Furnace

In the high-flux solar furnace sunlight is reflected onto a large parabolic dish mirror by four 53.61 m^2 heliostats with 90% average (clean) mirror reflectivity, each illuminating a quarter of the mirror. At design conditions, the parabolic dish mirror is capable of concentrating 0.6 MW of radiant power on a circular focal spot 20 cm in diameter with a Gaussian flux distribution reaching power densities up to 3 000 kW/m^2.

Fig. 1.6: View of the High Flux Solar Furnace

The large parabolic mirror is made up of 89 (0.91 m x 1.21 m) sandwich facets, and has a total width of 11.01 m and a height of 10.41 m. It has a total reflective surface area of 98.51 m^2 with an average (clean) reflectivity of 92%, focal length of 7.45 m and a focal height of 6.09 m. Concentration of sunlight is controlled by an 11.44 m x 11.20 m louvered shutter with thirty 5.60 m x 0.93 m slats. The shutter can be set to 15,800 positions between 0º (open) and 55º (closed), with a fastest closing time of 5 seconds. Experiments can be mounted on a 0.7 m x 0.6 m test table movable on three axes. The concentrator test table and shutter are located inside the solar furnace building.

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.4 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.6
Top: 1.4.2.5 - 0.6 MWth High-Flux Solar Furnace

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.5 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.7

1.4.2.6 - Solar Detoxification Loop (SDL)

Fig. 1.7: Partial view of Solar Chemistry Facilities

The Solar Detoxification Loop consists of 12 two-axes solar tracking parabolic trough collectors, called Heliomans, originally designed to concentrate and transform solar radiation into thermal energy by heating thermal oil to 290 ºC, which has been modified for solar chemical applications. The concentration factor is 10.5 suns and the energetic efficiency achieved in the UV solar spectrum is 58%, which indicates the ratio between the number of UV photons reaching the collector aperture area and the number of these photons available inside the absorber tube where the reaction takes place. The solar collector used consists of a turret on which there is a platform supporting 4 parabolic trough collectors with the absorber in the focus. The platform has two motors controlled by a two-axes (azimuth and elevation) tracking system. Thus the collector aperture plane is always perpendicular to the solar rays, reflected by the parabola onto a borosilicate glass tube at the focus through which the contaminated water to be detoxified circulates. The reactor is 216 m long with an inner diameter of 56 mm. The 12 modules, in two rows of 6 each, are connected in series by pipes in such a way that any one of them may be eliminated or modified with a bypass valve on each. Modules are 12 m apart with 10.5 m between rows. The nominal aperture area of each module is 32 m^2, implying a total effective loop aperture area of 384 m^2. Residence time, or the time that each unit of the test liquid volume is exposed in the absorber, is computer controlled. Simultaneously, different process parameters are continuously measured by on-line instrumentation, transmitted to the Data Acquisition System (DAS) and sent to the computer which is constantly controlling the process and recording data. Maximum admissible working pressure is 6 bar and maximum pressure drop is 3 bar. Total loop capacity is 838 liters and flowrate can be altered and controlled from 500 to 3 000 l/h.

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.5 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.7
Top: 1.4.2.6 - Solar Detoxification Loop (SDL)

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.6 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.8

1.4.2.7 - Compound Parabolic Concentrator (CPC) Photoreactor

This low concentration photoreactor, built by Industrial Solar Technology Corp., consists of eight 48 mm diameter tubes mounted in compound parabolic concentrators (CPC). Each CPC reflector is 152 mm wide and 1 m long. The bank of tubes is inclined at approximately 37º facing south. According to the manufacturer, the acceptance angle for the CPC is 60º either side of the normal. This wide acceptance angle allows the reflector to direct both direct-normal and diffuse sunlight onto the receiver tube.

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.6 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.8
Top: 1.4.2.7 - Compound Parabolic Concentrator (CPC) Photoreactor

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.7 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.9

1.4.2.8 - The SOLFIN (Solar Fine Chemicals Synthesis) Test Facility

The SOLFIN facility consists of a small closed-loop solar-photochemical production plant. The reaction mixture is pumped from a supply vessel through the solar photoreactor system, a Compound Parabolic Collector (CPC). Heat absorbed by radiation and convection is discharged in the cooling system (process cooler and plate-type heat exchanger) to keep the liquid temperature below 20 ºC. If necessary, reactant gas can be introduced in the reaction mixture by a static mixer after the pump. Sensors measure temperature, pressure and mass flow along the loop. The loop components are connected by tubes. The total loop volume can be varied from 7 to 25 liters.

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.7 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Next: 1.4.2.9
Top: 1.4.2.8 - The SOLFIN (Solar Fine Chemicals Synthesis) Test Facility

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.8 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3

1.4.2.9 - The LECE (Building Components Test Laboratory) Facility

The laboratory consists of several 16 m^3 cube-shaped test cells. They are thermally insulated and for any given test, one of the walls can be substituted by the element to be tested. Tests may measure component thermal losses, determine optical properties, such as transmittance of sunlight, etc.

Fig. 1.8: View of LECE test cells

In the LECE, any type of element used in construction can be tested under real outdoor conditions. All the corresponding test procedures have already been developed and verified.

The LECE has been a key factor in PSA participation in important European Commission projects such as the PASSYS II, COMPASS and PASCOOL. Within the framework of these projects, some new test cells were developed and erected, such as the CIEMAT CESPA cells. These cells, manufactured at the PSA, have an innovative mobile base which enables testing under different sunlight orientation and shadow conditions.

Annual Technical Report 1996
Last: 1.3 | Back: 1 - Overview of PSA Activities in 1996 | Next: 2
Last: 1.4.1 | Back: 1.4 - Resources | Next: 1.5
Last: 1.4.2.8 | Back: 1.4.2 - Facilities and Infrastructure | Next: 1.4.3
Top: 1.4.2.9 - The LECE (Building Components Test Laboratory) Facility

UAL

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Last: 1 Annual Technical Report 1996 Next: 3

2 - Technical Description and Project Achievements

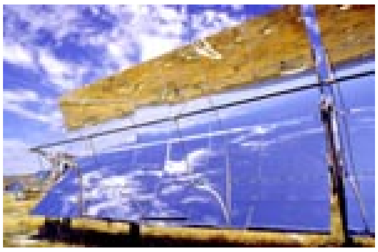
Contents:

Last: 1 Annual Technical Report 1996 Next: 3

Top: 2 - Technical Description and Project Achievements

Annual Technical Report 1996

Contents:



Last: 2 Annual Technical Report 1996 Next: 4

3 - Operation & Maintenance

The Operation and Maintenance (O&M) activities in 1996 were carried out as planned, with the exception of some modifications due to storm damage (CESA-I facets and RAS salt pipes).

José Antonio Rodríguez Povedano

Antonio Valverde

Javier León

Contents:

José Rodríguez

Last: 2 | Annual Technical Report 1996 | Next: 4

Top: 3 - Operation & Maintenance

2.1 - Low Temperature Applications

Knowledge of the energy behavior of building components is the key to good building design. New legislation in EU countries (Construction Elements Directives 89/106/CEE and SAVE 93/76/CEE) and public awareness are setting new energy quality standards for the construction sector. Also, new passive design solutions are being used as alternatives to traditional fuel consumption. At the Plataforma Solar, the Area of Low Temperature's LECE laboratory offers the building sector and research centers working in this field the opportunity to test both already existing components and new innovative designs.


María José Jiménez


Guillermo Schwartz


Juan de Dios Guzmán

Contents:

Last: 1
Last: 2.1
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Next: 3
Next: 2.3

2.2 - Parabolic Trough Technology

The activities of the Parabolic Trough Technologies Area during 1996 were grouped into six projects.

Eduardo Zarza

Pedro Balsa

Andrés López

Contents:

Last: 1
Last: 2.1
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Next: 3
Next: 2.3
Top: 2.2 - Parabolic Trough Technology

Last: 1
Last: 2.2
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Next: 3
Next: 2.4

2.3 - Dish / Stirling Systems

Martin Stegman

More then 120 years ago the famous inventor **Ericsson** designed the “sun-engine”, the first dish/Stirling system. Later, with the invention of the combustion engines, the further development of Stirling engines was limited to the isolated activities of some enthusiastic researchers.

The dish/Stirling technology saw a comeback after the first energy crisis in 1973 with the development of the **Vanguard** 25 kWe system, which still holds the world record in solar-to-electrical energy conversion efficiency of over 29%.

An important step forward was taken in 1988 when Schlaich Bergerman und Partner (SBP) decided to improve the V160-engine and develop an appropriate dish. The highlight of this commitment up to now has been the 25,000 hours of pure solar operation accumulated at the PSA **DISTAL I** facility.

The dish/Stirling technology, which covers the gap between the small “Solar Home Systems” (PV technology) and Solar Power Plants (parabolic trough and central receiver technologies) in a single unit range of from 5 kWe to 50 kWe, has its greatest potential use in the scattered villages and small towns of the sparsely populated regions of the world’s sun-belt, where there is no large grid. Its modular design makes a farm-type plant easily adaptable to a rising energy demand by adding further units.

Technical maturity and reliability has already been achieved. The main objectives now are, on the one hand, hybridization with gas, on the other, exploitation of the enormous potential of cost reduction by production in series.

In 1996 the PSA main activities in the dish / Stirling area were:

1. Continuation of the long-term testing and operation of **DISTAL I**
2. Site preparation and erection of three new and improved dish / Stirling systems (**DISTAL II**)
3. Performance of the **DISTAL I** Center- Dish with Hydrogene as the working gas
4. Site preparation and erection of the HTC ‘Fix Focus’ dish
5. Comparison of Dish/Stirling- and PV- Systems

Contents:

Last: 1 | Annual Technical Report 1996 | Next: 3
Last: 2.2 | Back: 2 - Technical Description and Project Achievements | Next: 2.4

Top: 2.3 - Dish / Stirling Systems

Last: 1
Last: 2.3
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Next: 3
Next: 2.5

2.4 - Solar Tower Generating Systems

Contents:

Peter Heller

Gary Weinrebe

Javier León

Antonio Valverde

Rafael Monterreal

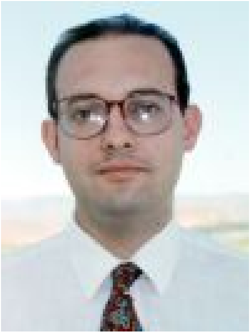
Ginés García

Team Developers of this PSA Web site thank you for visiting our site.
We'd like to hear from you.

Last: 1
Last: 2.4
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Next: 3
Next: 2.6

2.5 - Solar Chemistry

Contents:



Julián Blanco

Sixto Malato

Christoph Richter

Last: 1
Last: 2.4
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Next: 3
Next: 2.6
Top: 2.5 - Solar Chemistry

Last: 1
Last: 2.5
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Next: 3

2.6 - Materials Treatment

The activities of the PSA Materials Testing Area in 1996 have been devoted to the EU-DGXII ‘Training and Mobility of Researchers Program’, within the ‘Access to Large-Scale Facilities’ activity.

Thermal treatment has been carried out in the High Flux Concentration Facility (HFCF) for several European Research Groups. The PSA has also cooperated with the French aerospace company, ‘Dassault Aviation’ in the European Space Agency’s ‘Stamp’ project, for which critical thermal testing of a Mars probe prototype thermal shield was carried out in the CESA-1 tower materials test room.

Diego Martínez
Head of Materials Testing

Contents:

José Rodríguez
HFCF Facility Manager

Last: 1
Last: 2.5
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Next: 3
Top: 2.6 - Materials Treatment

Last: 1
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.1 - Low Temperature Applications
Next: 3
Next: 2.2
Next: 2.1.2

2.1.1 - The LECE

The LECE (**L**aboratorio de Ensayos **E**nergéticos para **C**omponentes de **E**dificación) on the south side of the PSA, forms part of the European PASSYS network of laboratories for energy testing of construction materials. It consists of four test cells with complete instrumentation for testing of the thermal performance of building materials and passive solar components under real outdoor conditions (See Fig. 2.1.1). The LECE carries out the experiments as part of a continuous action of the CIEMAT solar energy buildings R&D section.

Fig. 2.1.1: The LECE Laboratory

Last: 1
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.1 - Low Temperature Applications
Next: 3
Next: 2.2
Next: 2.1.2
Top: 2.1.1 - The LECE

2.1.2 - The Test Cells

Fig 2.1.2: Interior of a LECE test cell.

The test cells, which are well insulated by 40-cm thick polystyrene walls, are approximately the same size as a standard room. The opposite wall to the service room and the roof may be substituted by a test specimen. Once the test components are installed, the test sequence, procedures for different power and temperature conditions in the interior of the test cell, is started up.

Through the continuous measurement of various parameters, some of the thermal properties of the component, such as the overall thermal loss coefficient (UA), solar gain factor (gA), or system time response () can be determined.

These properties allow the reliability of these elements for energy savings in buildings to be assessed.

The existing laboratory equipment is:

- 4 test cells.
- 1 solar transmittance sensor (STS) for translucid panes.
- 2 data acquisition systems with a total of 350 channels.
- 120 surface temperature measuring points. (approx. 30/cell).
- 40 internal air temperature measuring points (approx. 10/ cell).
- 2 systems for measurement of air- tightness in components and buildings (tracer gas and pressurization methods).
- 4 heat flux sensors.
- 4 hot-wire low wind speed anemometers.
- 3 pyrometers.
- 2 humidity sensors.
- 2 automatic cooling systems.
- 4 automatic heating systems.
- 1 meteo station
- 1 Pseudo Adiabatic Shell (PAS), installed in one of the cells.

Last: 1
Annual Technical Report 1996
Next: 3
Back: 2 - Technical Description and Project Achievements
Next: 2.2
Last: 2.1.1
Back: 2.1 - Low Temperature Applications
Next: 2.1.3

Last: 1 | Annual Technical Report 1996 | Next: 3
Back: 2 - Technical Description and Project Achievements | Next: 2.2
Last: 2.1.2 | Back: 2.1 - Low Temperature Applications | Next: 2.1.4

2.1.3 - New Infrastructure at the LECE

One of the main tasks at the LECE, after having been developed under different European programs, was to complete the infrastructure needed to become an up-to- standards laboratory. Therefore, during the last two years, the LECE facility has been greatly improved. The changes range from improved instrumentation to acquiring completely new measuring capabilities (See Fig. 2.1.4).

Fig 2.1.3: PASSYS and CESPA Mediterranean test cells.

Fig 2.1.4: View of STS on Helioman Module.

To start with, the laboratory has now been provided with a small workshop so that some of the construction and assembly tasks can be performed by the LECE personnel themselves. This enables the lab to resolve the small technical problems that come up in all projects and speed up their completion.

As a second improvement, the facility's data acquisition system has been transformed into a more user-friendly tool so that any researcher can use the system straight away. It is also now connected by local net to the main computer of the Plataforma Solar. This makes standardized automatic routing of information possible and allows authorized persons direct access to the information whenever they wish. This is quite important in projects where analysis and control are shared by people outside the PSA, as in the ROOFSOL project, where easy access means that the corrections to the control parameters can be made much faster, saving precious time for the project.

New LECE capabilities feature:

- The PASSYS Mediterranean Cell has been upgraded with the installation of a rotating platform, enriching experiments with easily changed cell orientations with respect to the sun.
- A new instrument in the lab is the Solar Transmittance Sensor (STS), shown in Figure 2.1.4. This device contributes to the laboratory's capacity to calculate the energy and light transmittance of non- homogeneous translucid construction components. At the moment the STS sensor is a pyrometer, so the only measurable variable is total transmittance. Nevertheless, it can be used with a portable spectrometer, which would enable calculation of spectral transmissivity.

Construction of a calorimeter to calculate the Total Solar Energy Transmittance (TSET) through translucid non- homogeneous construction components is also being studied. Such a device would complete the laboratory requirements for testing the energy behavior of any type of building component.

Last: 1 | Annual Technical Report 1996 | Next: 3
Back: 2 - Technical Description and Project Achievements | Next: 2.2
Last: 2.1.2 | Back: 2.1 - Low Temperature Applications | Next: 2.1.4
Top: 2.1.3 - New Infrastructure at the LECE

Team Developers of this PSA Web site thank you for visiting our site.
We'd like to hear from you.

Last: 1 | Annual Technical Report 1996 | Next: 3
Back: 2 - Technical Description and Project Achievements | Next: 2.2
Last: 2.1.3 | Back: 2.1 - Low Temperature Applications | Next: 2.1.5

2.1.4 - Tests and Achievements during 1996

Several tests were performed this year.

- All the test cells have been calibrated to adjust to LECE quality standards.
- The new Solar Transmittance Sensor has been tested and calibrated with a well- known specimen. The system performance has also been obtained and the margin of error has been found. A series of new improvements will be carried out in order to obtain more robust equipment.
- A special Hunter Douglas double-glaze pane with interior venetian blinds, has been tested in the Mediterranean PASSYS test cell as well as the STS, and its thermal and optical properties characterized. These tests were carried out under IEA Task 18 for the study of advanced glazings and associated materials for solar and building applications.
- A glass pane from Pilkington has also been tested in different ongoing experiments in the lab.
- The first laboratory experiments under the Training and Mobility of Researches (TMR) program were performed this year. A shaded, argon-filled double glazing with a low-emissivity coating has been test in the Mediterranean PASSYS cell.
- In the CESPA cell, a first configuration of a wall with an air cavity and a doubled-glazed window has been tested. The experiment is part of a project in collaboration with the Polytechnic University of Madrid.

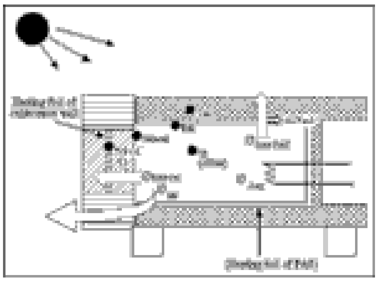


Fig 2.1.5: Heat flux in a PASSYS test cell.

This year the LECE has begun to follow the Spanish ENAC (accrediting institution) quality procedures in order to meet all accreditation requirements.

Last: 1 | Annual Technical Report 1996 | Next: 3
Back: 2 - Technical Description and Project Achievements | Next: 2.2
Last: 2.1.3 | Back: 2.1 - Low Temperature Applications | Next: 2.1.5

Top: 2.1.4 - Tests and Achievements during 1996

Last: 1 | Annual Technical Report 1996 | Next: 3
Back: 2 - Technical Description and Project Achievements | Next: 2.2
Last: 2.1.4 | Back: 2.1 - Low Temperature Applications

2.1.5 - New and Ongoing Projects

2.1.5.1 - Agreement between the Polytechnic University of Madrid and CIEMAT


Fig.2.1.6: Wall being tested in CESPA I cell.

LECE will be used as a basis for specific (UNE) regulation on this type of test sites. These regulations must be elaborated by the 7th AENOR Committee (Material Testing).

2.1.5.2 - Agreement between the Polytechnic University of Barcelona and CIEMAT

In this framework, the L.E.C.E. will test and characterize four types of bricks, fabricated with industrial waste (textile, cardboard, etc.) in the PASSYS II cell.

2.1.5.3 - ROOFSOL

ROOFSOL is one of the CIEMAT Solar Energy Building Section proposals accepted in the EU Joule Program in 1995. The project tests of roofs that cool through semi- passive techniques. Five roofs will be tested, two at the Plataforma Solar. The Roof Typologies solutions were selected using the following criteria:

1. Prevention and/or protection from heat gains,
2. modulation of heat gains and
3. heat dissipation to environmental heat sinks (atmosphere, sky, ground and water).

At the Plataforma Solar, one of the roofs will be a roof pond with a water sprinkling system. One of the important parameters to be optimized during the experiment will be control of the amount of water needed for the day’s weather.

2.1.5.4 - APISCO

APISCO (Application of Plants for Thermal Quality Improvement in Buildings) is a project in which the CIEMAT Solar Energy in Construction team participates. This project is under the umbrella of the EU JOULE Program.

The L.E.C.E. will test and characterize different types of vegetation on the vertical walls of the CESPA I cell during the summer to measure the thermal effect of plants in buildings interiors as well as environmental modification, depending on their use.

2.1.5.5 - PV-Hybrid

Another Joule project in which the Plataforma is participating is the so-called PV-Hybrid.

In this project a scaled PV building facade will be thermally tested and optimized in the PASSYS cells.

2.1.5.6 - Training and Mobility of Researchers

The Laboratory is part of the infrastructure included in the Training and Mobility of Researchers program (TMR). This project, which started at the beginning of 1996, opens the LECE facility to other researchers who will also thereby acquire new experience in our laboratory.

Last: 1
Annual Technical Report 1996
Next: 3
Back: 2 - Technical Description and Project Achievements
Next: 2.2
Last: 2.1.4
Back: 2.1 - Low Temperature Applications
Top: 2.1.5 - New and Ongoing Projects

2.2.1 - Direct Solar Steam (DISS)

Solar Thermal Power Plant state-of-the-art is marked by more than 2.5 million square meters of parabolic-trough collectors installed in the nine SEGS plants currently in operation in California. These plants represent, with the 354 MWe peak power they supply to the grid, more than 80% of all electricity produced by solar energy. SEGS plants use oil as the heat transfer fluid (HTF) between the solar field and the power block connected to the external grid. Though these plants have demonstrated their good performance, the potential for cost reduction and increased efficiency of their technology is limited. Therefore, new ways to reduce costs at better than the current performance levels must be sought for the solar thermal electric parabolic-trough technology, for it to become more competitive in the power market.

The DISS project offers a valuable chance to do just that, because its objective is the development of the Direct Steam Generation (DSG) technology. The potential improvements could lead to a new generation of solar thermal power plants with improved parabolic-trough collectors (with better tracking system, better mirrors, lighter structures, etc.) and direct steam generation in the absorber tubes, thus eliminating the oil heat-transfer medium between the solar field and the conventional power block, increasing overall system efficiency and, thereby, competitiveness. The goal is to reduce the current electricity generation cost by 30% through a 15% reduction in direct investment costs and a 20% increase in efficiency.

DISS planning consists of three phases. The official commencement of the first phase, with the financial support of the E.U. JOULE Program (contract JOR3-CT95-0058), was January 1st, 1996. Participants in the 1996 DISS activities have been:

- Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Spanish public research institution belonging to the Spanish Ministry of Industry
- Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V. (DLR), German public research institution
- Empresa Nacional de Electricidad S.A. (ENDESA), Spanish electric utility
- IBERDROLA (ID), Spanish electric utility
- Instalaciones Abengoa S.A. (INABENSA), Spanish industry

- Pilkington Solar International GmbH, German industry
- SIEMENS-KWU, German industry
- Unión Eléctrica Fenosa (UEF), Spanish electric utility
- Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), German research centre SOLEL Solar Systems (Israel), INITEC (Spanish Engineering Company), UFISA (Spanish Engineering Company) and the group of Electrical Engineering and Electronics of the University of Manchester (UMIST) have also participated as subcontractors, in the detailed design of the life-size test facility that will be implemented at the PSA to investigate the DSG process under real solar conditions.

Fig. 2.2.1 shows the complete DISS project plan of work for the three phases. Activities planned for each phase are shown in different colors.

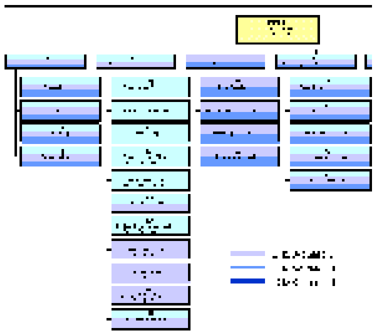


Fig. 2.2.1: DISS Work Plan

The following tasks are included in DISS planning:

Coordination and Management: This task includes project planning, project coordination and project and quality control.

Design & Implementation of the PSA DSG test facility: This task includes the design, procurement and erection of the PSA DISS test facility in two stages: a single row system will be installed during the first phase of the project, while a parallel row will be added at the end of the second phase. This test facility will be a key tool for life-size DSG process research. Results of simulations have already pointed out that there could be severe transients at a large DSG solar field when there are clouds and, therefore, implementation of a second row of collectors is considered essential to investigate the flow stability in parallel rows when the solar radiation distribution is not uniform. Implementation of the second row of collectors is planned for the fourth year of the project, after two years of testing experience with the single-row system.

Test and Operation: This task includes operation and maintenance of the DSG test facility to be implemented at the Plataforma Solar de Almería (PSA) within the framework of DISS Phase I, where tests will be performed to find out some open questions concerning the DSG technology that cannot be investigated at small test facilities.

Applied DSG Research: Thermohydraulic aspects of the DSG technology will be investigated to complement the experimental results gathered at the PSA. Control schemes for the DSG process will be developed and evaluated. Mechanisms to enhance heat transfer in absorber pipes with two-phase flow will also be investigated.

Collector Improvements: Possible collector improvements (e.g. front surface mirrors, lighter structures, new selective coatings, anti-reflective coatings, etc.) will be studied and evaluated in this task. An oil-loop test bed is currently being installed at the PSA to evaluate improved components under real solar conditions.

System Integration: Operation, maintenance and cost issues of a commercial DSG power plant will be analyzed taking into account the results of experiments at the PSA DSG test facility. The layout and configuration of a demonstration commercial plant using the DSG technology will be prepared.

Summary of activities in 1996

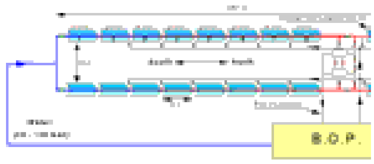


Fig. 2.2.2: Updated PSA DISS test facility diagram

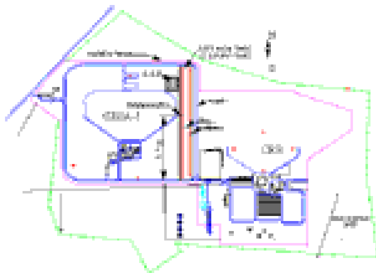


Fig. 2.2.3: Location of the DISS test loop at the PSA

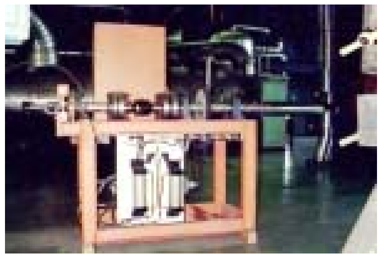


Fig. 2.2.4: Test Stand for ball joints

The system configuration proposed in 1995 for the PSA DISS test facility was revised in 1996. The number of collectors in each row, collector tilt and size of the absorber pipes have been modified. The updated system configuration is shown in Fig. 2.2.2.

The location of the facility within the PSA site has been also defined (see Fig. 2.2.3). The east side of the CESA-1 plant is the place chosen for the location of the DISS facility

Other DISS activities performed by the PSA team in 1996 were:

- Detailed design of the HTF (Heat Transfer Fluid) test loop to be used in DISS to evaluate improved parabolic trough components under solar conditions. All the equipment for this test loop was purchased in 1996 and system implementation began with the erection of half of an LS-3 collector. The oil circuit in this loop consists of: half an LS-3 collector, an oil cooler, an oil heater, an oil pump and the oil storage tanks. This equipment is connected in series (closed-loop) and is operated with Syltherm 800 heat transfer fluid. This test loop will be completed in 1997.
- The PSA published a technical report with the control scheme design studies performed by UMIST and ZSW for once-through and recirculation processes in August, 1996.
- The PSA Engineering Department coordinated the International Work Team involved in the detailed engineering of the DISS test facility, as well as tender and purchase of equipment.
- Design and fabrication of a small unit for testing the ball joints which will allow the rotation of the absorber pipes around the tracking axis of the DISS solar collectors. As these ball joints are key items in the design of the solar field and they have never been tested under real working pressure or temperature conditions, the test stand manufactured by the PSA will be used to validate the design before erection of the solar field.
- The PSA has been responsible for the overall management and coordination of the project. Preparation of the project proposal for the second phase was started in December, 1996, in order to submit a proposal to the European Union JOULE III Program in May, 1997.

