Lebrija 1: international solar thermal reference

HAVING A CAPACITY OF 50 MW, IT WILL SUPPLY 30,000 SPANISH HOUSEHOLDS WITH CLEAN ENERGY

The Lebrija 1 solar thermal power plant, located in Seville and with a capacity of 50 megawatts (MW) and based on parabolic trough technology, has been developed by Siemens and Valoriza Energy (now called Sacyr Industrial) as a joint venture. It includes a solar field consisting of over 412,000 square meters of mirrors (equal to the area occupied by 54 football fields), all set in 6048 parabolas, each with 28 individual mirrors. If all the parabolas are placed in line, they would cover a distance of 72 kilometers.

The Lebrija power plant is the first power plant that Iberese S.A.U (Valoriza Energía), along with Siemens, has built using this type of technology. Siemens has been in charge of the whole solar field, consisting of solar receivers, structures and mirrors, and has provided the steam turbine as well. As for Valoriza Energy, it has performed all the civil works, the power block (including the 50 MW steam turbine supplied by Siemens), the system of heat transfer fluid, auxiliaries and the connection of 220 kV between the plant and Puerto de Santa María (Cádiz). In addition, Siemens has implemented the control system of the plant as well as coordinated the integration of the different packages that make up the solar thermal plant. The two companies are responsible for using the same joint-venture operation as well as for the maintenance of the plant.

On December 27, 2011 the plant, designed as a turnkey project, was finally registered in the RAIPRE (Record Production Facilities Special Scheme) by the Andalusian government to generate energy from CSP plants. The field can supply about 30,000 Spanish homes with clean electricity at full capacity and prevent the emission of 47,000 tons of CO_2 annually.

All internal and external tests have been carried out satisfactorily and have successfully demonstrated the operability and availability of plant systems.

Composition of the plant: construction and technology

The Lebrija CSP plant consists of the solar field, thermal fluid circuit system (HTF), the power block (Power Block) and auxiliary facilities (Balance of Plant System, BOP). Iberese (Sacyr) has undertaken the turnkey construction of the Power Block, HTF and BOP. On the other hand, Sacyr has carried out the civil works, and finally, Siemens has built the solar field and supplied the steam turbine in the Power Block, the control system of the plant (DCS). The latter

has also carried out the integration of the packages.

The Thermal Fluid Circuit System (HTF System)

The HTF system, which contains 1,500 m^3 Thermal fluid Therminol VP-1, receives the solar energy from 126 parabolic trough collectors and transmits it through the two HTF water-steam generation train. Apart from solar energy, it has 2 natural gas boilers of 20 MWt to optimize starting and to compensate for any variations in production due to atmospheric phenomena such as clouds, fog, or any variations in the direct radiation received by mirrors.

The facility also has a 3.75 MW boiler to prevent the thermal fluid from solidifying or increasing its viscosity due to ambient temperature. This boiler starts working when it detects a temperature of 60 ° C in the fluid.

The main equipment of this system is:

- Piping system and pumps by Ditecsa: distribution to the 126 collectors across the four quadrants into which the solar field is divided, and return to the train generation.

Main pumps thermal fluid (Nuovo Pignone): three 6 kV pumps with frequency converter,

Expansion system (Indálicas boilers): consisting of three tanks of 200 m^3/unit and one of 120 m^3.

Boiler system to support the generation and avoid cooling (Sugimat): two natural gas thermal fluid boilers of 20 MWth and one of 3.75 MWt.

Thermal generation system (Lointek): 2 parallel trains, each consisting of a preheater, an evaporator and a superheater.

Electrical tracing system (ASK) in order to prevent the thermal fluid from solidifying, most are tracing circuits.

- Ullage and reclamation system: Designed to continuously purge the heat transfer fluid as it degrades over time. A portion of the treated fluid is recovered and the other is sent to its removal by an authorized agent.

Power Block (Power Block System)

The power block system consists of steam cycle and other auxiliary systems. The main equipment is the 49.9 MWe turbine consisting of two stages: on the high stage it gets the vapor at 104 bar and on the down stage at 18 bar. Both stages have extractions to improve and optimize the performance of the cycle.

