In Spain sun is the future
Per Stobbe – 1998

Plataforma Solar de Almeria (PSA - http://www.psa.es) is Europe's largest test facility for solar energy covering 103 Ha. It is located at an altitude of 504 meters east of the Sierra Nevada Mountains in Andalusia. The area experiences <6 days of rain and >3000 enviable hours of sunshine per year. The daily period between 0900 hours and 1530 hours typically sees up to 1000 watt irradiance effect per m^2 ground surface. The speed of the wind in the somewhat barren area is up to 5 m/sec, primarily from the northeast.

CESA-1 tower unit at PSA - PSA was founded by the Spanish state in the early 1980's with the primary objective to produce electricity to the local power supply on a commercial basis. The 82 meter high concrete tower is

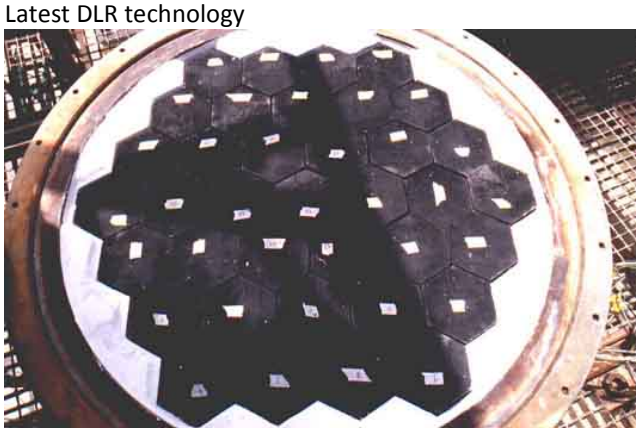
built with sliding form at 10 meter diameter and rests on a 250 ton heavy foundation. The 8th floor is the top platform with access from both a steel staircase and an elevator. A cable driven crane with a capacity of 5 tons situated on the top of the steel platform lifts the test units into place. Originally, CESA (Central Electro Solar de Almería) was equipped with an Austenitic steel tube heat exchanger made by Sulzer. The 17 m^2 single layer heating tubes was painted black and able to produce 2.2 MW of thermal power with a cooling Sodium mass flow of 7.3 kg/s. The concept quickly presented great problems during the daily start-up of the 600 kW steam engine or with an incidental cloud which resulted in going from a liquid phase to a saturated water vapor phase. After a few months of fiasco the facility was turned over to test purposes.

The 300 heliostats with a combined area of 11880 m^2 are all delivered by CASA (Construcciones Aeronáuticas, S.A.), covers an ground area of 70000 m^2 and installed in 1987. Each one is equipped with 32 similar silver coated glass mirrors with a reflectance of >92%. Each reflector has a slightly concave area of 39.6 m^2 which is cleaned manually once a month. Quite positively, 12 years of use have not reduced the general output of the heliostats. Even the original VAC Unix control has survived. Maximum power is 7,5 MW (950W/m^2 irradiance) distributed over a single surface or distributed over several test units on the tower, 99% within a 4 meter diameter and 90% within a 2,8 meter diameter. Thus, the maximum flux is 3,3 MW/m^2, which is quite impressive. Adjusting is done by manually pointing a single reflector at a 20 m^2 white test surface in the middle of the tower and then laying out the co-ordinates.
The new test program did with some difficulty find a to-step Siemens-Hazán steam turbine (Type HNK 25/28/125-3.Rankine cycle) which delivers 1.2 MW at 11,000 rev/min. 1.656 kg/s steam flow at 98 Bar inlet pressure and 520 °C. The turbine is connected to a Siemens gearbox which reduces the number of revolutions to 1.500 rev/min and is again coupled to a 1.5 MVA air-cooled Siemens generator. A transformer placed outside raises the 400 VAC generator voltage to 25 kV for coupling to the local power supply. Heat exchanger pressure is delivered by a 3 cylinder piston pump driven by a 40 HP asynchronous motor placed in the turbine house and the system delivers 45 Bar at the top of the tower. The condenser is placed under the turbine and is coupled to two 1.5 MW cooling towers (flow rate 88 m^3/h) placed on the roof of the turbine building.
The development of the transfer media
The medium for transferal of the solar radiation energy to the necessary 400°C high pressure steam at PSA is still the object of many efforts. PSA has carried out many tests with liquid Sodium which at one point leaked down the CESA-2 steel tower and caused severe corrosion and fire. Over the last years the development has