Last: 1
Last: 2.1

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology

Next: 3
Next: 2.3
Next: 2.2.2

Top: 2.2.1 - Direct Solar Steam (DISS)

Last: 1 | Annual Technical Report 1996 | Next: 3
Last: 2.1 | Back: 2 - Technical Description and Project Achievements | Next: 2.3
Last: 2.2.1 | Back: 2.2 - Parabolic Trough Technology | Next: 2.2.3

2.2.2 - STEM Project

The **STEM** (**S**olar **T**hermal **E**lectricity in the **M**editerranean) project prepared a feasibility study to assess the potential for improvement in performance and cost reduction of the **D**irect **S**team **G**eneration (DSG) technology with large parabolic trough collector fields when integrated into 100-200 MW combined-cycle thermal power plants in the Mediterranean area. This project was developed with the financial support of the European Union within the framework of its APAS'94 Program (contract RENA CT94-0014). Elaboration of the final design concept for the DISS PSA test facility and the HTF test loop was also included in project planning. STEM was completed in June, 1996.

The two main STEM objectives were:

- Develop the conceptual design of a commercial-scale 100-200 MWe Integrated Solar Combined Cycle (ISCC) demonstration plant with Direct Steam Generation and compare it to a state-of-the-art reference system with oil-cooled collectors. The benefit of a bottoming sea-water desalination system will also be investigated. A specific reference site will be chosen in Southern Spain or Morocco for these comparisons.
- Prepare large-scale testing of the DSG process and the most promising research concepts affecting performance, investment and/or O&M costs and leading to competitiveness. Checking the conceptual design of a test loop at the Plataforma Solar de Almería (PSA) in Spain for testing the DSG concept will be the first step toward the full-size demonstration of a DSG plant in the 100 MWe range.

The expected achievements of STEM were:

- Quantify cost and performance benefits of integrating Direct Steam Generation into a commercial 100-200 MWe combined-cycle plant.
- Conceptual design of such a hybrid solar/fossil combined cycle plant with Direct Steam Generation.
- Identify next technological collector design and system optimization development steps.
- Elaborate conceptual engineering of a DSG and HTF test loop at the Plataforma Solar de Almería (PSA).

STEM project participants were:

- Centro de Investigaciones Energéticas, Medioambientales y

Tecnológicas (CIEMAT), Spanish public research institution belonging to the Spanish Ministry of Industry
- Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V. (DLR), German public research institution
- IBERDROLA, Spanish electric utility
- INTECSA, Spanish engineering company
- Pilkington Solar International GmbH, German industry
- SIEMENS-KWU, German industry
- Unión Eléctrica Fenosa (UEF), Spanish electric utility
- University of Las Palmas (ULP), Spanish University
- University of Manchester (UMIST), English University
- Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), German research centre

Summary of activities in 1996

PSA participation in STEM during 1996 was devoted to the concept design of DSG and HTF test loops to be implemented at the PSA as part of the DISS project. The DISS facility concept design proposed in 1994 was revised during the first months of 1996.

The PSA team has prepared the conceptual design for an HTF test loop made up of half an LS-3 collector, an expansion oil tank, an oil cooler and an oil heater. This test loop will be used in the future to evaluate collector improvements and new designs of absorber pipes for parabolic-trough collectors under real working conditions.

Chapter 10 of the final STEM report, written at the PSA, was a compilation of the results of all STEM activities performed or coordinated by the PSA.

Last: 1
Last: 2.1
Last: 2.2.1

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology

Next: 3
Next: 2.3
Next: 2.2.3

Top: 2.2.2 - STEM Project

Last: 1
Last: 2.1
Last: 2.2.2

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology

Next: 3
Next: 2.3
Next: 2.2.4

2.2.3 - ARDISS Project

Fig. 2.2.5: ARDISS Test Loop

The objective of the ARDISS (**A**dvanced **R**eceiver for **D**irect **S**olar **S**team) Project is to analyze the constraints of Direct Solar Steam Generation with parabolic trough collectors and to develop an advanced receiver fulfilling the requirements of this process.

The photograph shown in Fig. 2.2.5 is of the ARDISS test loop in tracking position, at left the ARDISS SSR receiver and at the right the reference absorber.

ARDISS receives financial support from the EU JOULE-II Program. The project coordinator is the CIEMAT Institute of Renewable Energies in Madrid. The PSA team is to provide technical support and perform the ARDISS absorber efficiency and thermal loss evaluation experiments. Other participants in this project are: ZSW (Germany), CONPHOEBUS (Italy) and INETI (Portugal).

The main objectives are:

1. The design, construction and testing of the concentrator receiver.
2. The theoretical and experimental analysis of the Direct Steam Generation (DSG).
3. The assessment by simulation of the solar driven electricity production system applying DSG.

Summary of activities in 1996

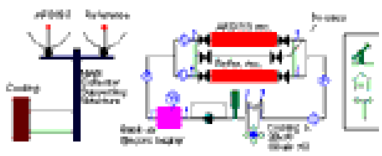


Fig. 2.2.6: Schematic Diagram of the ARDISS Test Loop

Due to some durability problems with the mirrors, fabrication of the ARDISS SSR (Secondary Stage Receiver) was somewhat delayed. It was finished at the end of 1996, so the SSR absorber will be mounted at the PSA and evaluated in 1997.

For the reason above mentioned during 1996 the ARDISS test loop has been used to evaluate the reference absorber of the ARDISS project and the absorber prototypes designed by DLR within the framework of the PAREX project.

In January, February and March reference absorber properties were evaluated (thermal efficiency, optical performance and thermal loses). Some unexpected anomalous results were obtained from these tests, such as higher thermal loses than expected. Insulation of the joint between the receiver and the circuit was therefore modified. In 1996, the lay out of the oil pipes at the Helioman was modified. The glass cover of the reference absorber was stained by a small oil leak, so to guarantee the optical properties, the glass cover had to be replaced in 1996.

After these changes, the collector was reevaluated and thermal losses were consistently lower than before, but the optical efficiency decreased. Deformation of the mirrors supports was assumed to be the reason for this reduction of the optical efficiency.

As the measurements delivered by the flowmeters installed in series at the oil circuit of the test facility did not coincide, all the flowmeters were checked in order to find the reason for this mismatch. An in depth study was performed in July, 1996, and the conclusion was that a fissure in the swivel joint installed at the bottom of the Helioman to allow rotation of the structure was provoking the by-pass of a small quantity of oil. So, it was verified that the measurements delivered by the flowmeters were correct, because the amount of oil going through them was different.

An automatic control designed by the PSA to keep oil outlet temperature steady despite the changes in the solar radiation by varying the oil flow was implemented in February 1996. Since the short pipe length of the oil circuit leaves little margin for regulation, final installation has been delayed until the SSR absorber evaluation in 1997.

Last: 1
Last: 2.1
Last: 2.2.2

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology
Top: 2.2.3 - ARDISS Project

Next: 3
Next: 2.3
Next: 2.2.4

Last: 1
Last: 2.1
Last: 2.2.3

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology

Next: 3
Next: 2.3
Next: 2.2.5

2.2.4 - PAREX Project

This German project managed by the DLR is aimed at developing and testing advanced parabolic-trough receivers to:

1. reduce losses at increased working temperatures,
2. reduce thermomechanical loads due to cyclic or uneven heating.

These advanced receivers are intended for parabolic-trough collectors either with thermal oil or direct steam generation. The main role of the PSA in the PAREX project is the installation of the PAREX absorber prototypes, as well as testing of such prototypes under real solar conditions using the ARDISS test facility.

A number of new receiver concepts were analytically and numerically evaluated to select promising configurations to be built and tested:

1. secondary concentrators
2. linear cavities
3. heat pipe
4. multiple pipes

By the end of 1995, the first PAREX receiver had been assembled at the PSA, called the PAREX 00b Prototype. It basically consisted of a normal round absorber, a black-coated chrome pipe with a HITRAN insert to increase thermal efficiency, with a glass cover, but no vacuum. Some components and insulation materials, were received for future prototypes. The absorber PAREX 00b was used as reference for the ARDISS SSR. Two prototypes were evaluated after PAREX 00b: PAREX-01 and PAREX-02 receivers using a semicircular glass envelope fitted to an insulating box attached to the front of the steel pipe.

Before the PAREX-01 absorber test campaign, the PSA engineering department designed and installed additional thermocouples to measure the temperature at different points on the glass cover and the insulation boxes. PAREX-01 receiver tests for thermal losses and efficiency started in May, 1996. The prototype’s glass cover broke twice for causes still unknown, so it was decided to dismount it and evaluate the source of this damage in parallel in order to save time.

During the first PAREX 02 prototype test some problems appeared which delayed the test campaign. The rubber seal located in the radiated area melted and the bracket holding half the glass cover had to be replaced by one that fit better. The PAREX- 02 prototype was evaluated in June, July and September 1996.

Last: 1
Last: 2.1
Last: 2.2.3

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology
Top: 2.2.4 - PAREX Project

Next: 3
Next: 2.3
Next: 2.2.5

2.2.5 - Control System Development

The main objective of this project is the development and testing of advanced control algorithms for use in solar power plants. The ACUREX parabolic though solar collector field served as a test bed. Apart from issues related to the relevance of solar energy, the motivations for this line of research are manifold. The techniques that have been applied to the Acurex field may also be applied to many industrial processes where the control system is important. The work carried out has served as an impulse for new theoretical development.

This project has been running at the PSA since 1990. In 1996, financed by the European Union DG XII Training and Mobility of Researchers and the Human Capital and Mobility programs, the number of institutions involved increased from three in 1995 to seven, from six different European countries. The time each research group was given access to the facility within the Training and Mobility of Researchers Program has been reduced compared to the former Human Capital and Mobility schedule due to the increase in the number of users and the reduction of total facility access time in the new contract signed with the E.U.

The main achievements in 1996 within the framework of this project are briefly listed below:

1. To the best knowledge of the authors, the Switching Controller and Linguistic Equation Controller were tested for the first time in an industrial environment.
2. Some of the algorithms developed within the project were used at existing power plants (Carried out by the INESC in an Electicidade de Portugal Coal Power Plant)
3. Two papers presented in the 8th Symposium on Solar Thermal Concentrating Technologies Conference at Cologne (Germany)
4. Five papers accepted for the 1997 European Control Conference
5. One book and one book chapter focused towards the solar control (Univ. Seville)
6. 140 % of fulfilment of the weeks compromised in the Training and Mobility of Researchers contract for the first year.

Besides the main goal mentioned above, this project has been highly productive academically. At the postgraduate level, two Ph.D. theses including experimental results obtained at the PSA, were presented by M. Berenguel (Univ. Seville) and F. Coito (Instituto Superior Tecnico, Lisbon) in 1996 and three more are currently underway. There was an exchange of postgraduate students among institutions involved in the project. At several European Universities, the project has also had a strong impact on undergraduates through the PSA student grant program and it has also provided industrial experience for researchers from different European universities.

The institutions involved are having a hard time maintaining the tight TMR time schedule. In an effort to overcome this lack of time, a model of Acurex field accuracy designed by the University of Seville was distributed among the participants so they could simulate controller performance and adjust it accordingly before coming to Almería. The PSA engineering department updated the Acurex Field control software to make it more robust and flexible. The reduction in available time means a short commissioning time (i.e., the time necessary for adjusting a controller), one of the most important parameters of an industrial controller, since fast implementation means saving money.

The Training and Mobility control project test campaign was designed to be performed in a very short period, from April to July, 1996, with some overlapping of visits of the researchers coming from different institutions. The expected goal is an exchange among users of their different approaches to control, permitting an effect of synergy. In a sense, it could be thought of as a mini research network where each researcher, in addition to his own work, also has access to the development at two other institutions.

A TMR Users Meeting took place in February, 1996. At this event, the results obtained in the HCM were presented and some useful information was distributed (papers, programs, etc).

The controllers tested under real operating conditions at the ACUREX Field in 1996 were:

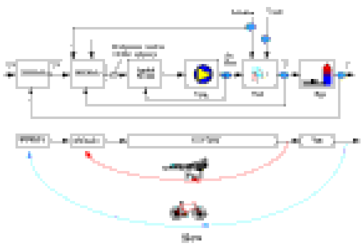


Fig. 2.2.7: MUSMAR Cascade block diagram

- **University of Seville(Spain):**

  Frequency-based adaptive controller:
  The key idea is to implement both the model of a plant and the controller with frequency-based interpolation models within an internal model control structure.

  Nonlinear neural model-based predictive control scheme:
  A neural network is used to predict future system output, or more specifically, to predict the free response. A linear model is used to obtain the forced response of the system, providing an efficient and easily installable MPC algorithm to cope with nonlinear systems subject to disturbances.

  Constrained Generalized Predictive Controller:
  This controller takes into account input and output constraints acting on the system (minimum and maximum allowable oil flow, minimum and maximum oil flow slew rate, maximum outlet oil temperature, etc.), as well as performance constraints within a GPC framework.

- **INESC (Portugal):**

MUSMAR Cascade.
The MUSMAR cascade is made up of two control loops. In the inner loop a MUSMAR adaptive-model-based predictive controller applying accessible disturbance information is used, in the outer loop another MUSMAR controller is employed (Fig. 2.2.7).

- **Univ. of Hertfordshire (United Kingdom):**

  Multilevel fuzzy controller.

- **Univ. of Strathclyde (United Kingdom):**

  Model-Based Predictive Controller.
  This model-based predictive controller applies the receding horizon principle. On- site implementation of the controller is composed of a process model, a supervisory system and a feed forward term.

- **Univ. of Oulu (Finland):**

  Linguistic Equation Controller.
  The Linguistic Equation approach provides a flexible environment for combining expertise in development of intelligent systems. The knowledge base of the expert system is represented by linguistic relationships which can be converted into matrix equations.

- **Univ. Firenze and INESC:**

  Switching controller.
  The switching control strategy has been used to cope with changes in plant dynamic behavior induced by different operating conditions. The underlying predictive models and controllers used by INESC and Firenze were different. INESC used the MUSMAR adaptive algorithm, while Firenze employs high order models obtained by the Recursive Least Squares (RLS) identification method and controllers synthesized by means of an LQG procedure. An example of the work done is shown in Fig. 2.2.8, which represents the results in a plant with a single controller designed by Univeristy of Seville in a test carried out on March 27, 1996.

- **Other control-related activities**

  As result of the activities carried out within the HCM and TMR Programs a proposal called “Advanced Control of Solar Systems” was submitted to the European Union INCO/COPERNICUS program. The coordinator is the University of Seville and the PSA was included as a partner.

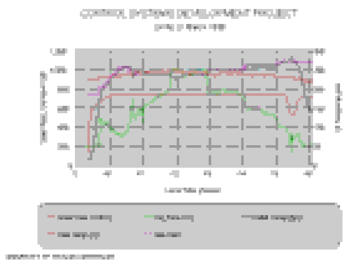


Fig. 2.2.8: Controller response during a set-point tracking test

Last: 1
Last: 2.1
Last: 2.2.4

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology

Top: 2.2.5 - Control System Development

Next: 3
Next: 2.3
Next: 2.2.6

Last: 1
Last: 2.1
Last: 2.2.5

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology

Next: 3
Next: 2.3

2.2.6 - TMR Desalination Project

Fig. 2.2.9: Multi-effect Solar Desalination Plant Diagram

In order to promote solar desalination in European countries, the Solar Desalination Plant was included in the PSA TMR program proposal. This project approaches the work carried out from 1987 to 1993 within the Solar Thermal Desalination project. An exergetic analysis by Trinity College, Dublin, in 1996, compared the desalination plant with the performance results obtained during the Desalination project. This work will be presented in an MS thesis in the near future.

The solar desalination system used for this project, inaugurated in 1988, is composed of:

- 14-effect MED plant
- parabolic trough solar collector field
- thermocline thermal energy storage tank.

These subsystems are interconnected as shown in Fig. 2.2.9. The system operates with a synthetic thermal oil (Santotherm 55) as the heat-transfer fluid, which is heated as it circulates through the solar collectors. The solar energy is thus converted into thermal energy in the form of sensible heat of the oil, and is then stored in the thermal oil tank. Hot oil from the storage system provides the MED plant with the thermal energy it requires. The collector field consists of east-west- aligned one-axis tracking collectors with a total aperture area of 2,672 m^2, manufactured by ACUREX (USA), model 3001. The thin-glass (0.6-0.88 mm) silvered-backside reflectors, are glued on flexible steel sheets (manufactured by GLAVERBEL, Belgium).

The ACUREX collector field is much larger than necessary for the "Sol-14" desalination plant. The daily thermal energy delivered by the collector field is about 6.5 MW_{th} while the daily thermal energy requirement of the desalination plant is less than 3 MW_{th} for daily 8-hour operation. Nevertheless, it was evidently more convenient to use the existing collector field at the PSA than to erect an entirely new, smaller collector field.

The desalination plant is connected to a single 115 m3 thermocline vessel (COUPAS, Greece) thermal storage system. The hot oil, which enters the tank through an upper manifold, acts simultaneously as a heat transfer fluid and heat storage medium. The tank is inertized by 4.8 m^3 of nitrogen. The thermal storage capacity is 5 MW_{th} (approx.) at charge/discharge temperatures of 300/225ºC. The thermal utilization factor (efficiency) is 92%.

The MED plant is composed of 14 cells or effects. The sea water is preheated from Cell to Cell in the 13 pre-heaters. From Cell (1), the feedwater goes from one Cell to another by gravity before being extracted from Cell (14) by the brine pump. Part of the sea water used to cool the condenser is rejected and the rest is used for the feed water required to spray the Cell-1 tube bundle.

Last: 1
Last: 2.1
Last: 2.2.5

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.2 - Parabolic Trough Technology

Top: 2.2.6 - TMR Desalination Project

Next: 3
Next: 2.3

Last: 1
Last: 2.2

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.3 - Dish / Stirling Systems

Next: 3
Next: 2.4
Next: 2.3.2

2.3.1 - DISTAL I

DISTAL I System Description

Fig. 2.3.1: Photo of DISTAL I Parabolic Dish Facility

The DISTAL I test facility consists of three single-faceted stretched metal-membrane concentrators with the Energy Conversion Unit (ECU) at the focal point.

The tube-receiver converts the concentrated solar radiation into thermal energy, which then runs the Stirling engine. A connected generator supplies 3- phase 380-V electrical energy to the grid.

The 7.5-m diameter concentrator is made of 0.23-mm thick stainless-steel membranes stretched on either side of a 1,2-m high outer ring. After both membranes are sealed to the ring, the front membrane is plastically deformed by the combined force of air-pressure and water to form a parabolic surface. Thin-glass mirrors are then fixed to this surface and the contour maintained by a slightly negative pressure (35 mbar nominal). The dish is held in a biaxial tracking system that permits rotation at 15 degrees per hour about a polar axis and seasonal adjustment of +/- 23,5 degrees.

The V-160 engine, designed by United Stirling of Sweden, originally manufactured by Stirling Power Systems (now defunct) and now being manufactured by SOLO Kleinmotoren GmbH of Sindelfingen, Germany, has a nominal power rating of 9 kW (according to proposed IEA guidelines) at 1500 rpm. The V-160 engine is configured in the alpha-configuration with separate, single-action compression and expansion pistons. The power piston has a 160 cm^3 displacement and 226 cm^3 total swept volume. The working gas until now has been helium at a maximum mean pressure of 15 Mpa, variation of which controls power output. Cooling is by a pumped-water/forced-air radiator cooling system.

A directly irradiated tube-type receiver operates at a maximum temperature of 740°C (measured on the non-illuminated side of the receiver) resulting in a maximum predicted gas temperature of 650°C.

Concentrator SBP DSO90		**Energy Conversion Unit SOLO Stirling V-160**	
Diameter:	7.5 m	Rated power:	9 kW
Aperture Area:	44 m^2	Working gas:	Helium/H^2
Reflecting Area:	42 m^2	Displaced volume:	160 cm^3

Mirror Reflectivity (clean):	94%	Swept volume:	226 cm^3
Concentration factor:	2200	Gas pressure max.:	150 MPa
Focal length:	4.5 m	Gas temperature:	--
Concentrator efficiency:	81%	Receiver temperature:	740 ºC
System mass:	2500 kg	Efficiency incl. Generator:	30%

Table 2.3.1: Technical Data of DISTAL I System

Testing Status

As in previous years, new records in long- term testing have been made with the three SBP 9.5 kW_e dish/Stirling systems, well known as DISTAL I as if teething problems had been eliminated from the beginning.

The relationship between hours of solar radiation over 300 W/m^2 and hours of operation of all three dishes is shown in the following graph for a period of 57 months. This also includes all the outage time caused by modification work required for test configuration.

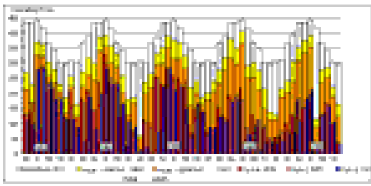


Fig. 2.3.2: Monthly operating hours of the 3 SBP 9 kWe Dish/Stirling Systems

From startup of continuous operation in May, 1992 to the end of 1996, they accumulated more than 25,000 operating hours.

All three dishes are fully instrumented and measurements for both gross power output and parasitic power consumption are included. Its data acquisition system records performance and weather data every 2 seconds for later evaluation.

From the recorded data, additional bench tests and thermodynamic calculations, the efficiency pattern of each system component has been determined. In Fig. 2.3.3 the results for 1000 W/m^2 insolation, low wind speeds and low ambient temperature are presented.

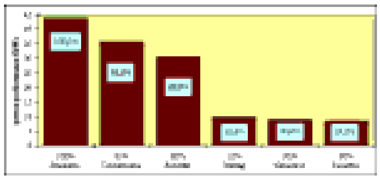


Fig. 2.3.3: Measured subsystem efficiencies

Last: 1
Last: 2.2

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.3 - Dish / Stirling Systems

Top: 2.3.1 - DISTAL I

Next: 3
Next: 2.4
Next: 2.3.2

Last: 1
Last: 2.2
Last: 2.3.1
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.3 - Dish / Stirling Systems
Next: 3
Next: 2.4
Next: 2.3.3

2.3.2 - DISTAL II

Encouraged by the excellent results of the DISTAL I facility, the design of the next generation was begun in 1994. The main goals were reduction of manufacturing costs and fully automatic operation. The next step was an in-depth study of integration of the new facilities into the existing PSA infrastructure in 1995. SBP and L.&C. STEINMÜLLER GmbH (LCS) in collaboration designed a pre-commercial 10 kWe Dish/Stirling system, three of which are currently under construction at the PSA. First system performance data will be reported in spring, 1997.

System	
Rated gross power output (800 W/m^2)	10 kWe
Concentrator	
Diameter	8.5 m
Total reflective area	56.7 m
Concentration ratio	2000
Concentrator efficiency	81%
Energy conversion unit	
Stirling	SOLO V161
Efficiency (thermal to electric energy)	31%

Table 2.3.2. SBP / LCS 10-kWe Dish/Stirling design data

An improvement of the V-160 Stirling engine was designed by SOLO and already tested in laboratory. This new Stirling, called SOLO V-161, significantly reduces cost with an increased nominal power output.

Last: 1
Last: 2.2
Last: 2.3.1
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.3 - Dish / Stirling Systems
Next: 3
Next: 2.4
Next: 2.3.3
Top: 2.3.2 - DISTAL II

2.3.3 - Performance of the DISTAL I Center Dish With Hydrogene as Working Gas

The best way to increase the power output and efficiency of Stirling engines is to use hydrogene as the working gas. Until now, the gas used in the DISTAL I project has been helium. During a short testing period, the better properties of hydrogene were demonstrated.

In theory, hydrogene has got the highest thermal capacity (2,8 cp_{He}), the best heat conductivity (1,6 l_{He}) and the lowest current resistance (0,5 Wr_{He}) of all gases.

The second advantage of hydrogene is the reduction in cost. The purchase of helium as working gas at regular intervals means a great deal of expense. Supposedly, the greatly decreased losses of hydrogene through the sealings will reduce cost by about 78%!

The following chart shows the higher power output of the same dish, with the same reflectivity and almost identical weather conditions.

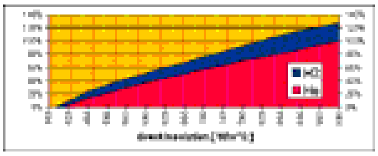


Fig 2.3.4: Power, relative to power output with helium

But not only the power output has increased, resulting in higher efficiency, the whole performance of the system was improved:

- the receiver temperature range was reduced from 140°C to 100°C, allowing higher maximum gas temperature
- the main efficiency increased about 3.6%
- the engine pressure decreased by about 7 bar

With the improved engine pressure, safer operation is possible at high insolation of over 940 W/m^2, resulting in engine conservation.

The goal for the future will be to reach full operation with the new working gas. To achieve this objective, the security rules have to be revised once again, but the risk for outdoor use of hydrogene is less than for propane or butane. There is no risk of explosion!

Because of these advantages of H2, its use with the new dishes of the DISTAL 2 project is desirable.

Last: 1
Last: 2.2
Last: 2.3.3

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.3 - Dish / Stirling Systems

Next: 3
Next: 2.4

2.3.4 - Site Preparation and Erection of the HTC ‘Fix Focus’

In June, 1996, a new type of solar concentrator was brought to the PSA. The HTC Herrmann Technologie-Centrum Schwerte GmbH company, Schwerte, Germany is responsible for this project. The PSA provides only space and infrastructure (electricity and water) for its operation.

Fig. 2.3.5: HTC FF-50

System description

The ‘Fix-Focus’ concentrator reflector shell is the excentric part of a paraboloid. The reflector itself tracks around the focal point. Due to this structure the focal point is fixed nearly all year long. The concentrator tracks by a combination of shadow-bar sensor and focal spot control. The concentrator shell shadow-bar sensor tracks the sun and the focal spot controls the concentrator by adjusting the focal spot to the focal plane.

The plane of aperture for a cavity-receiver is orientated parallel to the earth’s equatorial plane. The rim of the reflector shell is optimized for cavity-receivers by computer simulation.

The novelty is a precise 50 m^2, self-supporting reflecting surface consisting of a sandwich compound of

- 0,7 mm carbon-fiber laminate
- 30 mm PU-foam and
- 0,7 mm carbon-fiber laminate

The shell is composed of 4 joined segments. The reflecting surface is a self- adhesive specular silver reflective film (3M ECP305+).

Testing status

For the evaluation of the concentrators quality several measurement equipments were used. The concentration ratio is determined by a calorimeter. With 1000 W/m^2 direct insolation thermal power is 26 kW, received in a 16 cm diameter aperture. The evaluation of the reflectors precision was made by reverse-illumination methode. The decrease of performance is caused by a tilting between the 4 reflector segments. Flux density measurement will be performed with the PSA THETA-system in 1997.

Last: 1
Last: 2.2
Last: 2.3.3

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.3 - Dish / Stirling Systems

Next: 3
Next: 2.4

Top: 2.3.4 - Site Preparation and Erection of the HTC 'Fix Focus'

Last: 1
Last: 2.3
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Next: 3
Next: 2.5
Next: 2.4.2

2.4.1 - Receiver Technology

The following projects were carried out in 1996:

- TSA
- Falling Particle Receiver (FPR)
- ASM150
- GM100
- Volumetric Receivers
- Advanced Salt Receiver (RAS)
- Mini-GRAAL

Gerhard Weinrebe left the PSA and was replaced as Area Head by Peter Heller on 1.12.1996.

Gerhard Weinrebe

Peter Heller

Contents:

Last: 1
Last: 2.3
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Next: 3
Next: 2.5
Next: 2.4.2
Top: 2.4.1 - Receiver Technology

Last: 1 | Annual Technical Report 1996 | Next: 3
Last: 2.3 | Back: 2 - Technical Description and Project Achievements | Next: 2.5
Last: 2.4.1 | Back: 2.4 - Solar Tower Generating Systems | Next: 2.4.3

2.4.2 - The Heliostat Technology Program

Within the “Heliostat Technology Program”, two large scale heliostats were investigated in 1996, the 100 m^2 GM100 and the 150 m^2 ASM150.