The superheated steam generated in the HTF- steam exchangers is sent to the high stage at 104 bars and 377 ° C. At this stage extraction is to preheat the incoming water to the HTF-water preheater through two high steam and water preheaters.

The remaining steam is sent to the reboiler to again enter the turbine on the down phase at 18 bars and 379 ° C. In this second stage, four extractions are performed: three to preheat the feed water to the degasser by three low steam and water preheaters, and one more extraction is directly sent to the degasser.

The rest of the steam is expanded, cooled in the condenser and is pumped to the degasser, warming up initially in the three aforementioned low preheaters. The feed pumps take the water cycle to 186 ° C and 18 bar degasser and pump the water passing initially through the high-temperature preheaters. The HTF-water preheater water flows from the HFT-water preheater to the HTF-water/steam evaporator and thence to the super heater, thus closing the steam cycle.

The HTF-water / steam generation trains, which are part of the HTF, are duplicated so that the steam cycle comprises the following elements:

- One 49.9 MWe turbine with two-stage 62 MVA 11 kV generator by Siemens.
- 1 GEA condenser.
- Kirloskar condensate pumps and KSB feed pumps (6 kV distribution and variable frequency)
- 3 Lointek low-temperature water-steam preheaters.
- 1 Mecet degasser
- 2 Lointek high-temperature water-steam preheaters
- 2 Lointek HTF-water preheaters.
- 2 Lointek HTF-water/steam evaporators.
- 2 Lointek superheaters.
- 2 Lointek heaters.

Besides the steam cycle, the Power Block is comprised of the following auxiliaries:

- Piping system by Archanda Montajes.
- Main circulation system: consisting of a SPX 4-modules tower and three Hidrotecar pumps that cools the condenser.
- Auxiliary circulation system and closed cooling system: the first cools -in the tower- the closed cooling circuit which also cools by plate exchangers or directly, different equipment i.e. the Power Block, the HTF and the BOP: mainly, auxiliary systems of the turbine, HTF pumps, cooling, etc.
- Chemical dosing system by Pastech and sampling system: they are responsible for conducting a proper control of the chemical properties of water and steam.

Steam turbines (Siemens)

The SST-700 is a dual casing steam turbine. It is specially designed for power generation applications. In order to make the best use of large changes in volumetric flow from inlet to outlet, the SST-700 turbine steam expansion is divided into two different modules: one high-pressure turbine (HP) and one low-pressure turbine (LP).

Among the main advantages of the SST-700 turbine is: its compact design, its ease of installation and maintenance, its wide application range and high reliability, availability and performance. All this, makes the turbine particularly suitable for solar thermal plants.

Tanks (Arrospe)

Iberese trusted in Arrospe, for some of the tanks of the plant. Arrospe carried out successfully the following scope of supply:

- EN14015 Mechanical design, fabrication and erection on site of the Demineralized water tank: Ø 8.400, H 7.500mm, in LDX2101 Duplex 1.4162 stainless steel, including the CO_2 trap, access ladder and maintenance platform.
- This new Outokumpu duplex stainless steel has better mechanical properties and corrosion resistance than more common austenitic stainless steels like A304. This helped to optimize the thicknesses of the tanks, offering the client a better technical solution for less price. In short optimizing the costs of the project.

Arrospe also designed and fabricated the following tanks of the plant, but in this case were assembled by others:

- Condensate tank: Ø 3.500, H 6.500mm, in LDX2101 Duplex 1.4162 stainless steel
- Compensation tank: Ø 800, H 1700mm, in S235JR carbon steel
- 3 Flash tanks for the PSV discharge, in A516Gr60 & A106GrB carbon steel, one of them pressure vessel according to PED97/23CE.

- Compressed air system: consists of two Compair compressors, dryers and storage tank for the production and distribution of air tools and air service.
- Auxiliary steam system: is formed by a Cerney 1 t / h of superheated steam boiler for the turbine seals, HTF cooling pumps and other services. If a fault, a 100 kg / h electric boiler has been installed as well.
- Water treatment system by Sadyt (Grupo Sacyr) : it serves to draw water from the irrigation canal and generate filtered water to various services as well as demineralized water for the steam cycle. This system also takes care of minimizing the effluent in order to have a power plant with zero discharge. It comprises the following subsystems:
  - Pretreatment.
  - Ultrafiltration.
  - First stage reverse osmosis.
  - Second stage reverse osmosis.
  - EDI.
  - Blowdown water treatment.
  - Sand filters.
  - EDR.
  - Filtered water tanks as well as tanks of water replenishment towers, demineralized water etc.

