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PROCESS DESCRIPTON

METSIMATALA CSP PROJECT 150 MWe

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1.- INTRODUCTION

The following document´s aims are to define the general process of the solar thermal electric power plant and collect the documents to design the process engineering of this project. In particular this Process Description provides information and data about:

- General conditions.
- Type and capacity of the plant that is going to be designed.
- The main parameters of the process.
- Processes and systems of the plant.
- Consumption and input and output characteristics of the processes: raw material, consumables, waste chemicals, generated products (main products and by-products), waste water, emission or waste gas, waste solid, waste energies, etc...
- Conditions and limit of batteries in raw materials and energy supplies.

2.- GENERAL CONDITIONS

2.1.- Site

The site chosen for the location of the CSP facility located at Farm Groenwater 453 portion 4 and Remainder is this is located not far from Postmasburg Town in the Tsantsabane Local Municipality forming part of the Siyanda District Municipality Northern Cape Province.

- Latitude: -28º 17’33” N
- Longitude: 23º 17’ 11” E
- Elevation above sea level: 1465 m

2.2.- Environmental conditions

Typical years’ meteorological elements as below:

Meteorological elements	Unit	Value
Average temperatures (Mean/Max/Min)	℃	17.3 / 25.3 / 9.8
Extreme highest temperature	℃	38.4
Extreme lowest temperature	℃	-6.6
Average relative humidity	%	35
Relative humidity range	%	1.1 – 98.8
Maximum wind speed	m/s	15.8
Wind speed for design	m/s	TBD
Average atmospheric pressure	hPa	860

3.- TYPE AND CAPACITY OF THE PLANT

3.1.- Type of the plant

The plant uses solar radiation collected and concentrated by the parabolic mirrors to transfer heat to a thermal fluid to generate steam in a Rankine cycle with reheating. This steam is used to generate electricity by the steam turbine. The cylinder-parabolic collector technology bases its operation in the solar tracking and capturing of incident rays through a parabolic reflector that concentrates the rays reflected in high-efficiency tubes located along the focal line of such parabola. In these tubes the heat carrier fluid (HTF) is heated until 400ºC. This hot fluid goes to a series of heat exchangers in order to produce superheated steam. The energy of this superheated steam is converted to electrical energy using a conventional steam turbine and a power generator coupled to it.

The main components of the solar field are:

- Parabolic mirror: The aim of the parabolic mirror is to reflect and concentrate the direct solar radiation on the absorption tubes.
- Absorption tube: The absorption tube consists of two concentric tubes surrounded by a glass envelope. The receiver tube shall include a glass to metal hermetic seal and metal bellows to obtain the vacuum between the inner pipe and the outer envelope.
- Drive system: The most common drive system consist of a device that rotates around the collector´s the parabolic mirrors of an axis oriented from north to south.
- Steel structure: The aim of the steel structure of the collector is to stiffen the set of component parts.

The energy absorbed by the HTF flows to the power block where the steam generation, the turbo-generator set, the thermal storage system and the auxiliaries of the plant are.

3.2.- Capacities of the plant

The capacity of the plant shall be:

- Generator output 200 MVA (170 MWe MCR)
- Delivered energy to the grid: > 500 GWh/year
- Thermal storage system capacity 1,923 MWth.

4.- MAIN PROCESS PARAMETERS

4.1.- General

- Gross efficiency 39 %
- Generation of electrical energy 170 MWe

4.2.- Solar field parameters

- Number of SCE 18,240
- Number of SCE per SCA 12
- Number of SCA per loops 4
- Number of loops 380

4.3.- Steam generation parameters

- Main steam generation capacity 183 kg/s
- Superheated steam temperature 382.2 ºC
- Superheated steam pressure 101.6 bar(a)
- Reheated steam temperature 381.6 ºC
- Reheated steam pressure 17.8 bar(a)

4.4.- Thermal storage system parameters

- Cold molten salts minimum temperature 295 ºC
- Hot molten salts temperature 386 ºC
- Thermal storage capacity 1,923 MWth

4.5.- Steam turbine parameters

- Output power 170 MWe
- Electrical output power 200 MWA
- Generator voltage 15 kV
- Electromechanic efficiency 95 %
- Main steam inlet pressure 100 bar(a)
- Main steam inlet temperature 381ºC
- Reheated steam pressure 17.1 bar(a)
- Reheated steam temperature 381 ºC
- Steam outlet pressure 0.1 bar(a)

5.- MAIN PROCESSES AND SYSTEMS OF THE PLANT

The plants consist of these processes and system:

- Solar driving system and HTF heating system.
- HTF system.
- Auxiliary HTF heating system.
- Thermal storage in molten salts tanks.
- Steam generation.
- Electrical generation.
- Exhaust steam condensation in a surface condenser.
- Condensate water preheating.
- Feed water system.
- Feed water preheating.