Contents:

Last: 1 | Annual Technical Report 1996 | Next: 3
Last: 2.3 | Back: 2 - Technical Description and Project Achievements | Next: 2.5
Last: 2.4.1 | Back: 2.4 - Solar Tower Generating Systems | Next: 2.4.3
Top: 2.4.2 - The Heliostat Technology Program

Last: 1
Last: 2.3
Last: 2.4.2

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems

Next: 3
Next: 2.5

2.4.3 - Mini-Graal

First measurement campaigns in May and December, 1996, were conducted to prove the g-ray energy collecting concept with the CESA-1 heliostat field. At the 70-m level of the tower, two secondary concentrators with Cherenkov detectors were installed to collect the radiation from nearly 3000 m^2 of mirror surface. The aim is to analyze extra galactic energy sources in the range between 50GeV and 1 TeV.

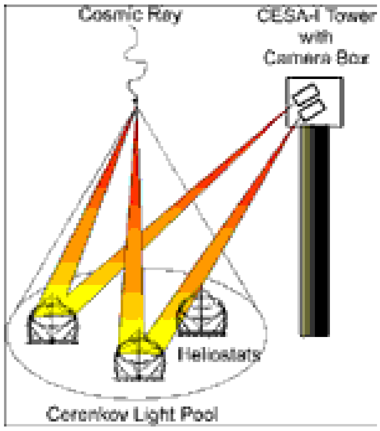


Figure 2.4.20: Mini-Graal setup

Last: 1
Last: 2.3
Last: 2.4.2

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems

Next: 3
Next: 2.5

Top: 2.4.3 - Mini-Graal

2.5.1 - Solar Detoxification

Initially, research in solar chemistry was focused on the conversion of solar energy into chemical energy, which could thereby be stored for long periods of time and transported over long distances. Environmental concerns and reasonable expectations for its technical and economic feasibility have led to a rising interest in solar chemical research culminated in recent years by the spectacular development of many other potential applications, such as photocatalytic detoxification of waste water.

However, their technological development still requires a combination of basic and applied research and experience in the industrial scale engineering to convince potential industrial partners. This kind of labor can only be carried out at solar chemical facilities with engineering-scale test programs such as the one at the PSA.

In the last few years, research in new methods for advanced waste-water treatment has gone from processes involving phase transfer of a contaminant (e.g. activated carbon, air stripping, pyrolysis) to its complete destruction. Over the last decade, the possible application of heterogeneous photocatalysis for removing organics from water has also been extensively investigated. The complete mineralization of simple and complex organic compounds, most of them included in various lists of priority pollutants compiled by the EPA (U.S. Environmental Protection Agency) and other regulating organizations, by this “soft” technology has been demonstrated repeatedly. Blake (NREL) has reported more than 1200 references to work in photocatalytic oxidation.

In a photocatalytic process, the catalyst (usually a semiconductor) absorbs energy at a definite wavelength interval from the incident light, generating electron/hole pairs. Part of these charges can be transferred to the semiconductor surface, promoting redox reactions (See Fig. 2.5.1). The advantages of this technology over conventional processes is that the catalyst may be removed from the water and the energy proceeds from that cheap, clean supplier, the Sun.

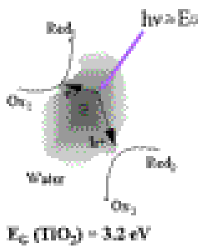


Fig. 2.5.1: Illuminated TiO_2 with UV (lambda <= 387 nm).

Contents:

Last: 1
Last: 2.4

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.5 - Solar Chemistry

Top: 2.5.1 - Solar Detoxification

Next: 3
Next: 2.6
Next: 2.5.2

2.5.2 - Solar Fine Chemical Synthesis

Among the chemical applications of solar energy, the photochemical production of fine chemicals is frequently considered a field with good prospects for industrial realization in the near future.

Photochemical synthesis is usually very efficient and selective, and some compounds of interest can only be reasonably produced photochemically. The idea of using direct solar radiation for photochemical reactions has been mentioned since the beginning of this century, but until the beginning of the nineties there have only been a few isolated efforts to bring solar photochemical synthesis into practice.

A first successful demonstration of solar photochemical synthesis using a concentrating parabolic trough collector system was achieved in the Solaris Project performed at the PSA in collaboration with DLR-Cologne and RWTH Aachen. A good many photochemical reactions of interest for synthesis fall within the UV-range, 300 - 400 nm, where the solar spectrum offers only low density photon flux. One possible approach to improving UV-range performance is non-concentrating collector systems, e.g., CPCs, capable of collecting more UV- photons per aperture area during a year than concentrating systems.

Fig. 2.5.10 View of the Solfin CPC collector

These considerations led to the installation in September, 1996, of a CPC collector as the SOLFIN photoreactor, access to which is offered to European research groups within the TMR-Programme. The photochemical receiver/reactor installed consists of a CPC-collector with aluminium reflectors and Duran glass-tubes with an optical concentration factor of 1, total aperture 2 m^2 and an irradiated volume of up to 10 l. It is connected by polyethylene and corrugated Teflon tubing in a closed loop with an overall volume of 10 - 20 l to a gear pump, process cooler, solvent supply vessel, gas supply and instrumentation to monitor temperature, pressure and flow within the loop. A view of the CPC collector is given in Fig. 2.5.10.

Three photochemical research groups from France, Italy and Germany received funding from the EU-TMR Programme to test the following photochemical reactions in the Solfin-facility as of September 1996:

- **CNRS-Inst. de Chimie des Subst. Naturelles, Gif-sur-Yvette, France:** Aerobic photocatalyzed oxidation of alkanes with polyoxytungstate catalyst ($W_{10}O_{32}^{4-}$). Adamantan was used as a model compound to test the selectivity of oxidation. The maximum absorption of the catalyst used is 320 nm, but tails at 400 nm, thus allowing for rapid formation of hydroperoxides during the course of a day. (See Fig. 2.5.11.)

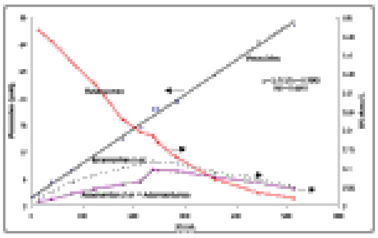


Fig. 2.5.11: Oxidation of Adamantan

- **Organic Chemistry Department, Univ. of Pavia, Italy:** Various photoinduced reaction involving the UV-A portion of the solar light were tested.
  1. Benzophenone-sensitized radical alkylation: A satisfactory dioxyalkylation of alpha, beta,- unsaturated ketones (see drawing beside) was obtained in dioxolane by irradiation of cyclohexenone and methylvinylketone. 0.2M ketone solution were 92% converted in 1 day exposure, with quantitative (98%) conversion to the oxyalkylated product. The latter could be hydrolyzed to 1,4- dicarbonyl derivatives useful as intermediates e.g. for the synthesis of odoriferous substances. The dioxolane could be distilled and reused.

  2. Electrocyclic cyclization - oxidation of azobenzene (5mM in EtOH-H_2SO_4 1:3) to give benzo[c]cinnoline. This was made both as a test for drastic chemical conditions and as model for the synthesis of benzo[c]cinnolines, some of which are used as drugs.

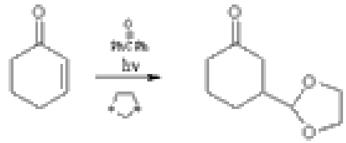


Fig. 2.5.12: Benzophenone-sensitized radical alkylation

- **Inst. f. org. Katalyseforschung, Rostock, Germany:** Various tests of solar driven and cobalt(I) complex-catalyzed pyridine synthesis in water were tested. A large number of 2-substituted useful pyridines (e. g. in drugs) can be synthesized starting from ethyne and different nitriles with CpCoCOD as catalyst. Benzonitrile, (+)-3-Menthyloxypropionitril and lauric acid nitril were tested, showing high turnover and selectivity of the reaction and low formation of benzene as undesired homocyclization product (see Fig. 2.5.13). The reaction with ß-Methoxyproionitril worked less satisfactorily due to the high solubility of the nitrile in the aqueous phase.

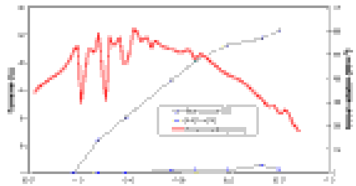


Fig. 2.5.13: Turnover of (+)-3-Menthyloxypropionitril

Last: 1
Last: 2.4
Last: 2.5.1

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.5 - Solar Chemistry
Top: 2.5.2 - Solar Fine Chemical Synthesis

Next: 3
Next: 2.6

Last: 1
Last: 2.5
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.6 - Materials Treatment
Next: 3
Next: 2.6.2

2.6.1 - High Flux Concentration Facility (Solar Furnace)

Fig. 2.6.1: Aerial View of the Solar Furnace

Completed in 1991, the Solar Furnace was conceived as a necessary tool for further penetration in the field of very high temperatures and energy densities, thus all possible ranges of concentrated solar energy research could be covered at the PSA. From the moment of its inauguration it was devoted to Materials Testing and fully open to the European Union “Access to Large-Scale Installations” programs.

To briefly describe the facility, the main components of this system are the tracking mirrors (heliostats), concentrator, test table and shutter.

There are four MBB heliostats, each consisting of sixteen 3.35 m^2 flat mirror facets with 90% nominal reflectivity, distributed in such a way that the whole concentrator surface is illuminated. The 11.01 x 10.41 m concentrator is a modified McDonnell-Douglas dish concentrator with 89 curved facets in 9 vertical columns and 12 horizontal rows supported by a truss structure and totaling 98.51 m^2 reflective area. The concentrating optics, including a total nominal reflectivity of 92%, focal length of 7.45 m and focal height of 6.09 m with estimated focal point diameter of about 20 cm and total power of 60 kW, provide a peak flux of 3 MW/m^2.

The attenuator (shutter) consists of thirty 5.6 x 0.93 m slats and measures a total of 14.4 x 11.2 m. It is PC-controlled and can be positioned in 15896 intermediate positions from 0º (open) to 55º (closed). An opening/time sequence can be previously programmed and then run automatically.

Finally, the programmable computer- controlled 0.7 x 0.6 m test table is movable on three axes, 0.92 m along the X-axis, 0.66 m on the Y-axis and 0.5 m on the Z-axis. With the automatic shutter and table, a test piece can be submitted to any complex sequence of power during testing or several pieces can be tested simultaneously.

Since 1993, a vacuum chamber provided by the Russian IVTAN (High Temperature Institute of the Russian Academy of Sciences) for materials experiments within a controlled atmosphere is available in the HFCF, by bilateral agreements between CIEMAT/IVTAN and DLR/IVTAN.

Contents:

Last: 1
Last: 2.5

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.6 - Materials Treatment

Next: 3
Next: 2.6.2

Top: 2.6.1 - High Flux Concentration Facility (Solar Furnace)

2.6.2 - European Space Agency (ESA) Test Facilities at CESA-1 for Materials Testing

CESA-1 is, apart from a test plant for solar power plant components (heliostats, receivers, storage systems, etc.), a very flexible thermal testing facility for large pieces of advanced materials, as demonstrated since 1988 in the various ESA test campaigns. It consists of a field of 300 heliostats, able to generate up to 7 MW_t on the receiver with energy densities of up to 3.5 MW/m^2.

Fig. 2.6.3: ESA’s Sample in the CESA testing facility

The receiver is the test piece installed in the 80-m tower at any of the several levels prepared as test beds, in particular, the 45-m and 60-m materials test rooms. The 45-m level has been used for Wing Leading Edge (WLE) and shingle tests and the 60-m level for the Nose Cap and the ‘Stamp’ probe. Computerized control of thermal testing was implemented in 1993, enabling testing of very large pieces and complex temperature profiles in semi-automatic mode.

After termination of the HERMES Program, a new project called ‘STAMP’ was launched in 1995.

STAMP Project Testing at the CESA-1 Facility in 1996

An agreement was signed with the French DASSAULT AVIATION company for a new test setup which would enable the existing Nose Cap Facility to be used for a piece from the ESA STAMP Project, a program for sending exploratory sensors to the surface of Mars in a vehicle built by DORNIER.

This vehicle carries a capsule where the scientific material is to be placed and a refractory shell made of SiC, which protects the vehicle from thermal loads during entry into the atmosphere of Mars.

A reduced-scale demonstrator was fabricated and successfully underwent mechanical and thermal testing under DASSAULT management.

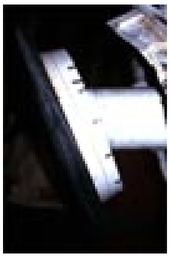


Fig. 2.6.4: The ‘Stamp’ Sample

Thermal testing was the responsibility of the PSA, including preparation of the test setup, i.e., supports, cooling, instrumentation and procedures, always according to ESA quality assurance standards.

Special care had to be taken in the preparation of the test because only one trial was possible, since the material degrades at over 400ºC.

The test, successfully carried out on July, 25th, was attended by Dornier and Dassault.

Last: 1
Annual Technical Report 1996
Next: 3
Last: 2.5
Back: 2 - Technical Description and Project Achievements
Last: 2.6.1
Back: 2.6 - Materials Treatment
Top: 2.6.2 - European Space Agency (ESA) Test Facilities at CESA-1 for Materials Testing

2.4.1.1 - TSA

In 1996 two different heliostat field control systems were used for TSA receiver operation. The Automatic Aiming-Point Strategy (AAPS) developed by the DISEL company and an improved version of the automatic control developed by the University of Seville.

The AAPS of the University of Seville was used to operate the TSA receiver during the first quarter of the year. The AAPS of DISEL was installed in the heliostat field control master computer on May 27th. Tests carried out validated the two different algorithms, which kept the maximum temperature deviations of the absorber elements at around 80 ºC.

At the end of the year, 22 absorber elements were replaced with a new enhanced design and additional thermocouples were mounted for their evaluation. Fig. 2.4.1 shows the TSA receiver in full operation.

Fig. 2.4.1: TSA Receiver in operation

Main Results

Results obtained show deviation of the individual absorber element control ranges to be similar to and even less than those obtained with manual aiming during operation. In the manual mode much time and effort had to be spent on the minimization of temperature differences. The implemented Automatic Aiming-Point Strategy provides very good results at different temperatures of work without any change of the control parameter. Absorber element temperature deviations from their individual operating range have been reduced and are now within 35 K. The risk of entering erroneous aim- point coordinates was eliminated.

Fig. 2.4.2 shows the behavior of the Automatic Aiming-Point Strategy at one of the 38 absorber temperatures. Tag CT060 is the receiver outlet temperature, which is also used to establish the ranges for the individual control of each element.

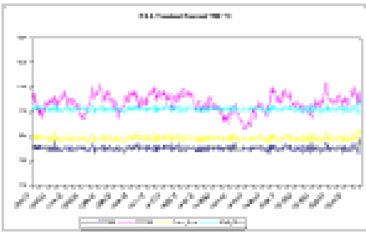


Fig. 2.4.2: Behavior of the Automatic Control

Fig. 2.4.3 shows the temperatures of the thermocouples controlled by aiming-point no. 1. The differences in maximum and minimum temperatures of the absorber elements are almost always within 100 ºC and during testing this difference has sometimes been reduced to 75 ºC.

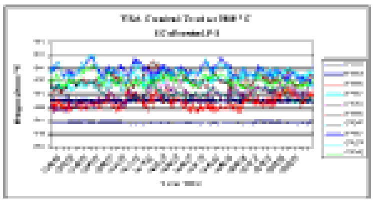


Fig. 2.4.3: Aiming-point-1 temperatures

Last: 1
Last: 2.3

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Back: 2.4.1 - Receiver Technology

Next: 3
Next: 2.5
Next: 2.4.2
Next: 2.4.1.2

Top: 2.4.1.1 - TSA

Last: 1
Last: 2.3
Last: 2.4.1.1

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Back: 2.4.1 - Receiver Technology

Next: 3
Next: 2.5
Next: 2.4.2
Next: 2.4.1.3

2.4.1.2 - Falling Particle-Receiver (FPR)

The basic idea of the Falling-Particle-Receiver (FPR) is the direct absorption of highly concentrated solar irradiation by particles without the need for any tightly integrated absorbing structure. These particles may be inert for reaching high temperatures in a thermodynamic cycle or chemically reactive to produce a high efficiency storable energy carrier.

The particles are driven in the closed loop of a circulating fluidized bed (CFB, Fig. 2.4.4) and the irradiation enters a so- called "particle curtain“ in the receiver section. This is a broad, thin, free- falling particle downflow in the downcomer of the CFB. A quartz window in front of the curtain prevents outflow of the air and particles. Surplus energy can be removed from the system in the fluidized bed cooler. In later experiments, this would be replaced by a chemical reactor.

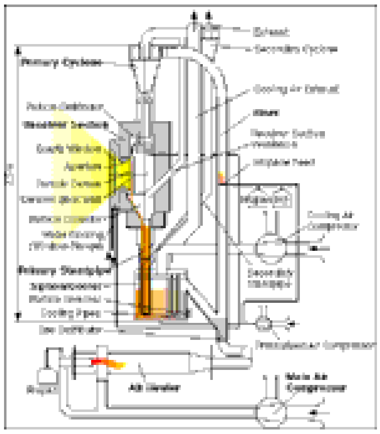


Fig. 2.4.4: FPR - System Overview

The FPR was successfully operated in the Solar Furnace (50 kW, 20 cm) of the Plataforma Solar de Almería from December 95 to April 96 (Fig. 2.4.5). Particles were of inert Silicon Carbide (SiC) and Sand. The maximum temperature reached in the cooler was 800 ºC, in the particle curtain over 850º. In general, the hot particle window protection was highly successful. It could be improved by a simple treatment of the window before the operation with an anti-static brush (See Fig. 2.4.9).

Fig. 2.4.5 The Falling-Particle-Receiver in the Solar Furnace

An example of the data received over one day is given in Fig. 2.4.6. Fig. 2.4.7 shows the temperature distribution in the particle curtain and Fig. 2.4.8 over the whole loop between 14:00 and 14:30 at this day. The efficiency of the receiver (Fig. 2.4.10) is influenced by the reflectivity of the quartz window and the particles, the thermal emissions, and the conductive heat losses. It has to be compared with other solar-chemical processes, e.g. water electrolysis driven by solar generated electricity.

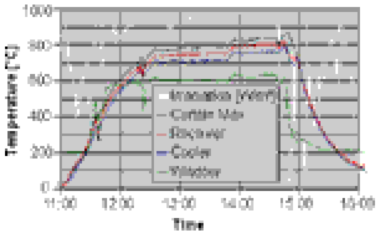


Fig. 2.4.6: Measurement Data example (April 2, 1996)

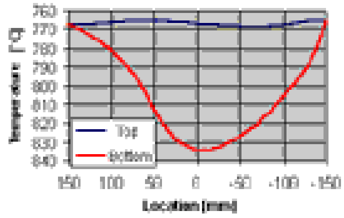


Fig. 2.4.7: Particle curtain temperature distribution

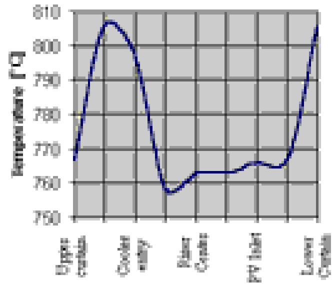


Fig. 2.4.8: Particle loop temperature distribution

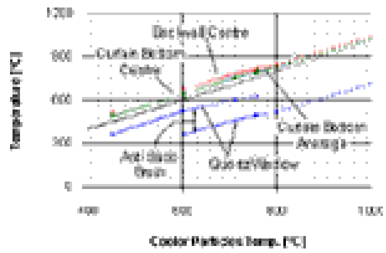


Fig. 2.4.9: Temperatures of the Falling Particle Receiver

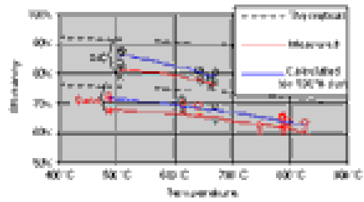


Fig. 2.4.10: Efficiencies of the Falling Particle Receiver

Last: 1 | Annual Technical Report 1996 | Next: 3
Last: 2.3 | Back: 2 - Technical Description and Project Achievements | Next: 2.5
Back: 2.4 - Solar Tower Generating Systems | Next: 2.4.2
Last: 2.4.1.2 | Back: 2.4.1 - Receiver Technology | Next: 2.4.1.4

2.4.1.3 - Advanced Salt Receiver (RAS)

The Internal Film Receiver (IFR) concept as a cost-effective alternative to the conventional molten salt in-tube technology is presently being evaluated at the PSA. The Advanced Salt Receiver (RAS), a joint project of CIEMAT/SNLL/DLR, consists of a molten salt loop including the IFR, a storage vessel, a security tank, a submerged salt pump and a salt/air heat exchanger (See Fig. 2.4.11). The project test plan is now in the 3rd phase (flux levels up to 460 kW have already been reached). The temperature data were read in three ways: an infrared camera system from SODEAN was used for measuring temperatures on the back side of the panel (See Fig. 2.4.12), by thermocouples connected to the DAS and PSA's Hermes-II system was used for measuring front panel surface temperatures (See Fig 2.4.13). Incident flux was also measured for power and efficiency calculations by the Hermes- II system. Different tests were performed with fixed flow at different incident flux levels and constant flux with different flow conditions in order to evaluate system performance. Panel deformation is negligible when the power is increased. A leak at three points in a straight vertical pipe was probably caused by local overheating. The heat tracing has been working properly since it was modified.

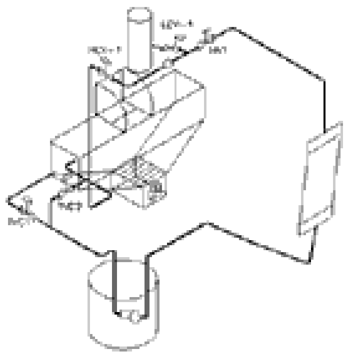


Fig. 2.4.11: Schematic drawing of the RAS Installation

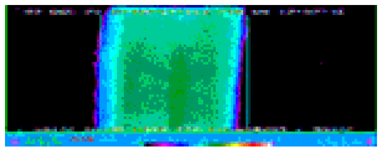


Fig. 2.4.12: Back side of the panel during salt circulation

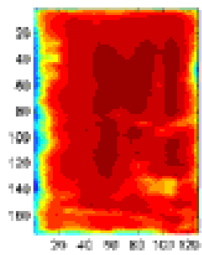


Fig. 2.4.13: Front side of the panel at the same time as Figure 2.4.12

Last: 1 | Annual Technical Report 1996 | Next: 3
Last: 2.3 | Back: 2 - Technical Description and Project Achievements | Next: 2.5
Back: 2.4 - Solar Tower Generating Systems | Next: 2.4.2
Last: 2.4.1.2 | Back: 2.4.1 - Receiver Technology | Next: 2.4.1.4
Top: 2.4.1.3 - Advanced Salt Receiver (RAS)

Last: 1
Last: 2.3
Last: 2.4.1.3

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Back: 2.4.1 - Receiver Technology

Next: 3
Next: 2.5
Next: 2.4.2

2.4.1.4 - Volumetric Air Receiver

In the CRS/SSPS testbed, the COR-REC volumetric air receiver made of Corderite ceramic, was operated in a first phase. It consists of 33 modules in an arc-like structure (See Fig 2.4.14). Each module has a flow adjustment, avoiding the necessity of an adapter with adjusting vanes.

Fig. 2.4.14: Back of the Cor-Rec Receiver

Last: 1
Last: 2.3
Last: 2.4.1.3

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Back: 2.4.1 - Receiver Technology

Next: 3
Next: 2.5
Next: 2.4.2

Top: 2.4.1.4 - Volumetric Air Receiver

2.4.2.1 - ASM150 Advanced Stretched-Membrane Heliostat

The ASM150 heliostat erected at the PSA by the German companies L&C Steinmüller, Schlaich Bergermann und Partner and Fichtner Development Engineering, has been characterized for its optical quality, wind load tolerance and surface reflectivity. In Fig. 2.4.15 and Table 2.4.1 the optical quality measured on a 12 m x 12 m target with the HERMES flux measurement system for the 477 m focal length is shown. With 1.5 mrad, the design value of 2.6 mrad was clearly surpassed.

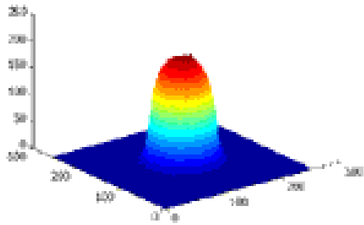


Fig 2.4.15: HERMES flux measurement at the focal length of 477 m

Date	sigma-Flux Map	Ellipticity of Measured Flux Distribution	DNI	Wind Speed [m/s]	sigma-Sunshape	sigma-Heliostat
23.2.96	2.67	1.003	910	7.5	2.2...2.3 (2.5)	1.51...1.36 (0.94)
23.2.96	2.65	1.007	910	7.5	2.2...2.3 (2.5)	1.48...1.32 (0.88)
26.9.96	2.65	1.037	875	4.7	2.3... (2.46)	1.48...1.32 (1.06)

Table 2.4.1: Data of some HELIOS measurements and the corresponding calculated ASM150 optical error. The values sigma-Heliostat resulting from the measured sigma-Sunshape are given in brackets.

The influence of wind speed on the deviation of the center of gravity is shown is Fig. 2.4.16. The measurement of the of the mirror surface reflectance over a 16 month period can be seen in Fig. 2.4.17.

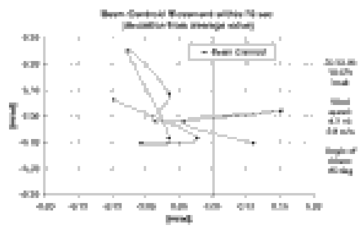


Fig 2.4.16: Short time beam centroid movements due to wind effects. The total time shown is 70s, maximum deviation 0.25 mrad.

To verify the manufacturer's design values, operability was tested at wind speeds of up to 50 km/h, survival in operating position at up to 80 km/h and survival in stow up to 120 km/h. New control settings were able to reduce consumption by the drives. Typical total consumption per day is less than 340 Wh and increases with the heliostat wind load (See Table 2.4.2).

Power Consumption of the ASM 150 Heliostat	Day 1 11.7.96	Day 2 8.7.96	Day 3 15.7.96

Wind direction [DEG] (Ø)	227	88	48
Ambient temperature [ºC](Ø)	29	25	23
Average wind speed [m/s]	3.3	4.9	7.9
Avge. consumption during azimuth reference-point search and fast drive [W]	137	112	121
Avge. consumption during elevation reference-point search and fast drive [W]	83	122	126
Avge. consumption during membrane reference-point search	140	128	195
Avge. azimuth consumption during normal tracking	16	20	19
Avge. elevation consumption during normal tracking	12	22	21
Avge membrane blower consumption during normal tracking	36	25	128
Total consumption for a typical day (8h tracking, reference search + back to stow 0.7h) [Wh]	**339**	**338**	**740**

Table 2.4.2 ASM150 Heliostat power consumption for different weather conditions and operating modes.

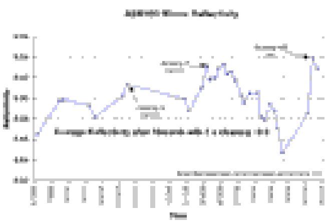


Fig. 2.4.17 Average mirror reflectivity of the ASM150 heliostat between June 1995 and September 1996. Estimated error is about 0.01, resulting from the random choice of the measurement points

Last: 1
Last: 2.3
Last: 2.4.1

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Back: 2.4.2 - The Heliostat Technology Program

Next: 3
Next: 2.5
Next: 2.4.3
Next: 2.4.2.2

Top: 2.4.2.1 - ASM150 Advanced Stretched-Membrane Heliostat

Last: 1
Last: 2.3
Last: 2.4.1
Last: 2.4.2.1

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Back: 2.4.2 - The Heliostat Technology Program

Next: 3
Next: 2.5
Next: 2.4.3

2.4.2.2 - GM100 Advanced Heliostat

CIEMAT has developed a third generation glass-mirror heliostat (See Fig. 2.4.18) introducing substantial improvements in large-area facets, drive mechanisms, canting procedure and local control, which comply with PHOEBUS-type heliostat specifications.