To ensure the water supply to the plant, a water storage tank with a capacity of 100,000 m^3 has been constructed. Similarly, in order not to make any discharge into public waterways, a 20,000 m^3 evaporation basin to which all rejections are sent has been built.

Auxiliary Facilities: Balance of Plant System (BOP)

It consists of various services required by these two systems shown above. The main facilities are:

Electrical installations

The steam turbine generates 11 kV and increases the voltage to 220 kV to evacuate power from Lebrija (Sevilla) to Puerto de Santa María (Cádiz). Ancillary services are fed with a part of the energy generated. In the event of failure of the 220 kV, a 20 kV line and a diesel aggregate to power critical loads for the facility are available. This system consists of:

High Voltage Electrical Installation

- Internal substation with 52/65 MVA ONAN / ONAF 11kV/220kV power transformer: gets power directly from the turbine generator for evacuation to the delivery point of Red Eléctrica de España.
- 500 m. airline between internal substation and evacuation substation in Lebrija.
- 220 kV Substation evacuation in Lebrija.
- 220 kV double circuit line with 50 km from the disposal of Lebrija and the 220 kV substation in Puerto de Santa María de REE.

Medium Voltage Installation

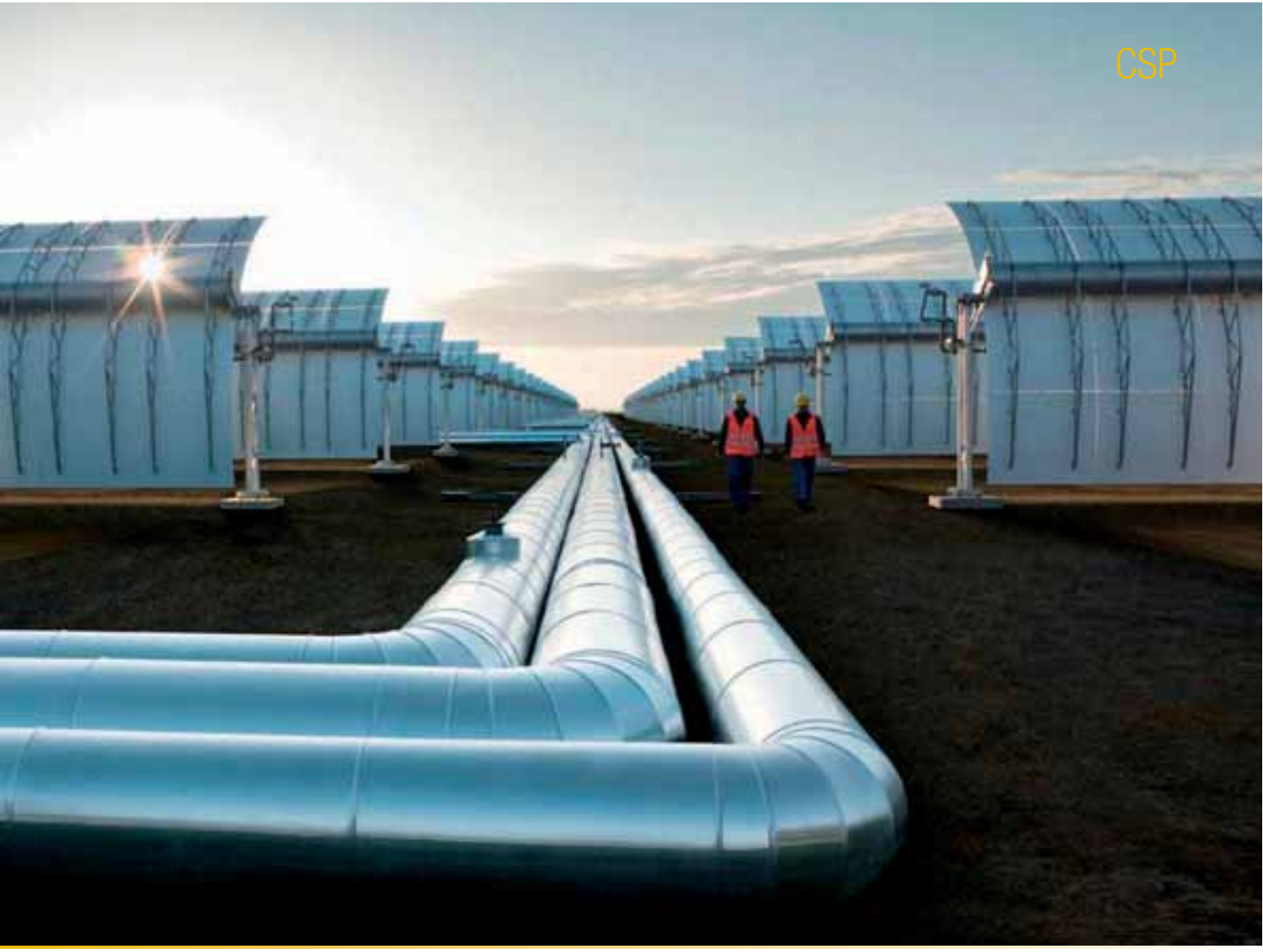
- MV Distribution to transformers and consumers (feed pumps and main steam cycle thermal fluid pumps)
- Power Transformers:
- One main 7/9, 1 MVA ONAN / ONAF 11 kV / 6 kV transformer by Siemens.
- 2 MVA ONAN 20 kV/11 kV emergency transformers.
- Four dry transformers for HTF, BOP and Power Block systems,: 2.5 MVA AN 6 kV / 0.4 kV by Tesar.
- A dry transformer for emergency diesel group of 2 MVA AN 6 kV / 0.4 kV by Tesar.
- A transformer to control building: 400 kVA ONAN 20 kV / 0.4 kV.
- Emergency Group Diesel emergency to power critical loads of 2.25 kV 0.4 MVA by Caterpillar.
- MV cubicles, frequency converter, etc.