5.1.- Solar driving system and HTF heating system

A cylinder-parabolic collector bases its operation in the solar tracking and capturing of incident rays through a parabolic reflector that concentrates the rays reflected in high-efficiency tubes located along the focal line of such parabola.

These collectors are oriented in a North-South axis and base its operation in orientating the aperture surface perpendicular to the solar rays.

The set made up of collector and tracking system, makes the collector be accurately positioned and move according to the sun movement during sun time. In this way, the heat-transfer fluid (HTF) circulating through the absorber tube is heated up to transform the solar energy into thermal energy. The HTF temperature increases the temperature up to a maximum of 393 - 395ºC. The HTF collectors drive the thermal fluid to a buffer tank. This tank is used as a heat accumulator, absorbing the reduction or the lack of solar radiation during shorts periods of time.

5.2.- HTF system

The HTF System will be a closed loop system that circulates the heat transfer fluid (HTF), by means of the HTF pumps, through the solar field, HTF supply and return piping, the Steam Generating system, Thermal Energy Storage system, expansion vessels and Ullage system.

5.2.1.- EXPANSION VESSELS

The HTF expansion vessels provide storage, expansion and surge capacity for the HTF system. Expansion vessels will be located at the cold side of the HTF loop, at the suction side of the HTF pumps.

The expansion vessels are the primary point in the HTF system for venting moisture and low boiling degradation products from the system during normal operation. Piping from the expansion vessel vent nozzles will convey the vented products to the Ullage system.

In order to reduce oxidation of the HTF and consequent solids formation and fouling, nitrogen blanketing of the expansion vessels shall be provided. The purpose of the nitrogen gas is to maintain a non-reactive and pressurized atmosphere in the vapour space of the expansion vessel, preventing the entrance of air and moisture, which could adversely affect fluid life. In order to obtain such HTF protection, the uninterrupted supply of nitrogen, controlled for both inlet and outlet flow shall be provided.

HTF system pressure relief valves will be provided to protect the expansion vessels from overpressure. Pressure inside the expansion vessel will vary with HTF temperature, but will be controlled as low as possible to minimize the nitrogen usage. Pressure relief valves will vent to the Ullage system.

5.2.2.- HTF PUMPS

The variable speed main HTF pumps will circulate the HTF from the expansion system through the solar field to the steam generating system and/or thermal energy storage system and then back to the expansion vessels. Pumps will be equipped with temperature instrumentation, API bearing lubrication and pump sealing systems with auxiliary cooling water, as required by pump vendor.

For night use or in emergencies, it includes additional HTF pump of sufficient capacity to maintain the flow and temperature in security conditions.

5.2.3.- ULLAGE SYSTEM

A mixture of nitrogen, HTF gases and volatile compounds from decomposition of the HTF is vented from the expansion vessel to the Ullage system, when temperature increases HTF. In the Ullage system through a series of heaters, separation vessels and air and water coolers, the degradation products of HTF are separated and recovered the HTF condensates for return them to the system.

The light compounds are collected in a vessel for shipment to waste Management Company. They will respect legal emission limits.

Additionally, a connection to the drain from the expansion vessel can be used to send a side stream of HTF to the Ullage system that will remove heavy compounds from the HTF and reclaim and return the clean HTF back to the expansion vessel.

The heavy compounds are collected in a vessel for shipment to waste Management Company.

5.3.- Auxiliary HTF heating system

The plant has 2 heaters (1+1 stand by) to heat the thermal oil. The fossil fuel is used as a source of auxiliary energy in order to heat the HTF is heated to prevent HTF freezing.

Each burner adjusts the pressure and the flow rate in order to get a complete and homogeneous combustion.

Are vertical boilers where the flame is centered (ascending) about the coil that receives heat radiation transmitting heat to the HTF which circulates inside the coil.

In a second step of flue gas, heat is transmitted by convection in an economizer with penpendicular tubes to the flue gas flow. In this economizer the HTF is preheating and works in series with the coil of the furnace.

With the remainder of the heat from the flue gas is preheated combustion air and, finally, the flue gas is sent to the stack.

5.4.- Thermal storage in molten salts tanks

The solar field is overdesigned in relation to power output in order to pile up the excess energy and use it in hours without radiation (1,923 MWth). To achieve that, some of the HTF which is heated in the solar field is forwarded to the HTF-molten salt heat exchangers. These shell and tube heat exchangers have two operating modes, charge and discharge modes. That is why the HTF and molten salt flow are reversible.

In charge mode, the hot fluid is the HTF, it send thermal energy from the solar field to molten salts. The hot molten salts are stored in the hot molten salt tank.

In discharge mode, the hot fluid are the molten salts, they discharge thermal energy from hot molten salt tank to the HTF. This hot HTF is directed to the steam generation system.