Fig. 2.4.18: GM-100 Heliostat at the Plataforma Solar de Almería

The net heliostat reflecting area (105 m^2) is composed of 32 newly designed facets (3.3 m^2 each) in which special support frames have been replaced by commercial ones and the glass-to-frame fastening mechanism has been simplified, resulting in an important weight reduction as well as a considerable reduction in the costs of fabrication and mounting, without penalizing optical quality. A new drive design contracted to the Spanish company PUJOL MUNTALA consists of very simple worm/gear azimuth and elevation systems (only 8 pieces) with integrated cast iron axis/gear elements from which brass has been removed. A new on-axis HOTL (Heliostat Optics Tracer Laser) based canting method, completely developed by CIEMAT, has optimized this transcendental task improving the optical quality of the heliostat and considerably reducing the time required for set-up of the reflective surface (focusing). Also developed by CIEMAT, the Heliostat Local Control is the result of more than fifteen years experience in heliostat field operation and maintenance at the Plataforma Solar de Almería (PSA). It enables optional communication with the central heliostat field control either by cable or radio, depending on the user, as well as a self- diagnosis test for maintenance optimization.

Concentrator	
Concentrator concept	glass/metal facets
Reflective surface	glass mirrors: 32 facets of 1.1x3 m
Focal length	480 m
Area	105 m^2
Desired beam quality	2.6 mrad for wind speeds up to 40 km/h
Specific facet weight	17 kg/m^2
Tracking unit	
Axis	azimuth/elevation
Support structure	T-shape
Startup/shutdown time	15 minutes

Stow position	face down (-90º +/- 5º)
Desired tracking quality	0.9 mrad elevation / 0.2 mrad azimuth
System control	
Heliostat control system	Theoretical calculation of sun position
Data acquisition system	None
Instrumentation	endlimit switches, encoders
Limits	
Survival (in stow position)	wind speeds up to 140 km/h
Normal operation	wind speeds up to 40 km/h
Reduced operation	wind speeds between 40-60 km/h
Ambient temperature	-10 < T < 50 ºC
Hailstones	20 mm at max. impact velocity 20 m/s in any direction
Seismic activity	0.6 m/s^2 horizontal dynamic acceleration
Lifetime	30 years for all components

Table 2.4.3: Technical specifications for GM100

The unit was manufactured and installed at the PSA by the Spanish company JUPASA, during the first half of 1996. A focal length of 477 m was established and beam quality tested by the PSA HERMES camera system (See Fig. 2.4.19) revealing beam quality of 2.4 mrad, which complies with specifications (2.6 mrad).

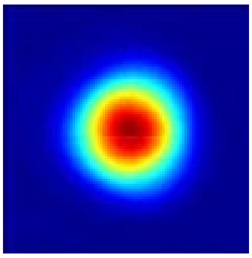


Fig. 2.4.19: Reflected Sunshape on the 12x12 m CESA-1 target at solar noon

Last: 1
Last: 2.3
Last: 2.4.1
Last: 2.4.2.1

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.4 - Solar Tower Generating Systems
Back: 2.4.2 - The Heliostat Technology Program
Top: 2.4.2.2 - GM100 Advanced Heliostat

Next: 3
Next: 2.5
Next: 2.4.3

2.5.1.1 - Main Results Achieved in 1996

Collaboration within the European Commission's TMR Program

During 1996, four different European Institutions used the PSA Detoxification Facility (16 weeks total) for very successful work in the destruction of organic compounds in water:

Instituto Nacional de Engenheria e Tecnologia Industrial (INETI): The effect of photocatalysis on the degradation of diluted wastewater from an olive-oil mill (initial TOC 250-1000 mg/L, phenols 40-160 mg/L) was studied using CPC collectors and TiO_2 with and without sodium persulphate ($Na_2S_2O_8$) and hidrogen peroxide (H_2O_2) as additional oxidants (See Fig. 2.5.3). Degradation of phenols was complete, but the TOC concentration decreased only when water was discolored (initially brown, see Fig. 2.5.2). Best results were obtained with 10 mM persulphate.

Fig. 2.5.2: View of the CPC field in operation with olive-mill waste water

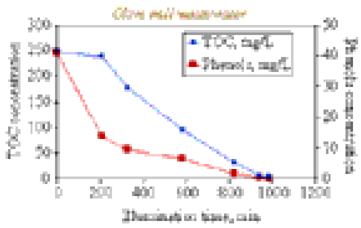


Fig. 2.5.3: TOC and phenols degradation in olive mill wastewater

Institut für Solarenergieforschung GmbH Hannover (ISFH): Comparison of the degradation of dichloroacetic acid, DCA, in a new reactor (Double-Skin Sheet Reactor, DSSR, see Fig. 2.5.4) and in the existing PSA-CPC field. Two types of TiO_2 were tested (P-25 and Hombikat, different surface areas). The same volume of water and collector surface were used and the efficiency of both photoreactors in DCA mineralization is quite similar (See Fig. 2.5.5). The most relevant difference between the reactors was related to the P- 25 concentration. The maximum effectiveness of the DSSR was achieved with 5 gr/l and in the PSA-CPC with 1 gr/l. The reason must be related to the different light-path lengths of the two photoreactors.

Fig. 2.5.4: View of DSSR (ISFH) in operation at PSA

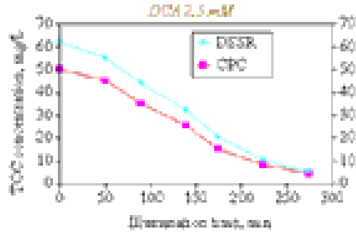


Fig. 2.5.5: Dichloroacetic acid mineralization in two different photoreactors

Institut für Physikalische Chemie, Technische Universität Wien (TUW): The photo-Fenton reaction has proven to be an alternative to TiO_2 processes in a widespread class of industrial waste waters. The production of hydroxyl radicals (OH·) by solar radiation and Fenton reagent can be very simply summarized: First, iron (II) is oxidized to iron (III) by hydrogen peroxide ($Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH\cdot + OH^-$) and in a second step, iron (III) is reduced by radiation ($Fe^{3+} + H_2O + h\nu \rightarrow Fe^{2+} + OH\cdot + H^+$). This closed loop of catalytic reactions produces powerful hydroxyl radicals which are able to oxidize organic contaminants and mineralize (decontaminate) them. The system consumes hydrogen peroxide as a function of the concentration of organics in the aqueous medium. The experiments carried out in the PSA-CPC pilot plant have demonstrated the feasibility of the solar process with typical contaminants (See Fig. 2.5.6). The very promising results have opened a new field in PSA Detoxification Projects.

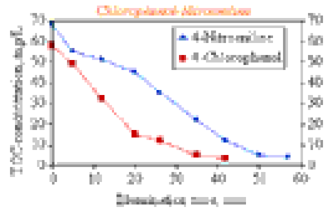


Fig. 2.5.6: Photocatalysis with photo-Fenton reagent

CNRS; Ecole Centrale de Lyon; Photocatalyse, Catalyse et Environement: The experiments carried out by this group, in close collaboration with the PSA team, have focused on the photocatalytic decomposition of two products with TiO_2. 2,4-dichlorophenoxy acetic acid (2,4-D), which is a common herbicide, and benzofurane (BZF), a model molecule representing heterocyclic aromatic molecules. Both contaminants (See Fig. 2.5.7) and their principal intermediates (2,4-dichlorophenol and salicylaldehyde) were efficiently degraded in PSA photoreactors. Total mineralization of 2,4-D (30 mg/l) and benzofurane (10 mg/l) was achieved with 1 hour of illumination.

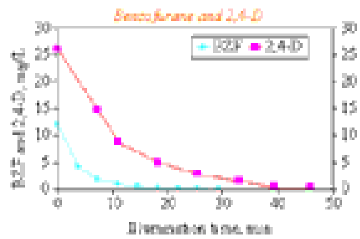


Fig. 2.5.7: Degradation by TiO2 of two model organic molecules in PSA photoreactors

Last: 1
Last: 2.4

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.5 - Solar Chemistry
Back: 2.5.1 - Solar Detoxification

Next: 3
Next: 2.6
Next: 2.5.2
Next: 2.5.1.2

Top: 2.5.1.1 - Main Results Achieved in 1996

2.5.1.2 - Pesticide Detoxification Project in El Ejido (Almería)

The agricultural sector is clearly a very important economic activity in the Mediterranean area. Moreover, in the last decade it has significantly increased with the expansion of greenhouses and intensive agriculture methods. As productivity and economic importance rise, the sector is also becoming more complex. Associated problems deriving from the wide use of pesticides, particularly the contamination of the region's groundwater, its main water source, and the immense amount of empty plastic containers generated, place increasing pressure on the environment.

According to 1995 data, 5,200 tons of herbicides were consumed in the 35,000 hectares of greenhouses in Almería, which produce around 1.5 million of these containers per year. In view of recent steep growth of the problem, parallel growth of environmental consciousness in the region has become concerned. However, recycling of the containers involves washing the shredded plastic, which produces contamination of water, in relatively small amounts, but with several hundred mg/l of persistent toxic compounds. Solar photocatalytic detoxification appears to provide an adequate solution for which there is no clear alternative as the biological purification of water polluted by organics is quite inefficient at low levels of the substrate.

The PSA has been one of the promoters in the formation of a consortium of 10 municipalities and 3 private companies for the organization of the complete recycling process of pesticide containers and the treatment and reuse of the water needed for the process. The project is scheduled in the following three phases: I) feasibility demonstration of photocatalytic herbicide degradation and first draft of detox plant; II) small pilot plant installation (on site) for full process testing; III) full plant installation and operation. The final contract for the first phase was signed by the end of 1995 and tests were during 1996.

The following data have been obtained from an AEPLA (National Organization of Pesticide Manufacturers) phytosanitary market study of Almería. Fig. 2.5.8 shows the distribution of the different types of pesticides sold during 1995. From this, the 10 phytosanitary products most used in greenhouses in Almería province have been identified and selected as representative (making sure that all main chemical families were present) to carry out solar photocatalytic degradation tests: Rufast® Rhône-Poulenc (Acrinathrin, $C_{26}H_{21}F_6O_5$ 15% w/v), Vertimec® Merck (Avermectine B_1, $C_{48}H_{72}O_{14}$ 1,8% w/v), Thiodan® AgrEvo (Endosulfan-a-b, $C_9H_6Cl_6O_3S$ 35% w/v), Dicarzol® AgrEvo (Formetanate, $C_{11}H_{16}ClN_3O_2$ 50% w/w), Confidor® Bayer (Imidachloprid, $C_9H_{10}ClN_5O_2$ 20% w/v), Match® Ciba-Geigy (Lufenuron, $C_{17}H_8Cl_2F_8N_2O_3$ 5% w/v), Tamaron 50® Bayer (Metamidofos, $C_2H_8NO_2PS$ 50% p/v), Vydate® Dupont (Oxamil, $C_7H_{13}N_3O_3S$ 24% w/v), Scala® AgrEvo (Pirimethanil, $C_{12}H_{13}N_3$ 40% w/v) and Previcur® AgrEvo (Propamocarb, $C_9H_{20}N_2O_2$ 72.2% w/v).

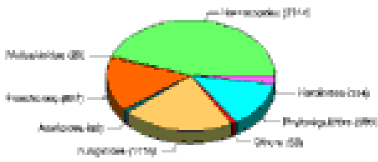


Fig.2.5.8: Tons of pesticides used in Almería (1995 data)

Based on this hypothesis, a mixture of the above ten plaguicides, each at the same concentration, would be representative of the water to be found after bottle washing. A final concentration of 100 mg/l of total organic carbon, from all the contaminants, is also considered very similar to the real situation to be expected. Solar degradation experiments were performed at the PSA Detox Facility using both the Helioman and CPC systems. In these tests, sodium persulfate ($Na_2S_2O_8$) was used as an additive in the mineralization process. This reactive agent, which is an active oxidizer, has been tested before at the PSA and found to strongly augment the mineralization rate in the presence of UV light. This is indicated in Fig. 2.5.9, which shows the degradation rate of total organic carbon of the selected plaguicides. The tests were performed with 200 mg/l of catalyst (TiO_2-Degussa P25) and 0.01 M of persulfate. The average solar ultraviolet radiation (global) during the experiment was 29.5 W/m^2 (sunny day); the total volume treated during the experiment was 270 l.

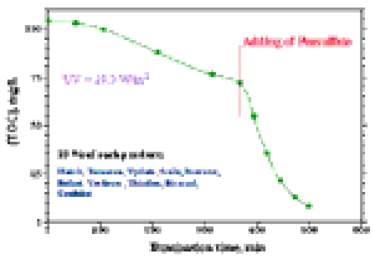


Fig. 2.5.9: Degradation of 10 pesticides mixture in CPC collectors

This application of the solar photocatalytic oxidation process is an appropriate, feasible and economical solution to the reuse of contaminated water in the Mediterranean area, demonstrating that this environmentally benign technology can actively help to solve water resource problems in the Mediterranean region. Following the demonstration of the technical and economical feasibility of the process, El Ejido, the main center of Almería’s greenhouse production, may become the first European town to include a solar photocatalytic detoxification plant in a real waste-treatment process, and would thereby become the first solar photocatalytic demonstration of the destruction of toxic compounds in industrial waste to make the jump from the laboratory to industrial scale systems, a significant milestone in solar research.

2.5.1.3 - SolarDetox

Solar Detoxification Technology Applied to the Treatment of Persistent Industrial Non-Biodegradable Chlorinated Water Contaminants (SOLARDETOX)

A new project proposed in 1996 within the “Detoxification of Water and Effluents” topic of the European Union’s Brite-EuRam III program, is being coordinated by CIEMAT with four industrial partners (HIDROCEN, SETSOL, SCHOTT, ECOSYSTEM), two research partners (CISE, DLR) and one educational partner (University of Torino). The project is due to start in May, 1997, and will last 3 years.

The aim is to acquire sufficient experience through the proposed pilot plant studies to be able to develop a fully commercial system for the detoxification of real industrial waste waters by the end of the project. The main focus of the working program is the improvement of the already existing technology of photocatalytic degradation of organic compounds. Existing efficiency of the detox systems is expected to be increased by optimizing the optical efficiency, the catalyst efficiency and the process efficiency.

Due to the fact that C_1 and C_2 non-biodegradable chlorinated hydrocarbon solvents (NBCS) play a major rule in various chemical processes they are chosen as model contaminants for the degradation tests. During the first year lab-scale degradation of NBCS will be tested and analytical methods including a kinetic model will be developed. At the same time highly UV-transmissive glass and reflective mirrors will also be developed. Improvement of the efficiency of the TiO_2 catalyst and the procedure for catalyst fixation on glass will be optimized.

After this first period of optimization, construction of four different systems of prototypes will be possible using the newly developed materials. Construction is planned for the beginning of the second year of the project. Outdoor degradation tests in the prototype reactors will use the results of the lab-scale degradation tests for the test profile. Further development of the project will be based on the results of the outdoor tests. The best prototype reactor system will be chosen for scaling up to a small pilot plant. Real on- site testing completes the series of degradation tests within this project. All results will be summarized in a final report. The conclusion will indicate the best detox system and the final increase in efficiency.

Last: 1
Last: 2.4
Last: 2.5.1.2

Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.5 - Solar Chemistry
Back: 2.5.1 - Solar Detoxification

Top: 2.5.1.3 - SolarDetox

Next: 3
Next: 2.6
Next: 2.5.2

2.6.1.1 - Improvements in the Solar Furnace during 1996

Due to its continuing diversification and broadening range of experiments, a continuous effort has been exerted to improve the existing facility and install new components.

A main aspect of improvement has been the temperature-control algorithm successfully developed in cooperation with the Systems Engineering and Automatics Department of the University of Seville’s School of Industrial Engineers. Its usefulness is clear, given the need for precision- controlled thermal cycles on the samples under treatment. The amount of incoming energy is determined by the shutter aperture, which thus indirectly controls temperature. Therefore, a program to control shutter aperture using known temperature offset was implemented in the data acquisition system computer. Good results have been obtained with adaptive and predictive strategies.

Also installed this year is a fast shutter for thermal shock treatments. One of the main advantages of solar energy in the field of materials treatment is that all available energy can be applied instantly to the sample, the same way a laser beam does. Up to now, such thermal shock treatment could not be achieved in the PSA furnace due to the slow shutter opening time (about 10 seconds from 0 to 100%). With the new fast shutter, a pneumatic shield which needs only 0.5 seconds to fully cover or uncover the surface of the sample, the desired thermal shock effect is created.

Some improvements planned for 1997 are:

- The assembly and setup of the so-called ‘Minivac’ system being developed in cooperation with the Portuguese ‘Insituto Superior Tecnico’, which basically consists of a small vacuum chamber, able to operate at up to 1600º C. Samples can be treated horizontally either under vacuum or controlled atmospheres.

- ‘High-Temperature Wear-Test Equipment’ is being developed in cooperation with the Materials Department of the Catholic University of Louvain for ‘ball-on-cylinder’ materials wear testing of samples irradiated at a desired temperature in an attempt to reproduce the actual working conditions.

Last: 1
Last: 2.5
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.6 - Materials Treatment
Back: 2.6.1 - High Flux Concentration Facility (Solar Furnace)
Top: 2.6.1.1 - Improvements in the Solar Furnace during 1996
Next: 3
Next: 2.6.2
Next: 2.6.1.2

Last: 1
Last: 2.5
Last: 2.6.1.1
Annual Technical Report 1996
Back: 2 - Technical Description and Project Achievements
Back: 2.6 - Materials Treatment
Back: 2.6.1 - High Flux Concentration Facility (Solar Furnace)
Next: 3
Next: 2.6.2

2.6.1.2 - Testing in the Solar Furnace in 1996

The PSA was selected in 1995 by the Directorate General XII of the Commission of the European Communities as a ‘host facility’ within the ‘Training and Mobility of Researchers - Access to Large Scale Facilities Program’. One of the facilities involved in this activity, which will last from January, 1996, to December, 1998, is the Solar Furnace.

During 1996, three European research groups in the field of materials were users of the Solar Furnace facility.

Departamento de Ingeniería Mecánica y Ciencia de los Materiales. E.S.T.I.I. Universidad de Sevilla (Spain). Prof. José María Gallardo, Responsible Scientist.

Fig. 2.6.2: Steel Samples under Test in the Solar Furnace

Sintering, the process for shaping solid pieces from powders by mechanical compacting and heating, is being used more and more in industry. This process would appear to be a suitable application for the solar furnace technology, especially for pieces with a highly complex shape of refractory materials. One of the most important drawbacks of the process today is the low density of the pieces produced compared to those obtained by conventional casting. Some successful research has already been done to increase the surface density of sintered stainless steel parts by using a laser beam.

The E.S.T.I.I.’s work at the PSA is investigating whether concentrated solar energy could be used for the same purpose. A number of small sintered stainless steel samples were therefore tested in an inert atmosphere inside a refractory cavity while rotating them to obtain a temperature distribution as uniform as possible. Results were quite promising, although improved inertization and better temperature control are needed.

The Ceramics Research Unit of Materials Ireland, Forbairt (Ireland), Miss Aoibhe O’Riordan, Responsible Scientist.

The purpose of these experiments was to demonstrate the feasibility of sintering ceramic pieces in the Solar Furnace. Some compacted MgO samples were therefore used to identify the main problems in reaching the 2000 ºC necessary for that process.

The final purpose is to produce sintered silicon nitride samples. Silicon nitride is currently used to produce parts for diesel and gas turbine engines.

In the current manufacturing process, additives such as Y_2O_3 or MgO are used to improve liquid-phase sintering. However, those additives cause deterioration of the piece's oxidation-resisting properties. Use of a furnace rapidly heated to over 2000 ºC would allow those additives to be removed.

Department of Mechanical and Manufacturing Engineering. Trinity College Dublin University (Ireland), Dr. Andrew Torrance, Responsible Scientist.

This research group has focused on surface alloying of steel parts, which involves horizontal adaptation of the focal spot.

Surfaces are alloyed by localized melting of coatings so that certain elements in them are incorporated into the surface of the part. Thus surface layers harder and tougher than can be produced by conventional techniques, resulting in lower friction and wear coefficients and increasing resistance to contact fatigue, are possible.

Last: 1
Annual Technical Report 1996
Next: 3
Last: 2.5
Back: 2 - Technical Description and Project Achievements
Back: 2.6 - Materials Treatment
Next: 2.6.2
Last: 2.6.1.1
Back: 2.6.1 - High Flux Concentration Facility (Solar Furnace)
Top: 2.6.1.2 - Testing in the Solar Furnace in 1996

Last: 2 | Annual Technical Report 1996 | Next: 4

3 - Operation & Maintenance

The Operation and Maintenance (O&M) activities in 1996 were carried out as planned, with the exception of some modifications due to storm damage (CESA-I facets and RAS salt pipes).

José Antonio Rodríguez Povedano

Antonio Valverde

Javier León

Contents:


José Rodríguez

Last: 2 | Annual Technical Report 1996 | Next: 4

Top: 3 - Operation & Maintenance

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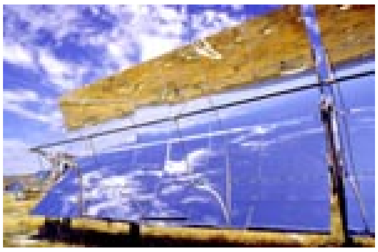
Annual Technical Report 1996

Contents:



4 - Engineering Department Activities

Andreas Holländer
Head of Department

Rosario Domech
Secretary

The Engineering Department has the most scientists of any department at the PSA. Ten engineers and technicians deal with the following work areas:

- Control and Instrumentation,
- Infrastructure,
- Informatics,
- Flux measurements,
- Safety.

Within the PSA organization, depending directly from the Directorate, the department works independently with the Area Heads on the different projects. Thus, Engineering know-how is concentrated in only one department. This implies that all internal PSA work is designed or supervised by this department and either performed by the PSA maintenance staff or subcontracted to other companies.

With 16 years of experience, some members of the department, such as the control, instrumentation and flux measurement personnel, are internationally considered experts in the field of solar energy research.

Contents:

Last: 2
Annual Technical Report 1996
Back: 3 - Operation & Maintenance
Next: 4
Next: 3.2

3.1 - Summary of Operation Hours

As in former years, 1996 facility operation was adjusted to the test plans foreseen in each area of work.

The table below shows the operating hours per project in each facility for the last two years.

Facility	Hours 1995	Hours 1996
CESA-1		
Collector System	2010	2132
TSA	308	206
ASM-150	201	283
GM-100	0	93
STAMP	0	261
GRAAL	0	133
CRS		
Collector System	1463	1609
Catrec-II Receiver	68	0
Cor-Rec Receiver	19	196
RAS	57	84
DCS		
ACUREX	590	621
Desalination Plant	115	367
Detoxification (Loop&CPCs)	1187	1483
HFC		
Collector System	1555	1569
Shuttle and Table	1317	1318
North Dish	1499	1287
Center Dish	1195	1300
South Dish	1042	1152

Table 3.1: Summary of operation hours 1995-1996

Contents:

Last: 2

Annual Technical Report 1996
Back: 3 - Operation & Maintenance

Top: 3.1 - Summary of Operation Hours

Next: 4
Next: 3.2

Team Developers of this PSA Web site thank you for visiting our site.
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Last: 2
Last: 3.1
Annual Technical Report 1996
Back: 3 - Operation & Maintenance
Next: 4

3.2 - Maintenance Plan for 1996/97

José Manuel Molina

The General Maintenance Plan (**GMP**) of the PSA, in effect since June 1994, has been followed and revised with satisfactory results as expected. The new company contracted for O&M activities updated the GMP and implemented subprograms, which smoothed some administrative and control tasks. The maintenance activities are illustrated in Fig. 3.2.1, 3.2.2, 3.2.3 and 3.2.4.

Fig. 3.2.1 analyzes the distribution of work by types of work within the GMP in 1994, 1995 and 1996. The construction activities were 6% and 5% less than in 1994 and 1995, respectively. However, corrective activities increased 9% and 8% in comparison with 1994 and 1995, which was mainly due to repair of damage produced by storms.

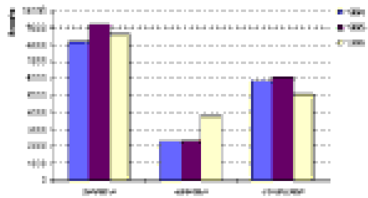


Fig 3.2.1: Analysis of direct labour by type of work

Fig. 3.2.2 presents the distribution of work by activities in 1996. Keeping in mind that all project maintenance work as well as general installation is included under “construction”, compared to Fig. 3.2.3, it may be observed that “general” work (preventive, corrective, construction) represents 79% of the total and projects 21%, which was one of the objectives outlined in 1994.

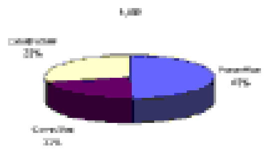


Fig. 3.2.2: Distribution by activities in 1996

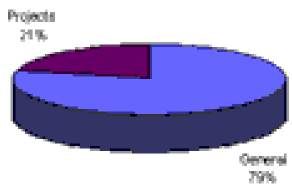


Fig. 3.2.3: General distribution of tasks

Fig. 3.2.4 shows the distribution of maintenance work by areas, where it may be observed that Mid-Temperature and CRS have absorbed 55% of the maintenance effort for projects.

“General” contains virtually all preventive maintenance work done for general infrastructure as well as the three test facilities. Indirect labor is not included.

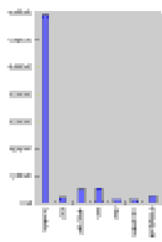


Fig. 3.2.4: Distribution by areas

General

- Installation of an electrical supply line from the CRS to the LECE and Fix-Focus test beds.
- Desalination plant: Maintenance and cleaning twice a year.

CRS

- RAS: Several modifications and repairs were made in pipes, insulation and heat tracing.
- Volumetric Receivers: Five radiometers were mounted.
- ACUREX: Damaged pipes replaced with new flexible pipe.

CESA-I

- Installation of a new feed-water pipe to the mixing tank.
- Modifications Sener heliostat feed worms
- Construction and installation of a new electrical distribution board in the low tension room.
- Contribution to GM-100 erection. Installation of the heliostat control and such maintenance of the ASM 150 heliostat as changing the motors.

TSA

Contributions to replacing the absorber modules.

GRAAL

Test room preparation and canting heliostats.

STAMP

Modification of water cooling circuit and preparation of the test article.

HCF

- Services for several modification of water lines, electrical installation, control, etc.
- Erection of a new pipe rack for supplying oxygen to the pneumatic cylinder.
- Removal of the DISTAL control to the HCF control room and remodeling.
- Small but careful work for test articles as mechanical pieces, thermocouples, etc.

DETOX

Installation of SOLFIN equipment and commissioning.

ARDISS

Support to repair and modification of the installation, replacing facets for use with different types of collectors.

TMR

Erection of a new circuit. Dishes Support and help as requested.

PSA General

- Maintenance and infrastructure
- Clean-up temporary outbuilding
- Cleaning out gullies and repairing the ditch around the edge of the CESA I heliostat field.
- Improvement of the three flat solar collectors in water.
- Preparation and control of maintenance jobs and monthly report.

Last: 2
Last: 3.1
Annual Technical Report 1996
Back: 3 - Operation & Maintenance
Next: 4
Top: 3.2 - Maintenance Plan for 1996/97

Last: 2
Annual Technical Report 1996
Back: 3 - Operation & Maintenance
Back: 3.1 - Summary of Operation Hours
Next: 4
Next: 3.2
Next: 3.1.2

3.1.1 - CESA-1 Facility

Central Receiver Systems (CRS)

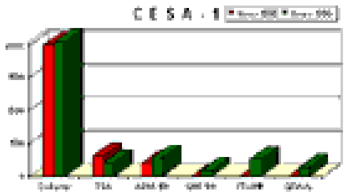


Fig. 3.1.1: Comparative operation hours in the CESA-I test facility

Heliostats field control modification was started at the beginning of the year. The objective of the first modifications was to facilitate implementation of automatic aiming strategy control. In May, the new control system manufactured by DISEL was installed and acceptance tests were carried out. As a result, TSA receiver operation is possible without intervention of the heliostat field master control operator.

At the end of the year on-axis laser canting of a remaining heliostat group was begun. Improvement of some other heliostat images was also included.

Some SENER heliostat elevating mechanisms were changed in order to evaluate the time and work necessary to change each of these mechanisms as well as the results of such a change.