Low voltage installations

- Distribution to consumers.
- CCM.
- Uninterruptible Power Systems.
- Emergency Diesel Group for general servicer 400 kVA 0.4 kV by Electra Molins.
- Protections.

Nitrogen system

The facility has a nitrogen plant develop by Praxair for hire to power and inerting HTF (generation trains, expansion tank etc.) and Power Block (steam turbine) equipment.



Firefighting system:
Made by Eivar.

Air-conditioning system

This system cools the electrical room in order to dissipate the thermal energy detached from the different equipment. It consists of chiller, air handler unit, roof-top and air conditioners. The system was carried out by Climanaher.

Natural Gas System

The natural gas supply (developed by Inglefuid) to three thermal fluid boilers and steam boiler is performed from an LNG plant with a 200 m^3 tank, made by Energy-Siemens Valoriza.

Operation System

The solar field is comprised of 756 sets of parabolic trough collectors called SCAs (Solar Collector Assembly), each with eight parabolas. These SCAs are grouped in loops of 6 units, arranged in two rows

HTF Scopes (Ditecsa)

The works that took place at the Lebrija 1 Solar Plant consisted on mounting the whole solar plant HTF Scopes, which includes the complete solar field and part of the power block, being the battery limit the exchangers (where HTF thermal oil heated water into steam).
Below is a small summary of the works that the company carried out, by areas:

- 11,040 meters of pipes in the solar field and 2,535 meters on the power island area, summing up to 52,430 nominal inches.
- A total of 2,408 supporting elements were mounted (sliding bearings, springs, etc.)
- 12,515 kg of secondary supports were used (profiles for primary supports).
- Structures for support of a total of 31,850 kg were mounted.
- Mounting of equipment: mainly the expansion tank and the three HTF overflow tanks, as well as the three HTF system main pumps, and preheaters, reheaters, overheaters.
- On the electrical scope, Electroconver (which belongs to the Ditecsa group) carried out the electrical tracing of the HTF system piping.

of three units each. The collectors concentrate solar radiation onto solar receivers (UVACs) created by Siemens through which a thermal fluid that absorbs heat circulates.