moved towards non-dangerous media such as air. Atmospheric pressure for the simple but relatively well tested volumetric receiver systems and up to 15 Bar system pressure for the advanced REFOS concept.
Heating surface technology on CRS - Central Receiver Systems
The volumetric receiver (VR) converts the short wave energy from the sun to long wave energy. By using air as the heat transfer medium in an heat exchanger, this energy can be used to produce high pressure steam to run a conventional steam turbine.

Depending on the concept, the 700-1000°C hot air is drawn out the back of the receiver by a centrifugal ventilator and immediately afterwards through a tube heat exchanger. A thermal storage (6 ton/MW) attached via valves acts as energy buffer. It equalizes a possible energy drop should f. ex. a cloud pass by and generally prolongs the daily operating time with a couple of hours. Isolated on the inside with porous stones, the container holds a mineral granulate that can handle a storage temperature >700°C. The air, now cooled to 100°C, is then recirculated to the receiver with a maximum air flow capacity of 1250 m^3/h. The right side of the photo shows the backside of VR with pipe outlet at the top. The yellow container is the steam generator. Air pumps and return channels are placed under the floor. The distance from the heat exchanger to the turbine is 125 meter. The view is breath taking and reveals an area with only a few trees.
There have been many problems with clouds over the years. When a cloud reduces the radiation energy effect, pumps reduce the flow to maintain a constant receiver output temperature. When the cloud disappears the input power goes up sharply to 0.4 MW/m^2 and no regulating mechanism has yet been able to prevent melt-down of conventional materials in the VR sun catcher surface. The German firm Steinmüller GmbH (recently taken over by Babcock) has delivered the volumetric receiver that is being tested during the Spring of 1999. This concept is based on Inconel 600 wire-mesh modules knitted to a stocking and rolled up flatly to a 40 mm high flexible disc with a diameter of 250 mm. 22 discs are pressed separately into to a hexagon and gathered into one receiver surface of app 3 meter diameter. The re-circulation of the air medium is limited to 60% by this VR design. Maximum operating temperature for this 3 MW electricity receiver is 750°C which does not, however, prevent melt-down.

Latest DLR technology



REFOS is a true high-tech concept from DLR in Stuttgart, the aim of which is to try to eliminate the heat

exchanger and the steam turbine. The receiver output on this combined-cycle concept is 600-800°C hot atmospheric air at a 15 Bar pressure. These modular pressurized units are capable of delivering 350 kW hot air and the idea is to couple together f. ex. 7 directly on one combustion/hot air turbine. REFOS is an abbreviation from *volumetric pressurized receiver for solar assisted fossil-fired gas turbine and combined cycle power plants*.
Danish technology on top of things
During the summer of 1998 DLR tested a 0,2 MW electricity (0.49 m^2) volumetric receiver (HitRec) based on 37 pcs. 120 mm hexagonal modules designed and produced in Silicon Carbide ceramic by Stobbe Tech Ceramics A/S. It is the first serious Danish participation in PSA with a component critical to the concept. The 200 hours of operation showed that choice of design and material permits a working temperature of >1000°C plus a further 2-300°C safety margin.

This eliminates melt-down and the unit can be made more compact. Re-circulation of the air medium is increased to 85% with the HitRec design. Maximum irradiance effect was 0.3 MW which gives a total efficiency of 68%. Mass flow through the receiver at 960°C is between 0.2-0.6 kg/sec.
White Alumina fiber insulation surrounds the hexagonal ceramic modules inside a mounting flange. Combined weight for the 37 ceramic modules is less than 50 kg. Coupled to a computer in the control room, more than 60 NiCrNi thermocouples gather data to evaluate the output.