Cooperation with the University of Seville for improvement of advanced system of heliostat control continued from October to the end of the year.

TSA

TSA receiver tests had to be alternated with the ASM-150 heliostat tests, since they use the same hardware. The tests carried out validate the two different aiming strategy control algorithms installed. Maximum temperature deviations in the absorber elements were around 80C. At the end of year, 22 absorber elements were replaced by a new enhanced design. Additional thermocouples were installed for evaluation.

STAMP

The STAMP project tests carried out required 261 hours of heliostat field operation, including off-set adjustment, calibration and preparation of the heliostats entrance sequences demanded to achieve the proper flux ramp for this purpose.

GRAAL

At the end of year, the GRAAL project tests were started. Very good weather conditions are necessary for these tests. It was therefore decided to continue measurements in spring. The results achieved forecast good perspectives in this field of work.

Last: 2
Annual Technical Report 1996
Back: 3 - Operation & Maintenance
Back: 3.1 - Summary of Operation Hours
Top: 3.1.1 - CESA-1 Facility
Next: 4
Next: 3.2
Next: 3.1.2

[Last: 2] [Annual Technical Report 1996] [Next: 4]
[Back: 3 - Operation & Maintenance] [Next: 3.2]
[Last: 3.1.1] [Back: 3.1 - Summary of Operation Hours] [Next: 3.1.3]

3.1.2 - CRS - DCS Facility

Central Receiver Systems (CRS)

Receptor Avanzado de Sales (RAS Project)

The test campaign was completed as planned at low and medium flux densities. Problems caused by heat tracing were completely solved and the salt in the loop did not freeze. Operation was normal with the exception of a stubborn structural salt leak. A change in the aiming strategy was necessary in order to increase the power in the receiver and reduce the spillage.

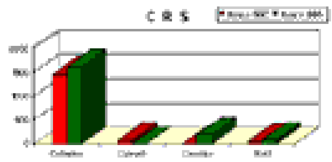


Fig. 3.1.2: Comparative operation hours in the CRS test facility

VOLUMETRIC PROJECT

In first phase testing of the Cor-Rec receiver mounted in 1995, system behavior did not reach nominal conditions. This behavior shows irregular distribution of air flow causing temperatures to be higher in the outer part than in the center.

Distributed Collector System (DCS)

ACUREX

The Human Capital and Mobility Program was terminated in February. The rest of the year was devoted to the EU-DGXII TMR Program test plan. The tests were distributed over the entire year among the following organizations: Univ. of Manchester (UMIST), Univ. of Sevilla (AICIA), Instituto de Engenharia de Sistemas e Computadores (INESC), Univ. of Florencia, Univ. of Oulu and Univ. of Strathclyde. In all cases, the response of the oil system to different controls was checked. Some of the energy collected by the system was used for desalinating water.

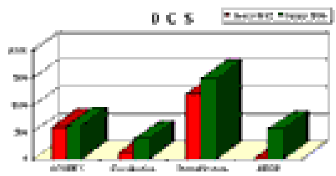


Fig. 3.1.3: Comparative operation hours in the Distributed Collector System test facility

DESALINATION PLANT

The desalination plant was included this year in the EU-DGXII TMR Program and it was operated regularly. The principal user was RTC Tallaght. Besides this, the continuous production of distilled water was used for the Detoxification and TSA projects as well as for such general uses as washing mirrors and cooling water.

Last: 2
Annual Technical Report 1996
Next: 4
Back: 3 - Operation & Maintenance
Next: 3.2
Last: 3.1.1
Back: 3.1 - Summary of Operation Hours
Next: 3.1.3
Top: 3.1.2 - CRS - DCS Facility

Last: 2
Annual Technical Report 1996
Next: 4
Back: 3 - Operation & Maintenance
Next: 3.2
Last: 3.1.2
Back: 3.1 - Summary of Operation Hours

3.1.3 - High Concentration Facility

Solar Furnace

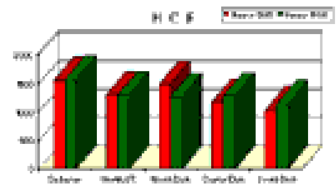


Fig. 3.1.4: Comparative operation hours in the High Concentration Facility

The Falling Particle Receiver (FPR) was mounted in January, and from February to the end of April it was tested in the Solar Furnace at a maximum temperature of about 800ºC.

Two kind of particles were tested, SiC and red sand with a maximum diameter of 0.3 mm.

The infra-red (IR) camera was calibrated at a range of 500ºC to 1000ºC, with a black body on graphite.

Within the Training & Mobility of Researchers (TMR) program, the following institutions performed tests in the Solar Furnace:

- The Trinity College of Dublin, which carried out tests on cylindrical cast iron samples with the secondary concentrator in order to get a better flux distribution on the samples surface.
- Materials Ireland tested MgO samples inside an alumina retro-reflector cavity. Steady conditions were reached around the samples in these tests.
- The Materials department of the University of Sevilla, whose tests with sintered stainless steel A316L specimens aimed to increase the surface density of the samples exposed on a rotating rod inside the alumina retro-reflector cavity and were inertized by means of a stream of gas (95%N2-5%H2) at 2.4 bar.
- The department of Automatic Control of the University of Sevilla tested a PID subroutine implemented in the Shutter and Table Control program for automatic control of the shutter.

Detoxification

Within the TMR program, the Helioman collector loop and the CPC's were used by the University of Barcelona, El Ejido, INETI, ISFH, the University of Vienna (TUW) and CNRS, for tests with contaminants such as chlorophenol, dichlorophenol (DCP), dichloroacetic (DCA) acid, pesticides, industrial waste water and others.

The catalysts used were mainly titanium dioxide (TiO_2), photophenton and sepiolita.

ARDISS

After the project had been mounted at the end of 1995, pre-operation tests were carried out in January, and in February testing started. The PAREX absorber pipe installed on the Helioman collector has been tested, focusing mainly on the efficiency and thermal losses of the PAREX absorber.

DISTAL

As in 1995, 5-day-a-week DISTAL operation continued in 1996. From March 1992 more than 89 000 kW/h gross power were produced and more than 23 000 operating hours were accumulated by the three dishes.

The new tube receiver was successfully tested, and the dishes needed less maintenance time than in any other previous year.

Last: 2
Annual Technical Report 1996
Next: 4
Back: 3 - Operation & Maintenance
Next: 3.2
Last: 3.1.2
Back: 3.1 - Summary of Operation Hours
Top: 3.1.3 - High Concentration Facility

Last: 3 Annual Technical Report 1996 Next: 5

4 - Engineering Department Activities

The Engineering Department has the most scientists of any department at the PSA. Ten engineers and technicians deal with the following work areas:

- Control and Instrumentation,
- Infrastructure,
- Informatics,
- Flux measurements,
- Safety.

Within the PSA organization, depending directly from the Directorate, the department works independently with the Area Heads on the different projects. Thus, Engineering know-how is concentrated in only one department. This implies that all internal PSA work is designed or supervised by this department and either performed by the PSA maintenance staff or subcontracted to other companies.

With 16 years of experience, some members of the department, such as the control, instrumentation and flux measurement personnel, are internationally considered experts in the field of solar energy research.

Andreas Holländer
Head of Department

Rosario Domech
Secretary

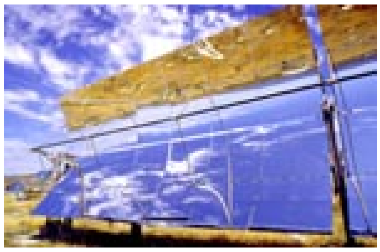
Contents:

Last: 3 Annual Technical Report 1996 Next: 5

Top: 4 - Engineering Department Activities

Annual Technical Report 1996

Contents:



Last: 4 Annual Technical Report 1996 Next: 6

5 - Training and Educational Activities

Bernhard Milow

Just as training and education play a key role in the worldwide development of solar energy, activities in this field are also given primary importance at the Plataforma Solar de Almería.

In 1996, cooperation with the University of Almería was further intensified. Two new lines of activities were initiated. One is the course for all persons interested in the field of renewable energies in the Expert Courses open to non- students, the other is the integration of renewable energy topics in the existing University of Almería doctoral program. In both activities, scientists of CIEMAT and DLR work together with their colleagues from the University of Almería.

New links to the EU Leonardo Program were established during 1996 which will allow more students from abroad to carry out their training courses or diploma theses at the PSA in the future.

The following table lists students who participated in the 1996 PSA Student Program. 35 students were trained in the different PSA areas and contributed a total of 122 man months to the PSA at a total cost of 9,959,226 Pesetas. 22 of the students were Spanish, 13 were German and 2 were from other countries.

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Castellano, Nuria	Solar Towers	3
Darge, Carsten	Materials	3
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García Hita, Purificación	Solar Chemistry	3
Haberfellner, Gerd	Solar Towers	3
Heras Latorre, Juan A.	Solar Towers	3
Lenze, Anja	Solar Towers	3

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López Horta, Asel Raquel	Dish/Stirling	3
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Rauscher, Jochen	Materials	3
Reinalter, Wolfgang	Dish/Stirling	9
Reinig, Melanie	Solar Towers	3
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Schillig, Frank	Solar Troughs	3
Soto Alba, José Daniel	Low Temperatures	3
Tonnar, Marcel	Dish/Stirling	4
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Last: 4 Annual Technical Report 1996 Next: 6

Top: 5 - Training and Educational Activities

Last: 3
Annual Technical Report 1996
Back: 4 - Engineering Department Activities
Next: 5
Next: 4.2

4.1 - Overview of Computer Services

As in former years, the Computer Services Department has had to deal with a wide range of tasks. The development of new data acquisition systems for PSA projects, as well as maintenance and improvement of already existing systems were carried out as a matter of routine. Within this scope of work the new computer-based project man- power control system was designed, an algorithm for the correction of the deviation of solar tracking systems was developed and some special data bases for the maintenance department were implemented.

Juan A. Camacho

In addition, the local network system connecting all scientists and employees was completed.

Jaime Aranda

Fig. 4.1 demonstrates the growth of the number of users and nodes on the server in the last five years. Connection was begun in 1992 with the SSPS building and was distributed from there to all other buildings. By the end of 1996 nearly 70 users were connected and 80 connection points were installed.

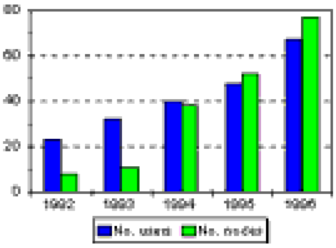

Fig. 4.1: Growth of users and network nodes in the last 5 years

With the installation of the server technology at the PSA, external communication has also been built up. A milestone was established with connection to the University of Almería over the new 64-kB data-transfer line, which allows PSA members a high degree of communication exchange. From 1995 to 1996 the amount of information sent increased from 618 MB to 5,013 MB, which represents an increase of about 800%. The amount of information received grew to nearly 8,900 MB or 360%.

The most important conclusions arrived at from Fig. 4.2 is that the PSA staff frequently uses this form of communication to obtain new information and updated software from all over the world and that nearly half the amount of information received was sent. Given the poor decentralized infrastructure in the desert of southern Spain, this is the quickest possible mode of information exchange.

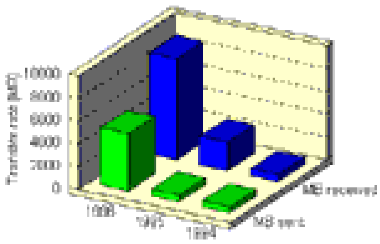

Fig. 4.2: External communication traffic of PSA

In March, 1996, a World Wide Web server was also installed. During 9 months of operation we had a total of 1,724 linkups from 28 different countries and links to the PSA were implemented at 54 scientific centers and commercial servers. The following Fig. 4.3 gives an overview of the most frequent connections to the PSA and their origin.

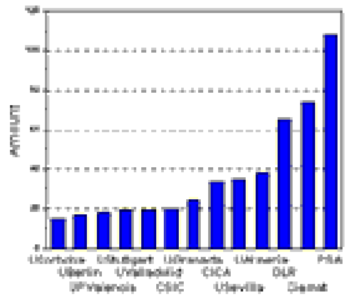

Fig. 4.3: Number of WWW links of the most important centres

The most frequent connections were with the two partner institutions, CIEMAT and DLR. Other connections worth mentioning came from universities in Spain and Germany.

Fig. 4.4 shows the most visited PSA pages. Besides project information, other information and general information were frequently visited.

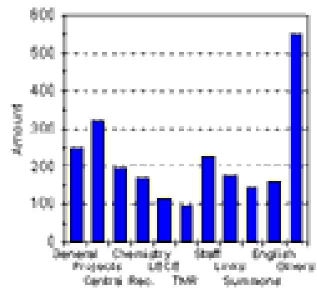

Fig. 4.4: Number of most visited WWW pages at PSA

Last: 3

Annual Technical Report 1996
Back: 4 - Engineering Department Activities
Top: 4.1 - Overview of Computer Services

Next: 5
Next: 4.2

Team Developers of this PSA Web site thank you for visiting our site.
We'd like to hear from you.

Last: 3
Last: 4.1

Annual Technical Report 1996
Back: 4 - Engineering Department Activities

Next: 5
Next: 4.3

4.2 - Infrastructure Activities

Bernabé Calatrava
Infrastructure & Safety

Since 1995, infrastructure spending has been affected by the economic constraints of the overall PSA budget. Thus, only the most necessary activities could be performed. An important part of the expenses were spare parts for defective equipment, preparation required for new projects or improvement of safety. The total department budget of roughly 6 million pesetas was divided among the following items:

- Improvement and maintenance of buildings
- Enlargement of the computer and communications equipment pool
- Improvement of the high and low voltage electrical supply.
- Update of equipment (spare parts).
- Safety
- General

Angel Soler
Draftsman

To give a general idea of the tasks involved, the following list shows some representative infrastructure activities at the PSA:

- Integration of the DISTAL project in the solar furnace control
- DISTAL II project site preparation
- Increase external data communication line from 9.6 kB to 64 kB
- Purchase of new server equipment
- Increase of UPS capacity
- Installation of safety equipment for high-pressure liquid gases.

The infrastructure investments were distributed as shown in the pie chart in Fig. 4.5.

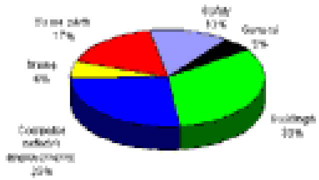

Fig. 4.5: Cost distribution of infrastructure budget

Last: 3
Last: 4.1

Annual Technical Report 1996
Back: 4 - Engineering Department Activities
Top: 4.2 - Infrastructure Activities

Next: 5
Next: 4.3

4.3 - Control, Instrumentation and Monitoring

The control, monitoring and instrumentation tasks are proportional to project activities. Due to the fact that the number of projects has increased in the last years, the work load is near to the working limit of the staff involved. Scheduling the work to be done during the summer months was the major problem in 1996.


Ginés García

Some main activities are listed below.

ARDISS

Detailed design of the instrumentation, data acquisition and control system. Purchasing and supervision of work.


Andrés Egea

DISS

Supervision of the detailed design, tendering and technical advice for the control and instrumentation of the largest PSA project in 1996.

Research, design, detailed instrumentation engineering, training of operators, start up of pre-project test devices, ball joint test stand and LS-3 test loop instrumentation.

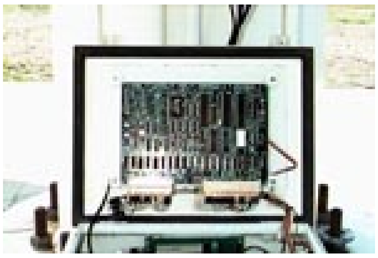
Fig. 4.6: GM100 local control prototype

GM 100

- Design of new local heliostat control system hardware components.
- Emulation tests with wire wrapping
- Development of the PCB (Printed Circuit Board) with the CIEMAT department of “Automation and Electronics”. Fig. 4.6 shows the new GM100 local control prototype cards resulting from this work.
- Implementation, adjustment and programming of the new software.
- Development and testing of an advanced radio modem prototype remote control in cooperation with the University of Almería.

Solar Furnace

- Manufacture of special thermocouples for TMR users from the

University of Sevilla.

- Development and design of the remote guillotine control.

SOLFIN

Pre-design, detailed design, tendering, quality control and supervision of the work. Fig. 4.7 shows the IMP Data Acquisition System and the PLC control system.

Fig. 4.7: SOLFIN instrumentation box

STAMP

Manufacture and bonding of 22 special thermocouples for the Dassault Aviation project.

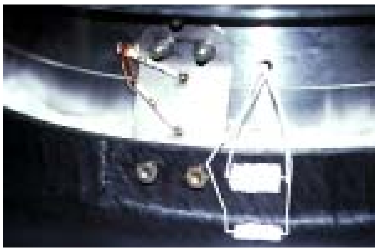

Fig. 4.8: Detail of special thermocouples for the STAMP project

The above mentioned tasks represent only the most important work carried out in 1996. Furthermore, the instrumentation team provided support for all PSA projects.

Last: 3
Last: 4.2

Annual Technical Report 1996
Back: 4 - Engineering Department Activities
Top: 4.3 - Control, Instrumentation and Monitoring

Next: 5
Next: 4.4

4.4 - Flux Measurements

The flux measurement activities are among the most important tasks at PSA as they determine the basis for qualification of every concentrating system used at the PSA. With the two Hermes measurement systems, the radiation distribution is measured and afterwards evaluated to deliver the parameters of the components.

Rafael Monterreal

Fig. 4.9 shows typical sun shape flux distribution on the target as measured last year.

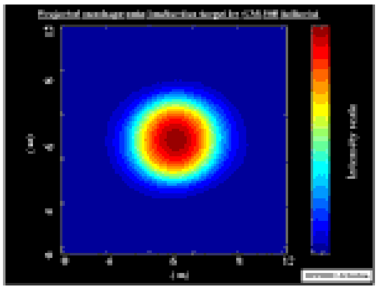

Fig. 4.9: Projected sunshape onto the Lambertain target of the GM 100

In 1996 the following measurement campaigns were carried out at the PSA:

- Advanced Salt Receiver (RAS)
- Volumetric Receiver (CATREC)
- Advanced Stretched Membrane Heliostat (ASM-150)
- Glass-Metal Heliostat (GM-100)
- Falling Particle Receiver (FPR)

Fig. 4.10 gives an evaluated measurement of the RAS receiver during operation.

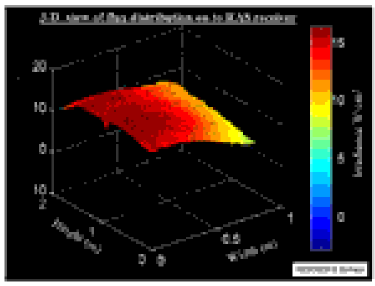

Fig. 4.10: 3-D view of the flux distribution onto RAS receiver

Furthermore, the PSA participated in the first flux-meter comparison campaign at the CNRS furnace in Odeillo, France.

The object was to measure the calorimeters of the different test centers in the world and to calibrate all of them to the conditions already determined in previous meetings.

Fig. 4.11 shows a front view of the CNRS calorimeter test bed with the Spanish HiCal calorimeter at the bottom.

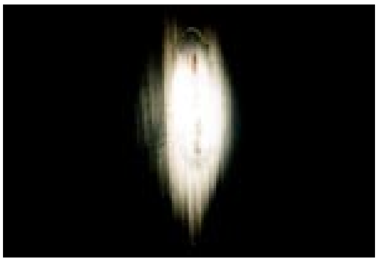

Fig. 4.11: Front view of CNRS calorimeter test bed at Odeillo, France

Besides all this measurement and evaluation work, the PSA bought two new 12-bit resolution CCD-camera systems keeping the PSA measuring devices state-of-the-art and allowing a detailed raster of 4096 gray levels for calculation instead of the 255 gray levels used until now. By the end of the year they were installed and ready for calculations in the solar furnace. Operation with the new equipment is scheduled to start in the first quarter of 1997.

Last: 3
Last: 4.3

Annual Technical Report 1996
Back: 4 - Engineering Department Activities

Next: 5
Next: 4.5

Top: 4.4 - Flux Measurements

4.5 - Ball-Joint Test Stand

Dieter Weyers

Special components have had to be tested within the Direct Solar Steam Generation project (DISS). Some of the most critical equipment is the connection between the solar collectors, which has to allow for independent rotation and compensation of thermal expansion. For this reason movable ball joints, based on a ball and socket, are being tested.

The ball-joint task tests the resistance of the injection packing and measures torque under operating conditions.

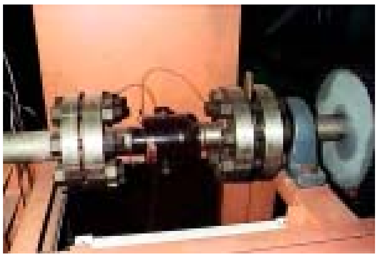

Fig. 4.12: Detailed view of the ball joints

The ball-joint test parameters are defined by DISS project solar-collector field operation. Daily rotation of the ball joint, installed at the rotating axis of the collector, will be 270º forwards and backwards. The maximum angular flexion of the ball joint is limited to a total of 15º. The test steam conditions of 110 bar and 450ºC are given by the maximum DISS project operating parameters.

The tests are performed at the ENDESA power station in Carboneras under a maximum of 530ºC, 160-bar steam. The pressure in the line is proportional to the energy which the power station produces during the day and ranges between 90 and 150 bar. The steam expands after the orifice plate to ambient pressure and passes through a water cooler where it is condensed.

Fig. 4.13: Equipment at the Carboneras power plant

The equipment was designed and built at the end of 1996 and the testing is scheduled for the beginning of 1997. Fig. 4.13 shows the equipment at the Carboneras power plant.

Last: 4 Annual Technical Report 1996 Next: 6

5 - Training and Educational Activities

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Last: 4 Annual Technical Report 1996 Next: 6

Top: 5 - Training and Educational Activities

Last: 5 | Annual Technical Report 1996 | Next: 7

6 - Training and Mobility of Researchers Program

Contents:

Diego Martínez
TMR Project Manager

Last: 5 | Annual Technical Report 1996 | Next: 7
Top: 6 - Training and Mobility of Researchers Program

Last: 4 | Annual Technical Report 1996 | Next: 6

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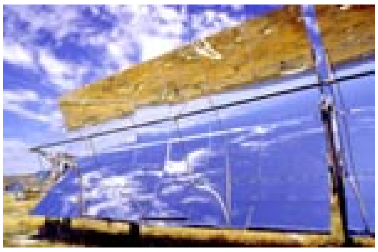
Annual Technical Report 1996

Contents:



Last: 6 | Annual Technical Report 1996 | Next: Ap 1

7 - Summary of 1996 Meteorological Data

Contents:

Martin Stegmann

Last: 6 | Annual Technical Report 1996 | Next: Ap 1

Top: 7 - Summary of 1996 Meteorological Data

Last: 5
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Next: 7
Next: 6.2

6.1 - The Program

The ‘Training & Mobility of Researchers Programme’ (TMR) is the modified continuation of ‘Human Capital and Mobility’ (HCM) and its aim is to promote, through the stimulation of training and mobility of researchers, a qualitative and quantitative increase in human resources within the Community and Associated States.

The program is managed by the Directorate General XII of the Commission of the European Communities for Science, Research and Development and comprises four activities:

1. Research Networks: To promote transnational cooperation on research activities proposed essentially by the researchers themselves.
2. Access to Large-Scale Facilities: To facilitate the access of researchers to existing large-scale facilities that are essential for high-quality research.
3. Training through Research: To foster better utilization of high-level researchers in the Community.
4. Accompanying Measures: For dissemination and optimization of the results of activities.

Last: 5
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Next: 7
Next: 6.2
Top: 6.1 - The Program

Last: 5 | Annual Technical Report 1996 | Next: 7
Last: 6.1 | Back: 6 - Training and Mobility of Researchers Program | Next: 6.3

6.2 - PSA Participation in the European Commission Access Programs

As one of the main PSA goals is to promote the use of solar thermal energy throughout Europe, it has long been interested in participation in of European Commission access programs.

Concretely its participation has its starting point on January 1990 when PSA joined the 'Large Installations Plan' of the Second Framework Program.

	LIP	HCM	TMR
CONTRACT Nº	ERBGE1*CT000019	CHGE-CT93-0038	ERBFMGE-CT950023
PERIOD	1/1/90 - 30/06/93	1/1/94 - 31/03/96	1/1/96 - 31/12/98
NUMBER OF FACILITIES	3	5	9
WEEKS OF ACCESS	231	290	168
DGXII FUNDING	2.200 KECU	1.400 KECU	1.600 KECU

Table 6.1: PSA Participation in CEC-DGXII Access Programs

In the table above the PSA participation as host facility for DGXII access programs is shown with relevant data.

Last: 5 | Annual Technical Report 1996 | Next: 7
Last: 6.1 | Back: 6 - Training and Mobility of Researchers Program | Next: 6.3
Top: 6.2 - PSA Participation in the European Commission Access Programs

Last: 5
Last: 6.2
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Next: 7

6.3 - Current Activities

PSA is now running a three-years contract with CEC-DGXII concerning the ‘Access to Large-Scale Facilities’ activity of the ‘Training and Mobility of Researchers’ program.

Concerning other activities within the program, it must be said that PSA hosts currently two ‘Marie Curie Research Training Grant’ holders and new applications will be considered in the new call of the Commission to be issued by mid March.

Contents:

Last: 5
Last: 6.2
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Next: 7
Top: 6.3 - Current Activities

Last: 5
Last: 6.2
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Back: 6.3 - Current Activities
Next: 7
Next: 6.3.2

6.3.1 - The PSA Commitments

In order to guarantee successful performance, fairness and compliance with the Commission’s objectives within that contract, PSA has assumed a series of commitments.

The tightest constraints imposed by them concern the user selection process, beginning with the call for proposals and including the selection panel itself.

Contents:

Last: 5
Last: 6.2
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Back: 6.3 - Current Activities
Next: 7
Next: 6.3.2
Top: 6.3.1 - The PSA Commitments

6.3.2 - Activities in Year 1996

The main activities supported by this contract during 1996, apart from user visits to the PSA, have been the following:

- First Annual Users Meeting. All 28 groups selected were invited to this meeting held at the PSA on February 20th. The main objectives were discussion of the access schedule and a first visit to the facility. The PSA and the program itself were presented in general sessions, followed by parallel sessions in which the users met their project leaders and other users of the same facility.
- Round-Table Meetings. The PSA was invited by the European Commission to attend a series of large-scale energy research facility Round Table discussions. At the first meeting, held in Amsterdam on June 21st, the Commission's scientific officer welcomed the two new facilities present and explained the goals of the activity. At the second meeting in Paris on October 4th, the basis for a Concerted Action proposal was established. This proposal has been prepared and is now being evaluated in Brussels.
- Second User Selection Panel. The panel met in Madrid on October 30th to select the users to be given access during 1997. On this occasion, experts more directly involved in the subjects of PSA research were chosen for the panel, respecting the proportion of CIEMAT members stipulated, and keeping it international. This panel should now be kept the same until the end of the program.

The technological achievements which follow are the most representative of the very different research areas, all of which have solar energy in common:

- Control algorithms: switching controller tuning by predictive adaptive methods and the Linguistic Equation Controller have been tested for the first time in an industrial environment.
- In the field of waste water detoxification, very promising results have been obtained in the degradation of TOC and phenol content in the wastewater from olive presses with TiO_2 as catalyst. This is especially important for the Andalusian region where PSA is located, because it is one of the main pollutants of rivers.
- The main issue in materials treatment has been the surface

densification of sintered steel with highly concentrated solar radiation in the Solar Furnace.

Through its recent participation in the Round Table meetings, the PSA has found alternative ways to manage access, for instance training activities. Up to now, the PSA has based access on the use of facilities for research. Now a new policy, addressing training, is to be incorporated.

No great difficulties have arisen in the execution of the program. Access opportunities were not broadcast well enough outside of Spain and Germany, even though the ‘Call for Proposals’ was advertised in several scientific journals with European and even worldwide distribution. It is hoped that this problem can be overcome with an intensive ‘Internet’ campaign in which the next ‘Call’ will be sent to many different institutions in electronic format. It will also be more widely advertised and presented in as many forums as possible.