The Lebrija solar field has 126 loops, connected in parallel. Each loop is oriented north-south, so that the SCA can track the movement of the sun from east to west throughout the day by a hydraulic drive, thus maximizing the absorption of energy.

An innovative idea that Siemens has launched in Lebrija has been the creation of an assembly line of intermediate modules to automate the processes of construction and installation of a solar thermal power plant, thus optimizing the process and improving assembling conditions.

The assembly process consists of the assembly and attachment of all the components of the parabola. In the area for the assembly of the parabolas, two semi-automated lines for drilling and assembly thereof were installed. An automatic welding station was designed for the welding process of the UVACs.

Emergency diesel generator set (Barloworld Finanzauto)

Barloworld Finanzauto, official dealer of CAT Power Systems, supplied the main emergency diesel generator set.

This diesel Genset has been installed to protect the power module and the solar field of the plant in the event of a black-out.

The Genset has been equipped with:

- Sound attenuated weather proof enclosure.
- Cooling system designed to work with ambient temperatures up to 45 °C.
- CAT EMCPII (Electronic Control Panel II) local control panel.
- Control switchgear for Automatic mains failure and synchronisation with utility.

The heart of the system is a well known CAT 3516B engine installed in the five continents and in the toughest conditions for its reliability, durability and cost-effective operation, coupled to a CAT SR4B generator.

The generator includes permanent magnet excitation for minimum total harmonic distortion, better transient response and maximum efficiency. A CDVR (Compact Digital Voltage Regulator) is mounted in the package providing peak performance and total flexibility.

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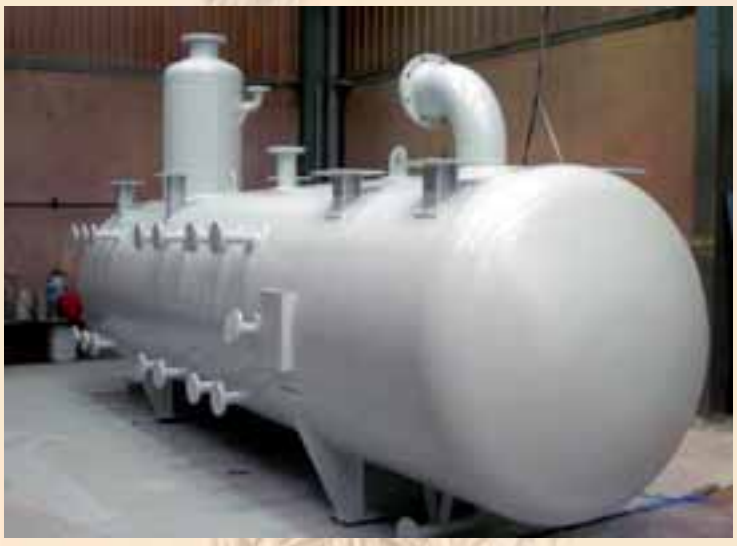

General boiler making company specialized in stainless steels, nickel-alloys and other metals (A304, A316, A904, 254SMO, LDX2201, 2304, 2205, SAF2507, Hasteloy, Titanium)
Founded in 1978, we have a 7100m2 workshop with lifting capacity up to 45 ton, integrating the fabrication processes of cutting, forming, welding, and surface finishing.

Detail engineering capacity (5 engineers, & 1 International Welding Engineer IWE) for mechanical / thermal calculations and managing the required additional subcontracting operations to get turn-key products/projects (machining, stress relieving, balancing, etc.)

Fabrication in workshop and/or erection- installation of piping and equipments at client's site
Pressure/vacuum vessels, Separators, Tubes-shell heat exchangers, Reactors, Columns, , Piping installations, Pre-assembled skids units.

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220 kV electrical substation (Aumansa)

Aumansa has performed the construction, installation, testing and implementation of the conventional outdoor substation of 220kV for the network connection to the Solar Thermal Plant.

The foundations, control buildings, installation of support structures for switchgear and main portal for connecting with the network as well as the installation of all necessary electric equipment have been executed.