Last: 5
Last: 6.2
Last: 6.3.1

Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Back: 6.3 - Current Activities

Next: 7

Top: 6.3.2 - Activities in Year 1996

Last: 5
Last: 6.2
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Back: 6.3 - Current Activities
Back: 6.3.1 - The PSA Commitments
Next: 7
Next: 6.3.2
Next: 6.3.1.2

6.3.1.1 - Users Selection Process

A Selection Panel must meet at least once a year to select the coming year's Users from among the proposals received during the period of the 'Call for Proposals'.

This Panel must be composed of at least 10 experts, at least six of these not from CIEMAT. The Panel must have a European scope. The members should be the same for the whole program.

The 'Call for Proposals' must be widely publicized and its publication in at least some scientific journals of European diffusion is mandatory.

Last: 5
Last: 6.2
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Back: 6.3 - Current Activities
Back: 6.3.1 - The PSA Commitments
Top: 6.3.1.1 - Users Selection Process
Next: 7
Next: 6.3.2
Next: 6.3.1.2

Last: 5
Last: 6.2
Last: 6.3.1.1
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Back: 6.3 - Current Activities
Back: 6.3.1 - The PSA Commitments
Next: 7
Next: 6.3.2
Next: 6.3.1.3

6.3.1.2 - Amount of Access Committed

For the entire three years of the contract, the following facilities and access time are offered:

- Detox Loop, Solar Furnace, Acurex Field and Solfin : 30 Weeks
- Dish/Stirling, Solar Dryer, Desalination Plant , LECE: 12 Weeks

The amount of access to CESA-1 facility is now under negotiation with DGXII. This facility has been included beginning of 1997 and a redistribution of the access to the other facilities must arranged in order to fit within the budget committed.

‘Access’ does not means simply the use of the facility, but also all infrastructure and technical and scientific support that is normally provided to external users of the PSA.

The CEC requires that a minimum of 28 groups of users per year be given access with a minimum of 50 different groups at the end of the program. Access to Spanish and German groups together is limited to a maximum of 15%.

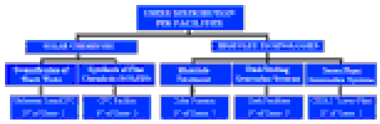


Fig. 6.1: User Distribution per Facility (I)

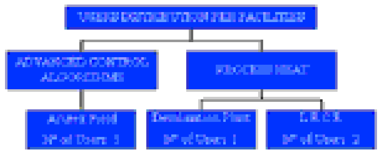


Fig. 6.2: Users Distribution per Facility (II)

Last: 5
Last: 6.2
Last: 6.3.1.1
Annual Technical Report 1996
Back: 6 - Training and Mobility of Researchers Program
Back: 6.3 - Current Activities
Back: 6.3.1 - The PSA Commitments
Next: 7
Next: 6.3.2
Next: 6.3.1.3
Top: 6.3.1.2 - Amount of Access Committed

6.3.1.3 - Other Commitments

The PSA program management also assumes some other commitments besides amount of access and number of users:

- Participation in the Round Table for European Facilities performing Energy-related Research: The purpose of the Commission is to bring together those facilities which participate in the Program and that work in common topics of research. Preparation of joint-research proposals as well as the exchange of access management experiences are the key point of this initiative.
- Preparation of an Annual Progress Report providing access activity statistics, the publications generated through the program, cost statement, and any other relevant information arising from program performance during the year.
- The Midterm Review: Before the end of the second year of the program at PSA, a meeting must be arranged by PSA management in order to review the program degree of progress and to take the necessary measures or perform the necessary modifications, if any.
- The Annual Users Meeting: Every year, before the starting of access activities, a general users meeting must be organized at PSA. The main objective of that meeting is to offer a first contact of the users with the corresponding facilities, as well as with the project-leaders on-site. Detailed explanations on how the program runs are also given.

[Last: 6](#) [Annual Technical Report 1996](#) [Next: Ap 1](#)

7 - Summary of 1996 Meteorological Data

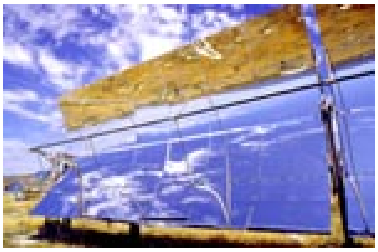
Contents:

Martin Stegmann

Last: 6 Annual Technical Report 1996 Next: Ap 1
Top: 7 - Summary of 1996 Meteorological Data

Annual Technical Report 1996

Contents:



Last: 7 Annual Technical Report 1996 Next: Ap 2

Appendix 1
Project Descriptions

Contents:

Last: 7 | Annual Technical Report 1996 | Next: Ap 2

Top: Appendix 1 - Project Descriptions

Last: 6
Annual Technical Report 1996
Back: 7 - Summary of 1996 Meteorological Data
Next: Ap 1
Next: 7.2

7.1 - Introduction

The PSA meteo station is one of the most complete in Spain. About 15 sensors report their values every two seconds to the central computer, which stores extreme and average values every 5 minutes. Since 1988 about 140 Mbyte have been accumulated and stored.

Besides its own Central Meteo Station, the Spanish “Instituto Nacional de Meteorología” also uses the PSA infrastructure for its measurements.

Even the best meteo stations have some failures during the year resulting in missing data. This problem, which occurs mainly during the summer vacation period in August, was solved by using data from independent projects running on the PSA, especially direct radiation data from the SSPS / DCS-project.

A PSA doctoral student is assigned the task of overhauling our central meteo station hard- and software during the next three years.

Last: 6
Annual Technical Report 1996
Back: 7 - Summary of 1996 Meteorological Data
Next: Ap 1
Next: 7.2
Top: 7.1 - Introduction

7.2 - Meteo Data 1996

Contents:

Last: 6
Last: 7.1
Annual Technical Report 1996
Back: 7 - Summary of 1996 Meteorological Data
Back: 7.2 - Meteo Data 1996
Next: Ap 1
Next: 7.2.2

7.2.1 - Direct Radiation

Fig. 7.1 shows the monthly and hourly averages of direct radiation. It is easy to see that the year started with a relatively bad winter, an average summer and autumn, and ended in a relatively cloudy December. An average peak of over 900 W/m^2 was only reached in August at high noon. 1996 offered **3466 hours of sunshine** with direct radiation **over 300 W/m^2** and a total of **1912 kWh/m^2** of accumulated solar energy.

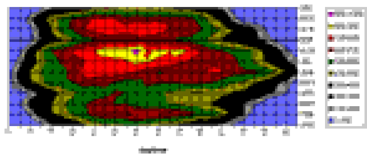


Fig.7.1: Direct Radiation (W/m^2)

Last: 6
Last: 7.1
Annual Technical Report 1996
Back: 7 - Summary of 1996 Meteorological Data
Back: 7.2 - Meteo Data 1996
Next: Ap 1
Next: 7.2.2
Top: 7.2.1 - Direct Radiation

Last: 6
Last: 7.1
Last: 7.2.1

Annual Technical Report 1996
Back: 7 - Summary of 1996 Meteorological Data
Back: 7.2 - Meteo Data 1996

Next: Ap 1
Next: 7.2.3

7.2.2 - Temperatures

The diagram in Fig. 7.2 giving the monthly and daily temperature distribution shows how inertia of the heated earth and atmosphere are dependent on the solar radiation.

The coldest time of day is between 6 and 8 o'clock a.m., hottest temperatures are reached between 2 and 4 o'clock p.m.

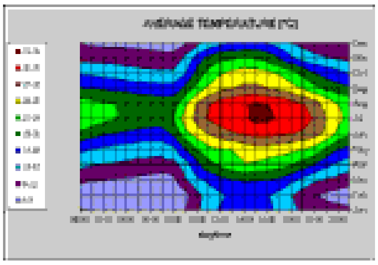


Fig.7.2: Monthly And Hourly Averages (°C)

Fig. 7.3 indicates monthly maximums, minimums and average temperatures. The maximum was 40.0 ºC in July, the minimum - 2 ºC in February.

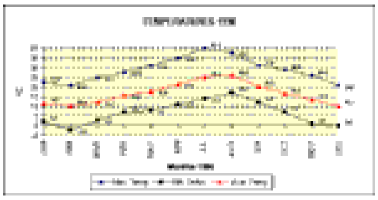


Fig. 7.3: Extreme and Average Values 1996

Fig. 7.4 shows average and extreme temperatures for the last twelve years. The average temperature in 1996 was about 16.9 ºC, the lowest since 1986.

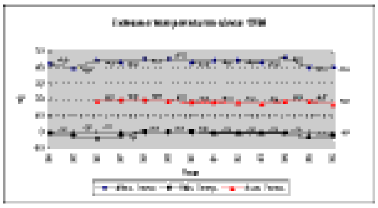


Fig. 7.4: Historical Pattern since 1984

Last: 6
Last: 7.1
Last: 7.2.1

Annual Technical Report 1996
Back: 7 - Summary of 1996 Meteorological Data
Back: 7.2 - Meteo Data 1996
Top: 7.2.2 - Temperatures

Next: Ap 1
Next: 7.2.3

Last: 6 | Annual Technical Report 1996 | Next: Ap 1
Last: 7.1 | Back: 7 - Summary of 1996 Meteorological Data
Last: 7.2.2 | Back: 7.2 - Meteo Data 1996 | Next: 7.2.4

7.2.3 - Wind

Fig. 7.5 gives the monthly and hourly average wind speeds, clearly showing that the windy season is generally in the first part of the year until July and that the wind rises mainly after midday and calms in the early evening.

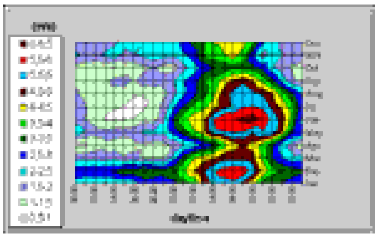


Fig. 7.5: Monthly and Hourly Average Wind Speeds at 10m

Figs. 7.6 and 7.7 represent the wind frequency and average wind speed by direction. Prevailing winds blow out of the East and North-East (Levante), but are not as strong as the westerly and south-westerly winds (Poniente).

The average wind-speed in 1996 was about 2.83 m/s.

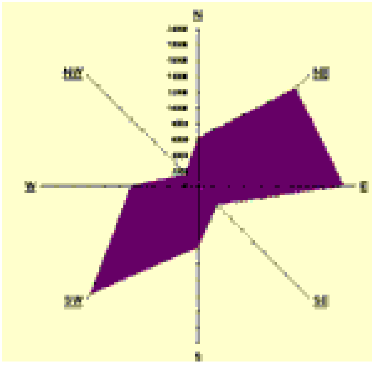


Fig. 7.6: Wind Frequency

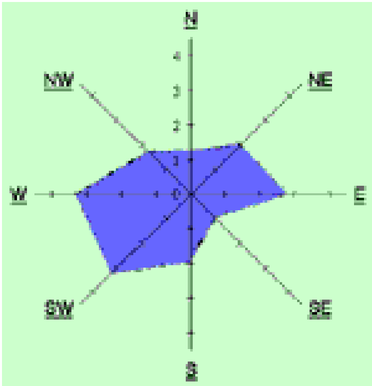


Fig. 7.7: Wind Speed

Last: 6 | Annual Technical Report 1996 | Next: Ap 1
Last: 7.1 | Back: 7 - Summary of 1996 Meteorological Data
Last: 7.2.2 | Back: 7.2 - Meteo Data 1996 | Next: 7.2.4
Top: 7.2.3 - Wind

Last: 6
Last: 7.1
Last: 7.2.3

Annual Technical Report 1996
Back: 7 - Summary of 1996 Meteorological Data
Back: 7.2 - Meteo Data 1996

Next: Ap 1

7.2.4 - Rain

Fig. 7.8 shows the precipitation and the number of rainy days since 1983. With a total precipitation of 335 cm/m^2 in 1996 it is more than twice that in 1995.

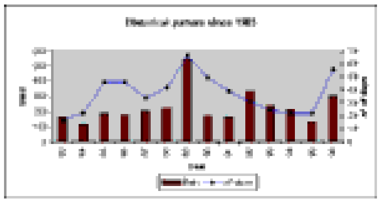


Fig. 7.8: Historical Pattern since 1983

Fig. 7.9 presents the average monthly and daily peak distribution of rain last year.

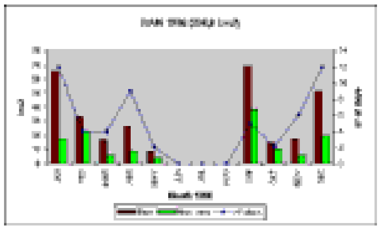


Fig. 7.9: Monthly Precipitation 1996

Last: 6
Last: 7.1
Last: 7.2.3

Annual Technical Report 1996
Back: 7 - Summary of 1996 Meteorological Data
Back: 7.2 - Meteo Data 1996
Top: 7.2.4 - Rain

Next: Ap 1

Last: 7 | Annual Technical Report 1996 | Next: Ap 2

Appendix 1
Project Descriptions

Contents:

Last: 7 | Annual Technical Report 1996 | Next: Ap 2

Top: Appendix 1 - Project Descriptions

Appendix 2
List of Collaborating Institutions and Companies

Contents:

Last: 7
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.2

Appendix 1.1
DISS - Phase I (Direct Solar Steam in Parabolic Troughs)

Project Leader:	E. Zarza
Participants:	CIEMAT DLR ENDESA INABENSA FLAGSOL ZSW Siemens Unión Fenosa Iberdrola UMIST
Duration:	From: January 1996 To: December 1997
Funding:	6.35 MECU
Source:	CEC - DG XII Partners

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	1.5	0.5	3.0	1.5
1997	3	1	3.3	1.5

Objectives:

The objective of the DISS project is to develop a new generation of Solar Thermal Power Plants using parabolic-trough collectors to produce high-pressure steam in the absorber tubes, thus eliminating the oil currently used as a heat transfer medium between the solar field and the conventional power block. DISS is an R&TD project including not only the development of a new technology (direct solar steam generation in the absorber tubes), but also improvement of the solar collectors and overall system integration, in order to increase the competitiveness and efficiency of this type of solar power plant.

Description:

The nine SEGS plants currently in operation supplying 354 MWe peak power to the California grid using the technology developed by the LUZ International company since the early 80's are a demonstration of state-of-the-art of solar thermal power plants. LUZ achieved continuous increase in efficiency while reducing costs. Unfortunately, its efforts were insufficient to withstand the reductions in conventional fuel costs and tax subsidies and the company collapsed. By that time, however, LUZ had identified a number of improvements capable of reducing the cost of electricity generation by 30%. These improvements were grouped into three categories:

1. Solar Collector improvements
2. Replacement of the oil with the new process of direct steam generation (DSG) in the

collector absorbers
3. Overall system improvements

In 1989, LUZ began an R&TD program to develop and implement all these improvements. Unfortunately, this program was aborted by the collapse of LUZ. From a technical standpoint, the most critical part of these improvements is the development of direct solar steam generation in the parabolic-trough collectors. This is due to the two-phase flow (liquid water+steam) in the absorber tubes of the collectors, which involves some technical uncertainties that must be clarified before the implementation of a commercial plant using this technology. Some of these unknown factors are:

- Solar field control
- Process stability
- Materials and components

Direct steam generation also has a certain number of technical problems that require real-scale experimentation and evaluation in order to resolve some design and cost issues for which the laboratory facilities currently available (HIPRESS, Siemens-KWU, Solel) are not sufficient. A specific test facility with proper dimensions (real scale) is needed, and this is an essential job for the success of this project. A key point of this project is the design and implementation of such a real-scale test facility to be erected at the PSA.

Since the DISS objectives cover not only the development of the new process (direct solar steam generation) but also all those potential improvements identified by LUZ in the past, parallel activities in system integration and collector improvement will be performed simultaneously with the design, implementation and operation of the PSA test facility.

Status:

The design prepared in 1994 for the DISS test facility to be implemented at the PSA was revised and modified in 1996 to take into account recent results gathered in the STEM and GUDE projects. The detail engineering of the Balance of Plant for the DISS test facility was started and some equipment has been purchased.

Control scheme design studies for the

once-through and recirculation processes done by UMIST and ZSW are finished and a technical report has been published with the results of simulation.

The detailed design of the HTF test loop was finished in 1996 and system erection was begun. This facility will be used to evaluate improved collector components developed within the framework of DISS.

The detailed design of the PSA HTF test loop was finished in 1996 and all the equipment required for this facility was purchased by the PSA. System implementation starting with the erection of half an LS-3 collector.

A new concept of parabolic-trough with stretched membrane was mechanically analyzed and interesting results were obtained. Also new selective and anti-reflective coatings have been studied by CIEMAT with positive results.

Plans for 1997:

The main tasks planned for 1997 are:

- completion of detailed PSA DISS test facility engineering
- Erection of the PSA DISS test facility
- Completion of HTF test loop erection
- Purchase of all the hardware and components for the DISS test facility
- Preparation of a project proposal for the second phase of the DISS project

Last: 7
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.2
Top: Appendix 1.1 - DISS - Phase I (Direct Solar Steam in Parabolic Troughs)

Last: 7
Last: Ap 1.1

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.3

Appendix 1.2
DISTAL (Dish Stirling Almería)

Project Leader:	M. Stegmann
Participants:	CIEMAT DLR Schlaich Bergerman und Partner (SBP) SOLO HTC
Duration:	From: Dec. 1991 To: Dec. 1998
Funding:	11 million Pts. (1996) 14 million Pts. (1997)
Source:	CIEMAT/DLR BMFT SBP CEC-DGXII Joule II

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	0.2	1.1	0.0	0.8
1997	0.2	0.9	0.1	2.9

Objectives:

- Prove and demonstrate ready-for-market designs with routine operation.
- Hybridization with gas for 14h-operation with constant energy output
- Automate operation and maintenance requirements
- Provide a PSA testbed for further development of the dish/Stirling technology

Description:

Three SBP dish/Stirling systems put into continuous operation at the PSA in May, 1992 have accumulated more than 25000 hours of operation (DISTAL I).

Attention now turns to the three new advanced systems (DISTAL II), which will start operation in 1997. As the high performance of Dish/Stirling systems has already been proven, remote-power market prospects look good. The goal of the DISTAL project is therefore not only to optimize system performance, but above all, to demonstrate system reliability and availability in continuous operation.

Status:

- Continuous sunrise-sunset operation of the SBP dishes (DISTAL I)
- Site preparation and erection of the third generation of dish/Stirling systems (DISTAL II)
- Site preparation and erection of the HTC fixed focus concentrator

- First performance tests operating with hydrogen as working gas
- Development of a high flux measurement system

Plans for 1997:

An important step for market introduction of this technology, will be hybridization with gas using a sodium heatpipe receiver developed by DLR. Two prototypes will be installed in the new DISTAL II facility.

Last: 7
Last: Ap 1.1

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.3

Top: Appendix 1.2 - DISTAL (Dish Stirling Almería)

Appendix 1.3
STEM (Solar Thermal Electricity in the Mediterranean)

Project Coordinator:	A. Cuevas (UEF)
Participants:	CIEMAT DLR ENDESA FLAGSOL ZSW Siemens Solel Solar Systems Unión Fenosa Iberdrola INTECSA ULP UMIST
Duration:	From: January 1995 To: June 1996
Funding:	141.6 MPtas.
Source:	CEC DG-XII Partners

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	--	--	0.3	0
1997	0	0	0	0

Objectives:

The two main objectives of STEM have been:

- Develop the conceptual design of a commercial scale 100-200 MWe Integrated Solar Combined Cycle (ISCC) demonstration plant with a direct steam generating solar field. Compare the conceptual design to a state-of-the-art reference system with oil-cooled collectors. Investigate the benefits of a bottoming sea-water desalination system. Chose a specific reference site in Southern Spain and Morocco for these comparisons.

- Prepare the large scale testing of the DSG (Direct Steam Generation) process and of the most promising research concepts on the road to competitiveness that can affect the performance, investment and/or O&M costs. Check the conceptual design of a test loop at the Plataforma Solar de Almería (PSA) for testing the DSG concept as the first step toward full-size demonstration of a DSG plant in the 100 MWe range.

Description:

The STEM project was planned as preparation for the DISS project. Most of the partners involved in STEM also participate in DISS. In STEM, a feasibility study assessed the improvements in performance and potential for cost re- duction of Direct Steam Generation (DSG) technology with large parabolic trough collector fields when integrated into 100-200 MW combined cycle thermal power plants in the Mediterranean Area. This project has been carried out with the financial support of the European Union APAS'94 Program (contract RENA CT94-0014).

Status:

The STEM project was finished in June 1996. The design proposed in 1995 for the DSG test facility to be implemented at the PSA in 1997, was revised and modified in 1996 to take into account recent results gathered in other projects (STEM and GUDE). Most of the detail engineering of the test facility was done in 1996 and purchase of components also started in 1996.

A compilation of the control scheme design studies performed by UMIST and ZSW for the once-through and recirculation processes was edited in 1996. Possible emergency situations which may occur at the DISS test facility have been identified and the relevant recovery procedures were defined.

Last: 7
Last: Ap 1.2
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.4
Top: Appendix 1.3 - STEM (Solar Thermal Electricity in the Mediterranean)

Appendix 1.4
Adaptive Control System Development

Test Engineer:	P. Balsa
Participants:	Univ. Manchester, Institute of Science and Technology (UMIST) (UK) Univ. Seville, Depto. Ing. de Sistemas y Automática, (E) INESC, Lisboa (P) Univ. of Oulu (Fi) Univ. of Firenze (It) Univ of Strathclyde
Duration:	From: April 1990 To: March 1996
Funding Source:	CEC DG-XII HCM and TMR Programs

Objectives:

The main objective of this project is the development and testing of advanced control algorithms for use in solar power plants, providing European research groups with the experimental facilities needed to:

- Perform an in-depth study of the difficulties involved in improving control design schemes for parabolic-trough solar collector fields.
- Test and validate their theoretical approaches to new advanced control algortihms, improving performance, response time, robustness and rejection disturbance.

Description:

Solar power plants deliver thermal energy in the form of the sensible heat of a fluid (liquid or gas) which is heated to a desired temperature. Since the primary energy (solar radiation) varies, without proper control, the temperature of the output fluid also changes.

Parabolic-trough collectors have proven to be an efficient way to meet the requirements of industrial processes. Good control with PI and PID controllers could only be achieved accepting a slow response speed and, consequently, long settling times, restricting the range of their application as an energy source. It became evident that improved control schemes for parabolic-trough solar-collector fields is a requirement for widening the field of application of these systems.

The PSA DCS facilities and the flexible and reliable control software provide a very valuable versatile test bed which has been used by several research groups who have tested different control systems in these facilities.

Last: 7
Last: Ap 1.3

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.5

Top: Appendix 1.4 - Adaptive Control System Development

Last: 7
Last: Ap 1.4
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.6

Appendix 1.5
ARDISS (Advanced Receiver for Direct Solar Steam)

Test Engineer:	P. Balsa (on site)
Participants:	CIEMAT CONPHOEBUS CEC-DGXII INETI ZSW
Duration:	From: December 1994 To: February 1997
Funding:	1 MECU
Source:	CEC DG-XII Partners

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	0.2	0.5	0.3	0.4
1997	0.2	0.27	0.1	0.2

Objectives:

The objectives of this project are to analyze the constraints of Direct Solar Steam Generation in parabolic trough collectors and to develop an advanced receiver fulfilling the requirements of this process.

ARDISS is being developed with the financial support of the JOULE-II program. The project coordinator is the CIEMAT Institute of Renewable Energies (Madrid) and the PSA only provides technical and experimental support. The specific project objectives are:

- The design, construction and testing of the concentrator/receiver.
- The theoretical and experimental analysis of Direct Steam Generation.
- The simulation of the solar driven electricity production system.

And the expected achievements are:

- The basis, from experimental research on the thermodynamics of direct solar steam generation in pipes, for the development of an advanced parabolic-trough collector for solar power plants, enabling the thermohydraulic design and layout of a test-stand at the PSA.
- The assessment of the theoretical and experimental performance of the receiver with a second stage concentrator and its effect on the DSG process.
- Assessment of the electricity production potential of the DISS concept and the

concentrator receiver at different electricity loads in different locations and economic scenarios.

Last: 7
Last: Ap 1.4
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.6
Top: Appendix 1.5 - ARDISS (Advanced Receiver for Direct Solar Steam)

Last: 7
Last: Ap 1.5
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.7

Appendix 1.6
PAREX

Test Engineer:	P. Balsa (on site)
Participants:	CIEMAT DLR
Duration:	From: 1995 To: 1996
Funding:	t.b.d.
Source:	CIEMAT DLR

Objectives:

Development and testing of advanced para- bolic trough receivers to:

- reduce losses at increased temperatures
- reduce thermomechanical loads due to cyclic and uneven heating ("bowing") for potential in parabolic trough collectors with thermal oil or direct steam generation.

Description:

A number of new receiver concepts will be evaluated by analytical and numerical methods to select promising configurations to be built and tested. These concepts comprise:

- secondary concentrators
- linear cavities
- heat pipe
- multiple pipes

and combinations there of. The experiments will be used to validate the design assumptions and to serve as a basis for further development and optimization.

Tests planned has been performed at the PSA´s ARDISS test loop facilities. During 1996 3 PAREX Prototypes PAREX 00b, PAREX 001 and PAREX 002 have been evaluated.

Since up-scaling of promising concepts to a commercial size collector (LS-3) is desirable, the 400ºC-HTF oil loop with half LS-3 collector to be implemented at the PSA will be used to perform the second test campaign of similar Prototypes at bigger size.

Last: 7
Last: Ap 1.5

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Top: Appendix 1.6 - PAREX

Next: Ap 2
Next: Ap 1.7

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Last: 7
Last: Ap 1.6
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.8

Appendix 1.7
TMR (Training & Mobility of Researchers)

Project Manager:	D. Martínez
Participants:	CEC DG-XII
Duration:	From: January 1996 To: December 1998
Funding:	264 million Pts.
Source:	CEC DG-XII

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	--	--	--	0.8
1997	--	--	--	0.8

Objectives:

TMR, an initiative of the CEC-DGXII, has four activities:

- Research Networks
- Access to Large-Scale Facilities
- Training through Research
- Accompanying Measures

The aim of the program is to promote, through the stimulation of training and the mobility of researchers, a quantitative and qualitative increase in human resources within the Community. The current PSA contract is under activity number 2, ‘Access to Large-Scale Facilities’.

The essential objective of the LSF activity is to provide access to large facilities important for high-quality research. This activity is intended to be of particular significance to researchers working in regions of the Community where such facilities do not exist.

The objectives of the program coincide with those of the PSA, in that this is one way of contributing to the dissemination throughout Europe the use of solar thermal technologies, covering a wide range of industrial applications, from electricity generation to passive architecture.

Description:

Under the above mentioned contract, the PSA offers access free of charge to the following facilities:

- Detox Loop, Solar Furnace, Acurex Field and Solfin : 30 Weeks of the three-year contract

- Dish/Stirling, Solar Dryer, Desalination Plant and LECE: 12 Weeks of the three-year contract

Access includes all infrastructure, logistic, technical and scientific support that is normally provided to external users of the facility.

Among the stipulations of the TMR contract:

- A minimum of 50 different groups should benefit under this contract, with a minimum of 28 groups to be given access per year.
- The users must be selected yearly
- The PSA must widely publicize access offered in a ‘Call for Proposals’ followed by an application period.
- A Selection Panel of 10 experts, at least 6 of them not from CIEMAT to meet in October to select the users for the following year.

Two types of access are offered:

- Access-to-Research: In this case, a research group is expected to bring its own research proposal to be performed at one of the facilities above, with the support of the corresponding PSA project leader. Typical duration is between two weeks and two months.

- Access-for-Training: This option is addressed to individual users who will receive a comprehensive overview of all the industrial applications of solar energy being currently developed at the PSA and will have the opportunity to take part in one of the on-going projects. Typical duration is between three and six months.

Status:

The program is now in its second year at the PSA. By the end of 1997, 35 different groups are expected to have participated.