The substation has been performed following the standards of REE. It installs the control and protection devices, consisting of a substation control center (SCC) which oversees the proper functioning and maneuvers that can be performed through screens (SCADA) performing all the functions of interaction with the operator, as well as the different communications equipment necessary for the integration into the network.

For the proper performance of all equipment installed in the substation, various ancillary service boards have been installed located in a separate room. Such equipment includes DC battery of 125 volts for protection system and maneuvering as well as 48 volts for the communications system.

The thermal fluid is pumped through the solar field, reaching a temperature slightly below 400 ° C (395 ° C design). Subsequently, this fluid goes to a set of heat exchangers (preheater-vaporizer-superheater) to generate steam at 100 barg and 377° C.

The thermal energy absorbed by water vapor is transformed into mechanical energy by a Rankine thermodynamic cycle with intermediate reheating. That is, the high pressure superheated steam is expanded in a high pressure turbine to an intermediate pressure, from which is extracted and reheated from the thermal fluid in a superheater. Then it is redirected to the low-pressure turbine, which completes its expansion.

The output of steam from the turbine is conducted under conditions of vacuum, which is achieved by a water cooled condenser which comes from water circulation system.

The closure of the steam cycle is performed by pumping the condensate to the feed water preheater, after passing through a train of heaters and thermal deaerator, where it reaches the feed temperature, after extraction of steam from the turbine.

A parabolic trough solar field operation is based on the use of direct solar radiation. Thus, cloud cover can lead to variations in the radiation capture collectors. It is therefore essential to control these fluctuations to optimize the performance of the solar thermal plant, which is achieved by the control system implemented by Siemens.

Structures

The plant in Lebrija is divided into four quadrants: northeast, northwest, southeast and southwest.

The total area of parabolic trough collectors is 412,020 m^2. In addition to the collectors, the system is composed of cold oil sumps, which are responsible for distributing cold oil to the loops, and hot oil collectors, who collect the hot fluid to be returned to power block of the plant.

Each SCA is supported by 9 pillars of metallic structure with a drive pylon in the center, which supports more load and incorporates the SCA drive of and eight typical pylons, located symmetrically on each side of the middle one.

LOC Unit (Local controller)

The LOC is the unit that controls the movement of the hydraulic unit of the SCA. Each SCA has a LOC unit installed in each drive local controller pylon. The local controller receives input from the solar sensor, the position sensor and the temperature sensor. These sensors analyze the data, di-

Deionized water plant (Sadyt)

The company Sadyt (Sacyr Group) has designed and built a plant of deionized water for steaming stream cycle, with a quality of 0.1 uS. The water comes from a swamp and, once filtered, is treated with an ultra filtration system, osmosis 1, osmosis 2 and CDI. To ensure the supply, two plants have been designed: one into service and one held in reserve, capable of supplying 8 m^3 / h each.

Goal related to the desired quantity and quality as well as a minimized environmental impact has been achieved with Siemens technology. A zero discharge initially screened with a RBS for the treatment of tower blowdown has also been fulfilled.

rect the movement of the drive system and report it to the control system of the solar field FSC (Field Supervisory Control system) by a two-way channel of communication.

The solar sensor is a device that detects the position of the sun at all times and is a part of the system of tracking (tracking). Based on this sensor, the local controller can accurately manipulate each SCA in the field. The mechanics of the solar sensor synchronization is crucial to achieve maximum efficiency of the performance of SCA. Also, the SCAs comprising the solar field are oriented according to a theoretical angle, but due to small misalignments which may have accumulated during the assembly andthe optimum angle of approach of each SCA may require adjustment and thus the virtual tracking performed by Siemens is necessary to compensate for the gap.

The temperature sensor, in charge of measuring the temperature of the thermal oil, is installed on the top of the reel for

joining two UVAC tubes in each drive pylon.

Power is distributed to the individual consumers through the power distribution units (PDU).

Responsible for powering the hydraulic ACS is composed of the drive system (oil tank, feed pumps and actuators) and the hydraulic control that coordinates the movement between the actuator and the power supply.