Plans for 1997:

The CESA-1 facility is to be included in the program in 1997-98, thus widening the possibilities of research for visitors by making our most important facility available.

A new proposal is to be prepared in 1997, answering the new DGXII’s ‘Call for Proposals’ to be issued by March. The idea is to increase the contract period to the end of the year 2000.

Some activities will also be carried out under point 3 of the 'Training through Research' program. Specifically, the PSA will be offered as a host center for young European researchers within the 'Marie Curie Research Grants' Program.

Under Activity no. 4, 'Accompanying Measures,' a proposal will be made for the organization of a Summer School in 1998.

Last: 7
Last: Ap 1.6
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.8
Top: Appendix 1.7 - TMR (Training & Mobility of Researchers)

Appendix 1.8
TMR Desalination

Test Engineer:	P. Balsa
Participants:	CEC DG-XII CIEMAT Trinity Colege Heliostat Ltd.
Duration:	From: 1996 To: 1998
Funding Source:	CEC DG-XII: TMR Program

Objectives:

The shortage of drinking water affects many countries in the third world which also lack conventional energy sources. There has been a sharp increase in the desalination plant market during the last decades. The many plants installed worldwide achieved a total daily production capacity of $13x10^6$ m^3 of desalinated water in 1989 (only those plants with 100 m^3/day or greater capacity).

The solar desalination plant was therefore included in the TMR proposal to promote solar desalination in European Countries.

Description:

In 1996 Trinity College of Dublin made an exergetic analysis of the desalination plant comparing it to performance during the Desalination project. The work done will be presented in an MS Thesis in the near future.

A test bed for testing solar collectors able to supply heat to a desalination plant was erected.

Appendix 1.9
Materials Testing at Solar Furnace

Test Engineer:	D. Martínez
Participants:	E.S.I.I. University of Seville (E) Trinity College of Dublin (IR) Materials Ireland. Forbairt (IR)
Duration:	From: January 1996 To: December 1998
Funding:	8.4 Million Pts.
Source:	CEC-DGXII's 'Training & Mobility of Researchers Program; Access to Large-Scale Facilities Activity'. CIEMAT-DLR Agreement

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	0.3	0.5	0.5	1.8
1997	0.6	0.9	0.6	1.1

Objectives:

In general, the main lines of thermal treatment of materials are:

- Widely used industrial treatments, that, contrary to conventional methods, use renewable energies and processes 'friendly to the environment', while saving energy and avoiding the production of toxic wastes. In general, the quality of the product obtained is also more homogeneous and has better physical properties with the 'solar option'. An example of this is transformation hardening of steels.
- Thermal shock testing of materials to be used under severe conditions, adhering to such very strict requirements as those of the aerospace or nuclear energy industries. In many cases solar energy is the only procedure which can simulate the real working conditions. This is the case of the tests carried out on ESA's 'HERMES' space shuttle pieces.
- A third line of application supporting the above two, is the development and implementation of new testing devices and techniques to broaden the range of 'solar thermal' possibilities.

Some current activities illustrating these general objectives are:

- Surface modification of steels by melting of pre-applied layers.
- Surface modification of steels by gas/solid reaction
- Photothermal oxidation of TiN-based coatings to create dedicated surface oxides

- Heat treatment of ferrous metals for improved friction and wear
- Sintering of advanced ceramics.
- Thermally induced alloying of composite coatings to create super-alloy coatings.
- Development and evaluation of materials for use in concentrated solar energy applications, such as secondary concentrators, reactors, etc..

Description:

The main tool in this project is the so-called High Flux Concentration Facility (HFCF) or Solar Furnace.

It basically consists of a 98.51-m^2 parabolic mirror, which collects and concentrates the sunlight directed at it by 4 flat-faceted heliostats each having an area of 53.61 m^2.

This light is concentrated at the focal point of the parabola, producing energy densities of up to 3 MW/m^2 by condensing the 60 kW of energy in a 20 cm. diameter circle.

The amount of energy can be regulated from 0% to 100% almost instantaneously by a computer-controlled shutter.

Auxiliary equipment available includes:

- Test Table movable in three axes
- Data Acquisition System
- Vacuum Chamber
- Infrared Camera for Temperature Measurement
- Tilted Mirror
- Rotating Device

Status and Plan for 1997:

At present, and until the end of 1998, the HFCF is involved in the European Union Activity ‘Access to Large-Scale Facilities’, within the

'Training & Mobility for Researchers Program'. Through this program, up to seven research groups, selected yearly by an independent panel of experts, are invited to stay at the PSA and perform their own materials research tests.

Last: 7
Last: Ap 1.8

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.10

Top: Appendix 1.9 - Materials Testing at Solar Furnace

[Last: 7](#)
[Last: Ap 1.9](#)
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.11

Appendix 1.10
STAMP Project

Test Engineer:	D. Martínez
Participants:	Dassault Aviation
Duration:	From: January 1995 To: December 1996
Funding:	4 Million Pts.
Source:	Dassault Aviation

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	0.15	0.1	0.4	0.2

Objectives:

The project consisted basically of performing a thermal shock on a reduced-scale model corresponding to an European Space Agency's Mars Penetrator.

The sample consists of the following parts:

- A spherical ablative cap
- A 'C-SiC' shell surrounding the cap and,
- An aluminum and titanium rear structure

General dimensions are:

- Diameter: 700 mm.
- Width: 200 mm.

Thermal Cycle: Only one thermal cycle was performed and consisted of:

- Solar Thermal Shock from 0 kW/m^2 up to 600 kW/m^2 in 25 seconds
- 5 seconds at steady state
- Cool down in 20 seconds.

The test was performed successfully in the 60-m-high CESA-1 tower test room, using the heliostat control system to generate the time- flux profile.

To adapt the sample to the existing facility, an interface between the probe and the HERMES Nose cap test jig was designed and fabricated.

Description:

Tasks under PSA responsibility were:

- Design and manufacturing of the above mentioned interface.
- Necessary simulations.

- Test assembly setup, including instrumentation of the test piece (thermocouples).
- Test performed following ESA quality assurance regulations
- Removal of the test article and return transport to France

Status:

The thermal test was carried out successfully 0n July 25th, with in the presence of representatives from Dassault and Dornier.

Further reports were required, as well as attendance at a General Test Campaign Review held on the ESA premises in Noordwijk (The Netherlands).

A presentation of the PSA solar thermal test facilities was given at this meeting since thermal testing is the most critical part of the test campaign. The final conclusions on the sample’s performance presented at that time, were considered by E.S.A. to be the formal end of the project.

Last: 7
Last: Ap 1.9

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Top: Appendix 1.10 - STAMP Project

Next: Ap 2
Next: Ap 1.11

Appendix 1.11
El Ejido Solar Detox Project

Test Engineer:	J. Blanco
Participants/Project Consortium:	Ciemat-PSA Asociación Empresarial para la Protección de las Plantas (AEPLA), Madrid Ibacplast S.A., Almería Ecosystem S.A., Barcelona Diputación Provincial de Almería Council of Adra, Almería Council of Almería. Council of Berja, Almería Council of Dalías, Almería Council of El Ejido, Almería Council of La Mojonera, Almería Council of Níjar, Almería Council of Roquetas de Mar, Almería Council of Vícar, Almería
Duration:	From: 1995 To: 1998

Objectives:

Feasibility study for a solar detoxification plant for the treatment of wastewater from the industrial washing of plastic herbicide containers

Description:

Agriculture activities in the Mediterranean area clearly represent a very important sector of the economy. Moreover, in the last decade, this has significantly increased with the expansion of greenhouses and intensive agricultural techniques. As productivity and economic importance have risen, the sector has also become more complex with associated problems that strongly threaten the environment. This is particularly reflected in the contamination of water by extensive use of chemicals and pesticides, and their removal from water is a pressing ecological problem. Such persistent organic chemical contaminants include pesticides, solvents, detergents and a variety of industrial chemicals which, due to the combination of their chemical stability, resistance to biodegradation and sufficient water solubility, penetrate deep into the soil to groundwater.

The Spanish province of Almería is a perfect example of important economic growth during the last 15-20 years, chiefly due to large numbers of greenhouses, for which it has an excellent climate and which, unfortunately, is also accompanied by intensive use of a wide variety of pesticides. One aspect of this is an increasing problem of empty plastic herbicide containers (in Almería alone, around 1.5 million of these containers per year), which are usually burnt or buried. Recently, a parallel rise in environmental consciousness is

Funding:	8.4 Million Pts. (in 1996)
Source:	Consortium

Man Power/Year:

Year	Eng./ Maint.	Oper.	Project Related	Students, etc.
1996	0.2	0.2	1	0.4
1997	0.1	0.2	1	1

concerned about their recycling. However the recycling process includes washing the shredded plastic containers, which contaminates the water used with relatively small amounts of highly toxic persistent compounds at concentrations of several hundred mg/l total organic carbon content.

Solar photocatalytic detoxification with TiO_2 would appear to provide a very promising and economical solution for this problem, which has no clear alternative solution since the biological purification of water polluted by organic micropollutants is quite inefficient at low levels of the substrate. Solar photocatalytic detoxification, however, using the interaction between ultraviolet radiation and the semiconductor catalyst, titanium dioxide (TiO_2) to promote a strong oxidation reaction, mineralizes low to medium concentrations of organics present in water, making it reusable.

Its strong potential for the industrial destruction of toxic organics in water has been widely demonstrated in recent research. The most energetic part of the solar spectrum, the ultraviolet wavelength under 400 nm, photoexcites the semiconductor catalyst in the presence of oxygen promoting a strong oxidation reaction and hydroxyl radicals (OH^0) which attack oxidizable contaminants are generated, progressively breaking up the molecules into carbon dioxide, water and dilute mineral acids. The most commonly used catalyst, TiO_2, is the semiconductor titanium dioxide, a non-toxic, cheap and abundant product commonly used in paint manufacture. In principle, the process is able to oxidize almost any chemical substance.

The PSA has promoted the formation of a consortium of municipalities and private companies to set up a complete pesticide container recycling process in which the water needed is treated and reused. This includes detoxification testing of waste water samples, and the design and construction of a solar detoxification plant at the recycling center.

Status:

Phase I was concluded at the end of 1996 and Phase II is under study. In this second part of the El Ejido Solar Detox Project a new Solar Photocatalytic Facility is going to be built on the bottle-recycling site (Campo de Dalías) to test real wastewater at Pilot Plant level.

The wastewater treatment plant and the plastic recycling plant are going to be connected in series during this period in order to obtain more realistic results. With the information obtained during Phase II the dimensions of the installations could be predicted. This pilot plant is to be enlarged to definitive size at the end of this phase. This is possible due to the modularity of this kind of Solar facility. By adding more collectors and related equipment, the First Solar Photocatalytic Detoxification Plant can be put into operation.

Last: 7
Last: Ap 1.10

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Top: Appendix 1.11 - El Ejido Solar Detox Project

Next: Ap 2
Next: Ap 1.12

Appendix 1.12
LECE (Laboratorio de Ensayos Energéticos para Componentes de la Edificación)

Test Engineer:	M. J. Jiménez
Participants:	CIEMAT DLR CEC DGXII Universidad Politécnica de Madrid Universidad Politécnica de Cataluña
Duration:	From: 1994 To: --
Source:	CIEMAT DLR EU Industry University

Man Power/Year:

Year	Maint.	Eng.	Project Related	Techn.
1996	0.2	0.2	2	2
1997	1	0.5	5	2

Objectives:

- Testing of construction materials and passive solar components or techniques using real-scale outdoor test cells to assess the reliability of these elements for saving energy in buildings.
- Study of the thermal transfer process in passive solar energy applications as well as climatic resources for use in natural air conditioning techniques.
- Establishment of standard testing and quality procedures for the integration of the LECE Laboratory into the ENAC network.
- Participation in studies on the integration of solar active energy systems (photovoltaic tiles, solar collectors, etc.) into buildings.
- Market survey of passive solar components and buildings materials suitable for energy optimization in buildings and publication of passive solar techniques.

Description:

The laboratory consists of four fully equipped quasi-adiabatic test cells, a tracking bench, and control room with two data acquisition systems. Heavy thermal insulation enables indoor cell environment response to be assigned exclusively to the test component. Test sequence and data treatment follow a carefully designed procedure to increase accuracy and obtain the maximum information.

The LECE participated in the EU PASSYS II

Program in 1992 and 1993. It has also been participating in CIEMAT initiatives for third parties, such as the Junta de Andalucía, Universidad Politécnica de Madrid, Universidad Politécnica de Cataluña or the Building Material Manufacturers Association.

Status:

After some modification and improvement, the LECE Laboratory is fully equipped to perform any outdoor energy testing of construction components. As a complement to these facilities, the LECE is developing the area of the translucid component energy studies (Transmittance, reflectance, TSET) in order to provide complete outdoor energy assessment of any building component.

Plans for 1997:

In 1997 three main JOULE projects will be undertaken, the ROOSOL project, for passive cooling, the PV-Hybrid project, which studies the use of plants for thermal quality improvement in buildings.

There is also an agreement with the Polytechnic University of Cataluña to characterize four types of special bricks and one agreement with the Polytechnic University of Madrid to contribute to the formulation of regulations for this type of laboratories.

The LECE will also be in constant renovation to adapt to new market demands. One of the fields in which we plan to undertake this is translucid component energy studies.

Last: 7 | Annual Technical Report 1996 | Next: Ap 2
Last: Ap 1.11 | Back: Appendix 1 - Project Descriptions | Next: Ap 1.13
Top: Appendix 1.12 - LECE (Laboratorio de Ensayos Energéticos para Componentes de la Edificación)

Appendix 1.13
PVPSA (Photovoltaic Testing on the PSA)

Test Engineer:	M. Stegmann
Participants:	CIEMAT/DLR ISET, Kassel
Duration:	From: May, 1991 To: Dec., 1996
Funding:	3.0 million Pts.
Source:	EC DGXII-HCM and PSA

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	0.1	0.2	0.3	0.1

Objectives:

DS/PV

Operation of a 2-axis tracking PV generator over at least one year in order to generate a database for the comparison of equivalent state-of-the-art PV and SBP dish/Stirling systems in the following respects:

- Comparison of systems with the same collector area
- Investment and estimated financial and energy amortizement
- Operation and maintenance costs
- Reliability
- System efficiencies under different weather conditions
- Energy production over at least one year

Telemetric PV:

Operation of an autonomous PV-powered telemetric meteo station for ISET over at least one year in order to:

- Test PV modules in different orientations
- Test the telemetric system
- Collect weather data and transmit them via satellite to Germany
- Compare with an identical system mounted at ISET in Kassel
- Compare with tracked PV and dish/Stirling systems

Last: 7
Last: Ap 1.12
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.14

Top: Appendix 1.13 - PVPSA (Photovoltaic Testing on the PSA)

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Last: 7
Last: Ap 1.13

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.15

Appendix 1.14
BRITE-EURAM III Solar Detox Project

Project Leader:	J. Blanco
Test Engineers:	S. Malato, B. Braun, C. Richter
Participants:	CIEMAT/DLR HIDROCEN S.L., Spain SETSOL, Energias Renovaveis, Portugal Torino University, Italy SCHOTT-ROHRGLAS, Germany CISE, Italy ECOSYSTEM, Spain
Duration:	From: 1997 To: 2000
Funding:	1.9 million ECUs
Source:	UE DGXII-C

Man Power/Year:

Year	Eng./ Maint.	Oper.	Project Related	Students, etc.
1997	0.1	0.1	2	1.3

Objectives:

The main focus and innovations in this project are specific technological developments in solar photocatalysis. The objective is to develop the solar detoxification technology to a commercial level and make the photocatalytic treatment of typical persistent non-biodegradable contaminants in chlorinated water found in effluents from chemical production processes feasible:

- High UV transmissivity glass reactor (up to 90 %, 1 mm wall thickness) in the solar UV range (310 to 400 nm)
- Solar collector upgrading design to minimise land required avoiding losses by collector shadows.
- Catalyst upgrading and supporting
- Highly UV reflective surface (up to 95 %)
- Demonstration of technical and economical feasibility under real conditions.

Description:

C_1 and C_2 Non-Biodegradable Chlorinated hydrocarbon Solvents (NBCS), such as methylene chloride, trichloroethylene, tetrachloroethylene, chloroform, methyl chloroform, etc, are difficult to replace because they influence process reaction and are compatible with most substrate materials; also, such traditional removal methods used in industrial process water such as stripping, adsorption by activated carbon, biological treatment, thermal or catalytic oxidation and chemical oxidation have important disadvantages or limitations in the treatment of low concentrations of organic pollutants (from 20 to

50 ppm). Now industry is minimizing or eliminating solvents to cut hazardous waste costs as well as chemical emissions. Emission Limit Values (ELV) are based on the Best Available Techniques (BAT), recognized as feasible from a technical and economical point of view and reasonably accessible to the operator. As multimedia regulations continue to be placed into effect, the approach to environmental management where treatment methods simply transfer contaminants from one medium to another becomes an increasingly unstable option.

The basic idea of the project is the development of a Solar Detoxification System, based on the simple, inexpensive and efficient non-concentrating solar collector technology (such as the compound parabolic collector and flat collectors with tubular photoreactors) which seems the best technological solution for Solar Detoxification Systems as static collectors can capture the diffuse UV sunlight as well as the direct beam (the diffuse component can make up 50% of the available UV light, even on a clear day, and the UV available on a cloudy day may be no less than half that on a clear day). When solar UV radiation is used, the beauty of the Solar System, which can destroy many of the most “difficult” persistent organic pollutants, is its intrinsic simplicity. It is cost-effective , easy to use, and requires a minimal capital investment. The technology is also ecological, as all the components are very simple, common materials.

The reaction takes place when UV radiation photo-excites a semiconductor catalyst in the presence of oxygen. In these circumstances hydroxyl radicals, OH^0, are generated which attack oxidizable contaminants producing a progressive break-up of molecules into carbon dioxide, water and diluted mineral acids. In addition to assessing its capacity for destruction, field demonstration attempts to identify any pre- or post-processing requirements, potential operating problems, and capital and operating costs. As the existing Solar Detoxification technology comes from the solar thermal technology with just some minor modifications, the state of the art still requires specific technological developments which could increase the present efficiency by a fac- tor of 3.

Commercial industrial systems are expected to be available within two years after termination of the project, and typical applications will use a field of up to a few hundred square meters. The partners are convinced that this is a unique opportunity for the industrial development of a remarkable environmental technology (the process works even with clouds as the UV radiation is not absorbed by atmospheric water and reaches the earth's surface as a diffuse component), the embryo of which has been developed by other EU Programs. Also, first market estimations show a huge potential in a large number of possible applications.

The consortium comprises a solar collector manufacturer (SETSOL), components manufacturers (SHCOTT, CISE), user of the technology (HIDROCEN/HIDRONOR) and an environmental & engineering consulting company (ECOSYSTEM), with the assistance of a worldwide recognized researcher in photocatalysis (UNITO), and solar facilities to process scaling up (DLR in the North of Europe and CIEMAT in the South).

Status:

The project was approved in 1996 and will formally begin in 1997.

Last: 7
Last: Ap 1.13

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.15

Top: Appendix 1.14 - BRITE-EURAM III Solar Detox Project

Last: 7
Last: Ap 1.14
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.16

Appendix 1.15
TMR Detoxification Project

Test Engineer:	S. Malato
Participants:	INETI (Instituto Nacional de Engenharia e Tecnologia Industrial), Portugal. ISFH (Institut für Solarenergieforschung GmbH Hannover), Germany. TUW (Institut für Physikalische Chemie. Technische Universität Wien), Austria. CNRS (Ecole Centrale de Lyon. Photocatalyse, Catalyse et Environement), France. Other EU Institutions for the next years
Duration:	From: 1996 To: 1998
Funding:	6.2 million Pts. (in 1996)
Source:	CEC DG-XII / PSA

Man Power/Year:

Year	Eng./Maint.	Oper.	Project Related	Students, etc.
1996	0.2	0.5	1	0.2
1997	0.1	0.4	1	0.2

Objectives:

- Determine the best conditions for degradation of organic substances by Solar Photocatalysis.
- Optimize the change of scale from laboratory to pilot plant.
- Train EU research groups in solar photocatalysis.

Description:

The photocatalytic degradation of organic compounds with illuminated TiO_2 is very well documented in the literature. The illumination of TiO_2 (band-gap energy, E_G = 3.2 eV) in water with less than 387-nm-wavelength light generates excess electrons in the conduction band (e^-_{CB}) and positive "holes" (h^+_{VB}) in the valence band:

$$TiO_2 + hv (>= E_G) \text{-->} e^-_{CB} + h^+_{VB}$$

·OH radicals are extremely reactive and readily attack organic molecules degrading them to CO_2 and H_2O (and inorganic ions when the organic molecule contains other atoms).

Due to environmental concerns and reasonable expectations for this process's technical and economic feasibility causing a rising interest in Solar Detoxification research, the PSA and other UE research groups with long experience in basic research, but lacking pre-industrial development, are carrying out R&D programs on Solar Water Detoxification. The aim of this Project is to go from laboratory to pilot scale developing effective systems to destroy toxic compounds in industrial wastes by means of solar radiation. This step is essential to make practical applications feasible, which seems attainable in the near future thanks to its technical and economic attractiveness for sunny locations.

Two different PSA facilities are used in this project: medium concentrating systems (parabolic collectors, PTC) and low concentrating systems (compound parabolic collectors). In both cases, a slurry of contaminated water and catalyst (titanium dioxide, TiO_2) is prepared in tanks and fed into the photoreactor. The systems are operated in a discontinous manner by recirculating the slurry solution with an intermediate tank and centrifugal pump. High flow rates are used because of the slow kinetics of degradation, and a complete-mixture regime is assumed (that is, the contaminant concentration is the same everywhere in the system at any given time). Under these experimental conditions, photodegradation of all the experimental mixtures is sufficient to evaluate feasibility of the data treatment. Three sensors for UV-light measurements are used, one for global UV over the horizontal surface installed normal to the earth's surface, a second for global UV over a 37º-inclined surface installed on the CPC support frame and the other for direct UV (International Light-SED 400), mounted on a sun-tracking platform. Global and direct UV irradiances are measured throughout the experiments, permitting the evaluation of hour-dependant incident radiation, clouds, atmospheric turbulence and other environmental variations.

Parabolic Collectors. This photochemical reactor consists of a 12-module Helioman-type system (Man, Germany) with a total reflective surface of 29.1 m^2). Depending on system con- figuration, it is possible to calculate the residence time (t_R) as the relationship between the total volume of water in the reactor (V_T), the volume of the glass tubes (V_R) and reaction time (t): $t_R = V_R\, t\, V_T^{-1}$. The reaction time is the difference in time between the initial sample (initial concentration of the pollutant, t = 0) and samples collected during the experiment (t > 0).

CPC Collectors. The present configuration of the PSA CPC field has 6 modules (total reflective surface 8.9 m^2) connected in series and mounted on a fixed platform inclined 37º to maximize performance (the PSA is located at latitude +37º). Each CPC module (Industrial Solar Technology Corporation, Denver) is 1.22 m wide and 1.22 m long (see Fig. 1) and consists of eight parallel CPC reflectors (152 mm wide) with UV-transparent tubular receivers (I.D. 48 mm). The acceptance angle for the CPC is 60 degrees either side of normal incidence. Polished aluminium is used as the reflective material because it is highly reflective in the UV range (0.829-300 nm, 0.861-325 nm, 0.834-350 nm, 0.810-375 nm and 0.890-400 nm) and fluoropolymer is used for the tube receivers because it is inert and has excellent UV stability and transmissivity (0.735-300 nm, 0.765-325 nm, 0.780-350 nm, 0.822-375 nm and 0.846-400 nm). The 6 modules are connected in series so that the water flows directly from one to the other and finally to the tank. A centrifugal pump then returns the water to the collectors. At the beginning of the experiments, with collectors covered, all the chemicals are added to the tank and mixed until constant concentration is achieved throughout the system. Then the cover is removed and samples are collected at predetermined times. The residence time (t_R) is calculated by the procedure explained above.

Status:

Activities during 1996 have been centred on solar degradation of different organic compounds with TiO_2 and a Photo-Fenton reagent. 4 different EU research groups have been at PSA for 1 month each. The future plan of work is focused on three goals, testing different catalysts, solar collector comparison and the training of researchers.

Last: 7
Last: Ap 1.15
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.17

Appendix 1.16
FIRE (Financing of Renewable Energy Systems in Europe)

Project Leader:	O. Langniss
Participants:	DLR EN-TT (Germany) DLR MD-PSA (Spain) ZSW (Germany) IEFE (Italy) CBS (Denmark) IMES (Sweden) ECOFYS (Netherlands) FIFEGA (Austria) SPRU (England)
Duration:	From: September 1996 To: August 1998
Funding:	450 kECU (EC)
Source:	CEC DG-XII Partners

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	--	--	--	--
1997	--	--	--	0.2

Objectives:

A large number of proven technical solutions exist for the use of renewable energies. However their dissemination is still too slow to meet the political goal of substituting 8-15% of primary energy demand in the European Union by the year 2010. Even economically potential renewable energy systems (RES) are only partially exploited. It had become clear, that the availability of financing and the way and conditions under which it is lent has a mayor impact on renewable energy deployment.

FIRE will analyze and compare the means of financing RES in Austria, Denmark, Germany, the Netherlands, Spain, Sweden and the United Kingdom in order make best practice recommendations to speed up renewable energy deployment. The main tasks in this study are:

- Analyze RES financing in a number of countries.
- Provide an analysis of the best means of financing RES
- Provide an analysis of the barriers to the implementation of these means in the countries investigated.
- FIRE addresses politicians, potential investors and project-developers.

Description:

Different types of RES financing will be analyzed in relation to the country-specific environment. This includes exogenous conditions such as fiscal and legal restrictions and subsidies, as well as individually defined management strategy risks and collateral requirements. For each country the prevailing financial schemes will be identified by questioning national experts. Eight in-depth case studies will be undertaken for each country. The influence of exogenous conditions will be simulated with a cash-flow model. An advisory board with members of the financing sector is established to ensure pragmatic conclusions.

Status:

In 1996, acquisition of data for the case studies and the country information had started as scheduled.

Last: 7
Last: Ap 1.15

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.17

Top: Appendix 1.16 - FIRE (Financing of Renewable Energy Systems in Europe)

Last: 7
Last: Ap 1.16

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.18

Appendix 1.17
Falling Particle Receiver

Project Leader:	G. Weinrebe
Participants:	DLR/EN-TT (Design, fabrication, assembly, evaluation) PSA (solar furnace infrastructure preparation, operation)
Duration:	From: December 1995 To: April 1996
Funding and Source:	DLR/EN-TT (SOLEP program) CIEMAT/DLR: 1.250 million Pts. (Basic Budget)

Objectives:

Based on the results of former investigations, DLR Stuttgart in 1989/90 performed a study with the result, that the best concept for the realization of a directly absorbing particle receiver is the circulating fluidized bed (CFB) with the irradiation entering from the side. For experimental investigations, the "TERZ" test facility was constructed to be tested in the Fix-Focus-Concentrator of DLR Stuttgart (solar power 4 - 10 kW). Chemically inert silicon carbide (SiC, average particle diameter 60 µm) served as particles. Based on the lessons learned from this experiment the current concept of the falling particle receiver was designed and constructed in the years 1993-95.

The particles are driven in the closed loop of a circulating fluidized bed and the irradiation enters a so-called "particle curtain“ in the receiver section. A quartz window in front of the curtain prevents outflow of the air and particles. Surplus energy can be removed from the system in the fluidized bed cooler. In later experiments, this would be replaced by a chemical reactor.

The FPR was successfully operated in the Solar Furnace (50 kW, 20 cm diameter) of the Plataforma Solar de Almería from December 95 to April 96. Particles were of inert Silicon Carbide (SiC) and Sand. The maximum temperature reached in the cooler was 800 ºC, in the particle curtain over 850 ºC. In general, the hot particle window protection was highly successful. It could be improved by a simple treatment of the window before the operation with an anti-static brush.