The junction between the collector of cold oil (input) and hot oil collector (output) with the ball-joint of the SCA is conducted through the riser. The ball-joints are the link clamps between the various pipes connecting the riser to the UVAC solar collectors, in order to absorb the movement of the parabolas during the solar path.

Mirrors

The solar field has about 170,000 mirrors with 6 mm thickness. All mirrors have been measured and geometrically tested with a laser beam to verify their interfering factor and the average reflectivity of the mirrors is approximately 98%.

Solar thermal plants use mirrors to concentrate the sun's energy. The curvature of the mirrors in Lebrija is so accurate that is equivalent to a fraction of a degree .

The Receiver Tube

More than 18,000 UVAC 2008 and 2010 receiver tubes with a diameter of 70 mm

Oil heaters (Sugimat)

The thermal oil heaters installed by Sugimat have the following characteristics:

Units: three.

Two of them with the following parametres:

- Thermal power per heater: 20 MW net.
- Oil outlet temperature: 395ºC
- Film temperature < 405ºC
- Output: 90%.

One with the following parametres:

- Thermal power: 3,75 MW net.
- Oil outlet temperature: 395ºC.
- Film temperature < 405ºC.
- Output: 90%.

They are equipped with a gas/oil heat recuperator to get the pre-set output and to control the oil film temperature; a gas/air economizer for combustion air pre-heating, natural gas fired burners with NOx reduction system; and power regulator depending on the oil flow provided from the plant.

The aims of these heaters are:

- To keep the installation functioning in case the solar radiation is insufficient, according with the conditions established in RD 661/2007.
- To keep the thermal fluid hot in case of a lengthy stop or unfavorable weather conditions.
- To bring forward the start-up of the plant by heating the thermal oil before the sunrise or to extend the plant's functioning after the sunset.

are employed in the solar field in Lebrija. These tubes maximize the absorption of solar radiation concentrated by the parabolic mirror in the receiver placed at the focal line.

The UVAC is a metal tube (approximately 4 meters long) inside which oil circulates and whose outer surface has a special coating to maximize the absorption of radiation and minimizes their emissivity to values lower than 0.09.

To avoid heat losses, the steel tube is surrounded by a glass tube with iron content in order to increase the transmission of solar radiation as it passes through the glass. The assembly is designed to maintain a high vacuum level between the two tubes, thereby reducing losses due to convection. Due to the high oil temperatures, hydrogen molecules pass through the metallic walls of the tube by diffusion; to prevent vacuum loss, these molecules are absorbed by an element called a getter which ensures a continuous vacuum during the entire lifetime of the receiver and is designed to operate for a period of 25 years under working temperature of 400 ° C.

The more efficient the receiver, the more electricity can be produced from a given size solar field.

The extensive experience and track record of the UVAC, as there are units installed since the early 80s, coupled with numerous patents in the vacuum maintenance system, coating and metal-glass joints make the Siemens UVAC a reference receiver in the market.

HCG 4/11 pumps (KSB ITUR)

In the summer of 2008 KSB ITUR obtained a pump order aimed for the production of conventional energy for the solar thermal plant of Lebrija.

The boiler feeding service is fulfilled with two HCG 4/11 pumps in stainless steel 14006 each of them with a 1200KW at 2967 rpm engine, being the volume to be pumped 289,6 m^3 /per hour for a height of 1193 metres.

The decision that has lead to the supply of this pumps was taken due to the fact that HGC pumps are suitable for pumping water at temperatures up to 200º C, being the temperature of the water handled in that plant 178º C.

Thermal oil distribution in the solar field

The thermal oil distribution in the solar field is carried out by carbon steel pipes with diameters ranging from 3" (connections to the loops) and 30" (exit to the solar field). The excess pressure is absorbed by an expansion system, especially for the expansion reservoir and the three overflow tanks.

The thermal oil is of the type Therminol VP-1 and works in the loops with an inlet temperature of 295 ° C and an outlet temperature of 395 ° C.

The main collector which distributes the 4 quadrants is the north-south collector. The thermal oil coming from them at 295 ° C is spread through the eastern and western collectors to the loops. Subsequently, the north-south collectors gather the thermal oil from all quadrants and send it to trains generating the steam