Last: 7
Last: Ap 1.16

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.18

Top: Appendix 1.17 - Falling Particle Receiver

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Last: 7
Last: Ap 1.17
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Next: Ap 1.19

Appendix 1.18
Phoebus Technology Program Solar Air Receiver (TSA)

Project Manager:	Leader: G. Weinrebe / P. Heller
Participants:	L&C Steinmüller (Design, fabrication, assembly of new absorber elements) University of Seville (Automatic Aiming-Point Strategy) PSA (Tests in Cesa-1, Evaluation)
Duration:	From: January 1996 To: December 1997
Funding and Source:	L&C Steinmüller (own budget) University of Seville (own budget) PSA: 6.377 million Pts. (Basic Budget)

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	--	--	--	--
1997	0.6	2.0	--	2.1

Objectives:

Integrate the Automatic Aiming-Point Strategy (AAPS) developed by the DISEL company and an improved version of the automatic control developed by the University of Seville into the CESA-1 heliostat field master control. The objective was to decrease the temperature deviation of single absorber elements and obtain homogeneous temperature distribution at the absorber front surface, minimizing reradiation losses.

22 new absorber elements were to be designed, constructed and mounted to improve the manufacturing process with respect to lower costs and better mass flow distribution.

Description:

The University of Seville's AAPS was used to operate the TSA receiver during the first quarter of the year. The DISEL AAPS was installed in the computer on May 27th. Tests carried out validated the two different algorithms, which kept the maximum temperature deviations of the absorber elements at around 80ºC.

The 22 new absorber elements had been mounted at the end of the year and are ready to be tested in 1997.

Last: 7
Annual Technical Report 1996
Next: Ap 2

Appendix 1.19
Heliostat Technology Program (ASM150, GM100)

Project Manager:	Leader: G. Weinrebe / P. Heller
Participants:	Ciemat (Design and construction GM100) Pujol Muntala (drive mecanism GM100) JUPASA (control GM100) L&C Steinmüller (Design and construction ASM150) Schlaich Bergermann und Partner (Design ASM150) Fichtner Development Engineering (control ASM150) PSA (Tests and Evaluation)
Duration:	From: January 1996 To: December 1997
Funding and Source:	PSA: 4.660 million Pts. (Basic Budget)

Objectives:

Within the “Heliostat Technology Program”, two large scale heliostats were investigated in 1996, the 100 m^2 GM100 and the 150 m^2 ASM150. Both comply with the specifications for the Phoebus-type power tower. After erection, the optical quality, energy consumption and wind load behavior had to be compared.

Description:

After erection, first tests showed excellent optical behavior of both heliostats. A new canting technique developed by the PSA for faceted heliostats was applied to the GM100. The optical quality was measured for the 477 m focal length. Investigation of behavior under different wind conditions was started. A comparison report will be published in 1997.

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	--	--	--	--
1997	0.1	0.6	--	2.7

Last: 7
Last: Ap 1.18

Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions

Next: Ap 2
Next: Ap 1.20

Top: Appendix 1.19 - Heliostat Technology Program (ASM150, GM100)

Appendix 1.20
Advanced Salt Receiver (RAS)

Project Manager:	Leader: G. Weinrebe / P. Heller
Participants:	CIEMAT (Design, construction, evaluation) SANDIA Nat. Labs PSA (Tests and Evaluation)
Duration:	From: January 1996 To: January 1997
Funding and Source:	PSA: 1.393 million Pts. (Basic Budget) CIEMAT (own basic budget) SANDIA: (own budget)

Objectives:

The Advanced Salt Receiver (RAS), a joint project of CIEMAT/SNLL/DLR, consists of a molten salt loop including the IFR, a storage vessel, a security tank, a submerged salt pump and a salt/air heat exchanger. It should be demonstrated that a molten salt film technique can be an alternative to the salt tube receiver (Solar Two) technology.

Description:

The project test plan is now in the 3rd phase. Flux levels up to 460 kW have already been reached. Different tests were performed with fixed flow at different incident flux levels and constant flux with different flow conditions in order to evaluate the system performance.

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	--	--	--	--
1997	--	0.1	--	0.2

Last: 7
Last: Ap 1.20
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2

Appendix 1.21
Volumetric Air Receiver

Project Manager:	Leader: G. Weinrebe / P. Heller
Participants:	DLR Cologne PSA
Duration:	From: January 1996 To: May 1997
Funding and Source:	DLR Cologne (own budget) PSA: 1.050 million Pts. (Basic Budget)

Objectives:

In the CRS/SSPS testbed, the COR-REC volumetric air receiver made of Corderite ceramic, was operated in a first phase.

The COR-REC volumetric air receiver consists of 30 modules in an arc-like structure. Each module has a flow adjustment, avoiding the necessity of an adapter with adjusting vanes.

The objective of the tests was to demonstrate the features of Corderite ceramic for high temperature high efficiency volumetric abosrbers. Stable operation was shown at temperatures of up to 800 ºC.

A second test phase should be carried out in 1997 to reach full load operation and test different operation conditions.

Man Power/Year:

Year	Maint.	Oper.	Eng.	Project Related
1996	0.1	0.2	--	0.5
1997	0.1	0.2	--	1.7

Last: 7
Last: Ap 1.20
Annual Technical Report 1996
Back: Appendix 1 - Project Descriptions
Next: Ap 2
Top: Appendix 1.21 - Volumetric Air Receiver

Last: Ap 1 Annual Technical Report 1996 Next: Ap 3

Appendix 2
List of Collaborating Institutions and Companies

Contents:

Last: Ap 1 Annual Technical Report 1996 Next: Ap 3
Top: Appendix 2 - List of Collaborating Institutions and Companies

Last: Ap 2 | Annual Technical Report 1996 | Next: Ap 4

Appendix 3
Publications

Contents:

Last: Ap 2 | Annual Technical Report 1996 | Next: Ap 4

Top: Appendix 3 - Publications

Appendix 2.1
Parabolic Trough Area

Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V.
EN-TT
z. Hd. Herrn O. Goebel
Vaihingen
Pfaffenwaldring 38-40
D-70569 Stuttgart
Alemania
Fax +49-711-6862783

Escuela Superior Ingenieros Industriales
Dpto. de Automática
Prof. Eduardo Fernandez Camacho
Avda. Reina Mercedes s/n
41012 Sevilla
Fax. +34 5 444-6849

Pilkington Solar International GmbH
Attn.: Mr. Paul Nava
Mühlengasse, 7
D-50667 Köln
Alemania
Fax +7 49 221 258 11 17

Siemens AG Power Generation
Dept. NT31
Attn.: Mr. H. Schmidt
Freyeslebenstr. 1
D-91058 Erlangen
Alemania

SOLEL
Att.: Mr. Eldad Dagan
Har-Hotzvim
P.O.B. 45033
Jerusalem 91450
Israel
Fax +972 2 5323 162

UMIST
Department of Electrical Engineering and Electronics

Att.: Dr. F. M. Hughes
P.O.Box 88
Manchester M60 1QD
Reino Unido
Fax +44 161 200 4820

ZSW
Attn.: Frank Lippke
Hessbrühlstr. 21 c
D-70565 Stuttgart
Alemania
Fax +49 711 7870 200

Last: Ap 1
Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Next: Ap 3
Next: Ap 2.2
Top: Appendix 2.1 - Parabolic Trough Area

Appendix 2.2
Solar Chemistry Area

Contents:

Last: Ap 1
Last: Ap 2.1
Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Next: Ap 3
Next: Ap 2.3

Last: Ap 1 | Annual Technical Report 1996 | Next: Ap 3
Last: Ap 2.2 | Back: Appendix 2 - List of Collaborating Institutions and Companies | Next: Ap 2.4

Appendix 2.3
TMR Users

Contents:

Last: Ap 1 | Annual Technical Report 1996 | Next: Ap 3
Last: Ap 2.2 | Back: Appendix 2 - List of Collaborating Institutions and Companies | Next: Ap 2.4
Top: Appendix 2.3 - TMR Users

Appendix 2.4
Parabolic Dish Area

Schlaich Bergermann und Partner (SBP)
Hohenzollernstr. 1
70178 Stuttgart
Germany

SOLO Kleinmotoren GmbH
Postfach 60 01 52
71050 Sindelfingen
Germany

L&C Steinmüller GmbH
Fabrikstrasse 1
51641Gummersbach
Germany

Intersol Corporation
PL 416 Marbak
30594 Halmstad
Sweden

Institut für Solare Energieversorgungstechnik (ISET)
Königstor 59
34119 Kassel
Germany

HTC Technologie-Centrum Schwerte GmbH
Im Heiligen Feld 17
58239 Schwerte
Germany

Appendix 2.2.1
Detoxification

AEPLA
D. Luis Roy Parge
Almagro, 44 - 3º
28010 Madrid
Fax: 91-3197734

Ayuntamiento de Adra
Concejalía de Agricultura
Puerta del Mar, 3
04770 Adra (Almeria)
Fax: 403000

Ayuntamiento de Almería
Unidad de Desarrollo Económico
Plaza de la Constitución s/n
04003 Almería
Fax: 210057

Ayuntamiento de Berja
Concejalía de Agricultura
D. José M. Villegas Cabrera
Plaza de la Constitución, 1
04760 Berja (Almeria)
Fax: 499475

Ayuntamiento de Dalías
Concejalía de Agricultura
D. Francisco Criado Gallegos
Plaza Ayuntamiento, 1
04750 Dalías (Almeria)
Fax: 495010

Ayuntamiento de El Ejido
Area de Agricultura
D. Antonio Escobar
C/ Cervantes, 122
04700 El Ejido (Almeria)
Fax: 485912

Ayuntamiento de La Mojonera
Concejalía de Agricultura
Plaza de la Constitución, 6
04740 La Mojonera (Almeria)
Fax: 331204

Ayuntamiento de Roquetas
Concejalía de Agricultura
D. Nicolás Pimentel
Plaza de la Constitución, 1
04740 Roquetas de Mar (Almeria)
321514

Ayuntamiento de Vicar
Concejalía de Agricultura
D. Antonio Osorio
Avda. Andalucía, 34
04738 Vicar (Almeria)
Fax: 553541

CNRS/Ecole Centrale de Lyon
Photocatalyse, Catalyse et Environement
Dr. P. Pichat
B.P. 163
69131 Ecully Cedex
FRANCE
Fax: 33-78330337

Diputación Provincial
Area de Fomento, Infraestructura, Medio Ambiente
D. Gonzalo Bermejo/D. Jorge Angulo
Hnos. Machado, 27 Edf. B
04004 Almeria
Fax: 211471

Ecosystem
D. Martin Vincent
Plaza de la Villa, 15, esc. A-3º-1º
08392 Llavaneras (Barcelona)
Fax: 93-7952870

INETI
Dr. Joao Farinha Mendes
Azhinhaga dos Lameiros a Estrada do Paço do Lumiar
1699 Lisboa Codex
Portugal
Fax: 351-1-7163797

Institüt für Solarenergieforschung GmbH (IFSH)
Dr. R. Goslich
Sokelandstrasse, 5
D-30165 Hannover
Germany
Fax: 49-511-3585010

Technische Universität Wien (TUW)

Institut für Physikalische Chemie
Dr. R. Bauer
Getreidemarkt 9/156
A-1060 Wien
Austria
Fax: 43-1-5868273

Universidad de Almería
Dept. Ing. Química, Dept. Física Aplicada
Cañada de San Urbano
04120 La Cañada - Almeria

Universidad de Barcelona
Facultad de Química
Dept. de Ingeniería Química
Dr. Jaime Giménez
C/Martí i Franqués, 1
08028 Barcelona
Fax: 93-4021291

Last: Ap 1
Last: Ap 2.1

Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.2 - Solar Chemistry Area
Top: Appendix 2.2.1 - Detoxification

Next: Ap 3
Next: Ap 2.3
Next: Ap 2.2.2

Appendix 2.2.2
SolarDetox Project (BRITE-EURAM)

CISE
Dr. Mirella Musci
Casella Postale 12081
20134 Milano, Italy
Tel: (+39) 1-21672520
Fax:(+39) 2-21672620
e-mail: 0253musc@s1.cise.it

HIDROCEN
Mr. Pablo Trincado
Camino del Valle, 12
Pol. Ind. Finanzauto
28500 Arganda del Rey, Madrid
Tel.: (+34) 1-8712112
Fax:(+34) 1-8715132

INETI
Mr. Joao Farihna Mendes
Estrada do Paço do Luminar
1699 Lisboa Codex, Portugal
Tel:(+351) 1-7162712
Fax:(+351) 1-7163797
e-mail: farinha.mendes@ite.ineti.pt

SCHOTT ROHRGLAS
Dr. F. Doenitz
Dr. Martin Brunotte
Erich-Schott.Strasse
Postfach 1180
95660 Mitterteich, Germany
Tel:(+49) 9633-80415
(+49) 9633-80401
Fax:(+49) 9633-80450
e-mail: pathworks!srmailmt!brt@drsmt.attmail.com

SETSOL
Mr. Joao Correira de Oliveira
Capa Rota

Manique de Cima
2710 Sintra, Portugal
Tel:(+351) 1-9259457
Fax:(+351) 1-9258675

UNITO
Dipartimento di Chimica Analítica
Università degli Studi di Torino
Prof. Claudio Minero
via P. Giuria 5
10125 Torino, Italy
Tel: (+39) 11-6707632
Fax:(+39) 11-6707615
e-mail: minero@silver.ch.unito.it

Last: Ap 1 | Annual Technical Report 1996 | Next: Ap 3
Last: Ap 2.1 | Back: Appendix 2 - List of Collaborating Institutions and Companies | Next: Ap 2.3
Last: Ap 2.2.1 | Back: Appendix 2.2 - Solar Chemistry Area | Next: Ap 2.2.3
Top: Appendix 2.2.2 - SolarDetox Project (BRITE-EURAM)

Last: Ap 1
Last: Ap 2.1
Last: Ap 2.2.2

Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.2 - Solar Chemistry Area

Next: Ap 3
Next: Ap 2.3

Appendix 2.2.3
SOLFIN

Univ. di Pavia, Dept. Org. Chem. (Italy)
Dipartimento di Chimica Organica dell'Universita di Pavia
Prof. Angelo Albini
Viale Tarematti, 10
27100 Pavia
ITALIA
Tel: (+39 382) 507 323

CNRS Gif-Sur-Yvette (France)
Institut de Chimie des Substances Naturelles
Dr. C. Giannotti
Ave. De la Terrasse
91198 Gif sur Yvette Cedex
FRANCIA
Tel: (+33-1) 69 82 30 55
Fax: (+33-1) 69 07 72 47

Institut für Organische Katalyseforschung and der Universität Rostock e.V.
Dr. Gunther Öhme
Buchbinderstraße, 5-6
D-18055 Rostock
ALEMANIA
Tel: (+49-381) 466 930
Fax: (+49-381) 466 9324

Last: Ap 1
Last: Ap 2.1
Last: Ap 2.2.2

Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.2 - Solar Chemistry Area

Next: Ap 3
Next: Ap 2.3

Top: Appendix 2.2.3 - SOLFIN

Last: Ap 1
Last: Ap 2.2
Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.3 - TMR Users
Next: Ap 3
Next: Ap 2.4
Next: Ap 2.3.2

Appendix 2.3.1
Process Heat

University of Patras,
Department of Physics
Dr. Panayiotis Yianoulis
GR 26500 Patras
GREECE
+30 61 997446
Fax: +30 61 991980
e-mail: yianpan@physics.upatras.gr

Tallaght RTC
Mechanical Engineering Department
Mr. Brian Smyth
Dublin, 24
IRELAND
+353 1 459 89 89
e-mail: brian.smyth@rtc-tallaght.ie

Pilkington Interglass, S.A.
Mr. J. Miguel González Batiz
Kareaga, s/n.
48903.-Barakaldo (Vizcaya)
SPAIN
+34 4 482 01 02
Fax: +34 4 482 08 10

Heliostat Ltd.
Mr. Christos Korres
10-12 Kifissias Ave.
Agora Center Bldg. 1, Suite 10
15125 Maroussi
Athens
GREECE
+30 1 6844 194
Fax: +30 1 6851 151

IST Energietechnik
Mr. Ulrich Luboschik
Ritterweg 1, D-79400 Kandern

GERMANY
+49-7626915417
Fax: +49-76267099

Last: Ap 1
Last: Ap 2.2

Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.3 - TMR Users

Next: Ap 3
Next: Ap 2.4
Next: Ap 2.3.2

Top: Appendix 2.3.1 - Process Heat

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[Last: Ap 1](#) [Annual Technical Report 1996](#) [Next: Ap 3](#)
[Last: Ap 2.2](#) [Back: Appendix 2 - List of Collaborating Institutions and Companies](#) [Next: Ap 2.4](#)
[Last: Ap 2.3.1](#) [Back: Appendix 2.3 - TMR Users](#) [Next: Ap 2.3.3](#)

Appendix 2.3.2
Control

University of Oulu
Dpt. of Process Engineering
Control Engineering Laboratory
Dr. Kauko Leiviskä
Linnanmaa 90570.-Oulu
FINLAND
+358-81-5531011/5532461
Fax: +358-81-5532466
e-mail: Kauko.Leiviska@oulu.fi

University of Hertfordshire
School of Engineering,
Division of Electrical & Electronic Engineering
Dr. Patrick Luk
College Lane
Hatfield AL10 9AB
UNITED KINGDOM
+44 1707 284190
Fax: +44 1707 284199

INESC
Prof. Joao Miranda Lemos
Rua Alves Redol, 9
Apartado 10105
1017 Lisboa Codex
PORTUGAL
+351 1 310 02 59
Fax: +351 1) 314 58 43

University of Strathclyde
Industrial Control Centre
Dr. L. Petropoulakis
Graham Hills Building
50 George Street
Glasgow G1 1QE
SCOTLAND
+44 141 552 4400
Fax: +44 141 553 1232

e-mail: akis@icu.strath.ac.uk

Universitat de Firenze
Prof. E. Mosca
Via de Santa Marta, 3
I-50139 Firenze
ITALY
+39 55 4796257
Fax: +39 55 4796363

Last: Ap 1
Last: Ap 2.2
Last: Ap 2.3.1

Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.3 - TMR Users

Next: Ap 3
Next: Ap 2.4
Next: Ap 2.3.3

Top: Appendix 2.3.2 - Control

Appendix 2.3.3
High Flux Technology

CENIM
Prof. Alfonso J. Vázquez Vaamonde
Av. Gregorio del Amo, 8
28040 Madrid
SPAIN
+34 1 553 89 00
Fax: +34 1 534 74 25
e-mail: avazquez@fresno.csic.es

Materials Ireland, Forbairt
Ceramics Research Unit
Ms. Aoibhe O'Riordan
Glasnevin
9 DUBLIN
IRELAND
+353 1 8082532
Fax: +353 1 8082046

E.T.S. Ingenieros Industriales
Dpto. Ingeniería Mecánica y de los Materiales
Dr. Jose María Gallardo
Avda. Reina Mercedes S/N
41012 SEVILLA
SPAIN
+34 5 445 6895
Fax: +34 5 423 4696

Dept. MTM
Katholieke Universiteit Leuven
Prof. J.P. Celis
de Croylaan, 2
B-3001 Leuven
BELGIUM
+32-16 32 13 12
Fax: +32-16 32 19 91
e-mail: jean-pierre.celis@mtm.kuleuven.ac.be

Dept. of Mechanical and Manufacturing Engineering

Trinity College
Dr. Andrew Torrance
Dublin, 2
IRELAND
+353-1 608 1729
Fax: +353-1 679 5554
e-mail: atorrnce@tcd.ie

Helsinki University of Technology
Processing and Heat Treatment of Materials
Dr. Seppo Kivivuori
Vuorimiehentie 2A
02150 ESPOO
FINLAND
+358 0 45 12 707
Fax: +358 0 45 12 660
e-mail: antti.korhonen@hut.fi

Instituto Superior Técnico
Depto. Engenharia Materials
Dr. Luis Guerra Rosa
Avda. Rovisco Pais
1096 LISBOA CODEX
PORTUGAL
+351 1 841 8135
Fax: +351 1 849 9242

Schlaich Bergermann und Partner
Herrn W. Schiel
Hohenzollernstr. 1
D-70178 Stuttgart
GERMANY
+49 711 6487120
Fax: +49 711 648 7166

L&C Steinmüller GmbH
Mr. Manfred Schmitz-Goeb
TA 2067
Postfach 100855
D-51641 Gummersbach
GERMANY
+49 2261 852067
Fax: +49 2261 852029

Intersol Corp.
Mr. Lennart Lundström
PL 416 Marbäk
30594 Halmstad
SWEDEN
+46 35 44170
Fax: +46 35 44171

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Last: Ap 1
Last: Ap 2.2
Last: Ap 2.3.3

Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.3 - TMR Users

Next: Ap 3
Next: Ap 2.4
Next: Ap 2.3.5

Appendix 2.3.4
Solar Chemistry

Institut für Solarenergieforschung GmbH Hannover
Dr. Roland Goslich
Sokelanstraße 5
D-30165 Hannover
GERMANY
+49-511 358 50 31
Fax: +49-511 358 50 10
e-mail: isfh.goslich@oln.comlink.apc.org

CNRS/Ecole Centrale de Lyon
Dr. Jean Marie Herrmann
Photocatalyse, Catalyse et Environement
B.P. 163
69131 Ecully Cedex
FRANCE
+33 72 1864 93
Fax: +33 78 33 03 37

CNRS/Ecole Centrale de Lyon
Photocatalyse, Catalyse et Environement
Dr. Pierre Pichat
B.P. 163
69131 Ecully Cedex
FRANCE
+33 72 18 64 95
Fax: 33 78 33 03 37

Instituto Nacional de Engenharia e Tecnologia Industrial
Dr. João Farinha Mendes
Azinhaga dos Lameiros a Estrada do Paço
do Lumiar
1699 Lisboa Codex
PORTUGAL
+351-1 716 51 41
Fax: +351-1 716 37 97
e-mail: fmendes@dms01.ineti.pt

Technische Universität Wien

Institut für Physikalische Chemie
Dr. Rupert Bauer
Getreidemarkt 9/156
A-1060 Wien
AUSTRIA
43-1 588 01-5162
Fax: +43-1 586 8273
e-mail: rbauer@fbch.tuwien.ac.at
e-mail: hfallman@fbch.tuwien.ac.at

Dipartimento di Chimica Organica dell'Universita di Pavia
Prof. Angelo Albini
Viale Tarematti, 10
27100 Pavia
ITALY
+39 382 507 323
e-mail: fasani@ipv85.unipv.it

CNRS
Institut de Chimie des Substances Naturelles
Dr. Charles Giannotti
Ave. De la Terrasse
91198 Gif sur Yvette Cedex
FRANCE
+33 1 69 82 30 55
Fax: +33 1 69 07 72 47
e-mail: Charles.Giannotti@icsn.cnrs-gif.fr

Institut für Organische Katalyseforschung an der Universität Rostock e.V.
Dr. Gunther Öhme
Buchbinderstraße, 5-6
D-18055 Rostock
GERMANY
+49-381 466 930
Fax: +49-381 466 93 24
e-mail: bhelle@chemiel.uni-rostock.de

Prof. Diego Armesto
Facultad de Ciencias Quimicas
Depto. Química Orgánica
Universidad Complutense de Madrid
Ciudad Universitaria
28040 Madrid
SPAIN
+34 1 394 43 16
Fax: +34 1 394 41 03
e-mail: darmesto@eucmax.sim.ucm.es

Last: Ap 1
Last: Ap 2.2
Last: Ap 2.3.4

Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.3 - TMR Users

Next: Ap 3
Next: Ap 2.4

Appendix 2.3.5
Process Heat

Dr. James A. McGovern
Trinity College
Dept. of Mechanical and Manufacturing Engineering
Parsons Bldg.
Dublin, 2
IRELAND
+353 1 608 1465
Fax: +353 1 679 5554

Last: Ap 1
Last: Ap 2.2
Last: Ap 2.3.4

Annual Technical Report 1996
Back: Appendix 2 - List of Collaborating Institutions and Companies
Back: Appendix 2.3 - TMR Users

Next: Ap 3
Next: Ap 2.4

Top: Appendix 2.3.5 - Process Heat

Last: Ap 2 Annual Technical Report 1996 Next: Ap 4

Appendix 3
Publications

Contents:

Last: Ap 2 Annual Technical Report 1996 Next: Ap 4
Top: Appendix 3 - Publications

Last: Ap 3
Annual Technical Report 1996

Appendix 4
Contacts

For up-to-date contact information, please visit the Staff Listing section of this web site.

Last: Ap 3
Annual Technical Report 1996
Top: Appendix 4 - Contacts

Last: Ap 2
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Next: Ap 3.2

Appendix 3.1
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Last: Ap 2
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Next: Ap 3.2
Top: Appendix 3.1 - Communications to Congresses

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Last: Ap 2
Last: Ap 3.1

Annual Technical Report 1996
Back: Appendix 3 - Publications

Next: Ap 4
Next: Ap 3.3

Appendix 3.2
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Last: Ap 2
Last: Ap 3.1

Annual Technical Report 1996
Back: Appendix 3 - Publications
Top: Appendix 3.2 - Books

Next: Ap 4
Next: Ap 3.3

Last: Ap 2
Last: Ap 3.2

Annual Technical Report 1996
Back: Appendix 3 - Publications

Next: Ap 4
Next: Ap 3.4

Appendix 3.3
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Last: Ap 2 | Annual Technical Report 1996 | Next: Ap 4
Last: Ap 3.2 | Back: Appendix 3 - Publications | Next: Ap 3.4
Top: Appendix 3.3 - Technical Reports

Last: Ap 2
Last: Ap 3.3

Annual Technical Report 1996
Back: Appendix 3 - Publications

Next: Ap 4
Next: Ap 3.5

Appendix 3.4
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Last: Ap 2
Last: Ap 3.3

Annual Technical Report 1996
Back: Appendix 3 - Publications
Top: Appendix 3.4 - Internal Reports

Next: Ap 4
Next: Ap 3.5

Last: Ap 2
Last: Ap 3.4
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Next: Ap 3.6

Appendix 3.5
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Last: Ap 2
Last: Ap 3.4
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Next: Ap 3.6
Top: Appendix 3.5 - Courses and Seminars

Last: Ap 2
Last: Ap 3.5
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Next: Ap 3.7

Appendix 3.6
Doctoral Theses

U-DGXII Human Capital and Mobility, JOULE Thermie and TMR publications written under CIEMAT contracts CHGE-CT93-0038, JOU2-CT93-0299 and ERBFMGECT95-0023

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Last: Ap 2
Last: Ap 3.5
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Next: Ap 3.7
Top: Appendix 3.6 - Doctoral Theses

Last: Ap 2
Last: Ap 3.6
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Next: Ap 3.8

Appendix 3.7
Academic Publications

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Last: Ap 2
Last: Ap 3.6
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Next: Ap 3.8
Top: Appendix 3.7 - Academic Publications

Last: Ap 2
Last: Ap 3.7

Annual Technical Report 1996
Back: Appendix 3 - Publications

Next: Ap 4
Next: Ap 3.9

Appendix 3.8
International Journals

U-DGXII Human Capital and Mobility, JOULE Thermie and TMR publications written under CIEMAT contracts CHGE-CT93-0038, JOU2-CT93-0299 and ERBFMGECT95-0023

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Last: Ap 2
Last: Ap 3.7

Annual Technical Report 1996
Back: Appendix 3 - Publications
Top: Appendix 3.8 - International Journals

Next: Ap 4
Next: Ap 3.9

Last: Ap 2
Last: Ap 3.8
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4

Appendix 3.9
Reports to the EC

U-DGXII Human Capital and Mobility, JOULE Thermie and TMR publications written under CIEMAT contracts CHGE-CT93-0038, JOU2-CT93-0299 and ERBFMGECT95-0023

1. Laing, D., Development of Advanced Hybrid Heat Pipe Receivers in Dish/Stirling Systems for Decentralised Power Production, DLR, Second Periodic Report (Contract JOR3-CT95-0085), December 1996

Last: Ap 2
Last: Ap 3.8
Annual Technical Report 1996
Back: Appendix 3 - Publications
Next: Ap 4
Top: Appendix 3.9 - Reports to the EC

Last: Ap 3

Annual Technical Report 1996

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Last: Ap 3

Annual Technical Report 1996

Top: Appendix 4 - Contacts