The HTF flows through the tubes and the molten salts through the shell.

There are four tanks, two to cold molten salts and other two to hot molten salts.

To maintain the temperature of the molten salts, the walls of the molten salt tanks, the top and the bottom are equipped with thermal insulation.

To avoid the solidification of the molten salts (238ºC) when the system shutdown, electric heaters should be installed. These heaters will guarantee the minimum operating temperature (265ºC).

5.5.- Steam generation system

The hot HTF from the solar field, the thermal storage system or the auxiliary HTF heaters is directed to the steam generation system. It consists in two steam generation trains, each one with a superheater, a steam generator with droplet separator, a preheater and, in parallel, a reheater in order to increase the temperature of the exhaust steam of the high pressure steam turbine.

5.5.1.- SUPERHEATER

The superheater is a shell and tube heat exchanger that superheats the steam from the steam generator.

The HTF, in the shell side, is the hot fluid, while in the tube side the steam is superheated. The superheated steam goes from the superheater to the high pressure steam turbine. The HTF is forwarded to the steam generator.

5.5.2.- STEAM GENERATOR

The steam generator is a shell and tube heat exchanger where the hot HTF flows inside the tubes. The water is preheated near saturation state and vaporized. The saturated steam generated and is forwarded to a droplet separator before entering in the superheater. The pressure and temperature drop in the droplet separator are not appreciable. The HTF is directed to the preheater.

5.5.3.- PREHEATER

The water preheater is shell and tube heat exchangers that raise the temperature of the water-steam cycle's water near to the boiling point.

In the shell side flow the hot HTF and heat transfer to the water which flows in the tube side.

The water is forwarded from the feed water preheater to the steam generator. The HTF goes to the expansion system.

5.5.4.- REHEATER

The function of the reheater is to increase the exhaust steam temperature from the high pressure steam turbine in order to be expanded again in the low pressure turbine. In this way the efficiency of the plant increases.

The reheater is shell and tube heat exchangers which the hot HTF, in the shell side, and the steam is into the tube side. After HTF are directed to the expansion system.

The inlet steam in the low pressure steam turbine has the same temperature of the one which enter in the high pressure steam turbine but the pressure is about 4 times less.

5.6.- Electrical generation

The steam from de steam generation train is expanded up to the condensing pressure in the steam turbine. The steam turbine converts the thermal energy of the steam flow into mechanical energy, producing electricity in this way.

The steam turbine consists of two bodies, high pressure steam turbine and low pressure steam turbine. After the steam is expanded in the high pressure steam turbine, the steam is reheated in the reheater and expanded again in the low pressure turbine with the same inlet temperature but less pressure than in the low pressure steam turbine.

The gearbox transmits the high pressure steam turbine's speed of the axis to the axis of the low pressure steam turbine which is coupled to the power generator. The velocity of the high pressure steam turbine depends on the type of the selected turbine and speed of the generator. The low pressure steam turbine is fixed by the frequency of the grid.

The generator, which involves three-phase synchronous alternator with two pairs of poles, transforms the mechanic energy into electrical energy.

The steam turbines are equipped with different bleeds.

The high pressure steam turbine consists of one bleed:

- The high pressure bleed E1 is forwarded to the high pressure feed water preheater 2, getting the final the temperature of the feed water before the steam generation system.

Most of the outlet of the high pressure steam is directed to the reheater and a small percentage of it (E2) shall feed the high pressure preheater 1.

The low pressure steam turbine consists of four bleeds:

- Bleed E3 shall feed the deaerator.
- Bleed E4 shall feed the low pressure preheater 3.
- Bleed E5 shall feed the low pressure preheater 2.
- Bleed E6 shall feed the low pressure preheater 1.

The exhaust steam is directed to the air cooler condenser.

5.7.- Air cooler condenser

The exhaust steam flows to the air cooler condenser.

Condensate is collected in tank under air cooler condenser and then is pumped to the feed water system by the condensate pumps.

Condensate system is connected to a vacuum system by the liquid ring pumps in order to remove incondensable gases that can enter in the water steam cycle and thereby increase the efficiency of the cycle.

Make up water of the water – steam cycle may be introduced in the circuit in the condenser or in the deaerator.

5.8.- Condensate water preheating

The low pressure preheaters are shell and tube heat exchangers. These preheaters take water from the gland steam condenser and is preheated for dispatched to the feed water system.

The preheater 1 has two heat inputs in the shell side, on one hand the sixth bleed of the low pressure steam turbine and on the other hand the steam from the preheater 2. The feed water is preheated in the tube side and is directed to the preheater 2.

The preheater 2 also has two heat inputs in the shell side, on one hand the fifth bleed of the low pressure steam turbine and on the other hand the condensate from the preheater 3. The feed water is preheated in the tube side and is directed to the preheater 3.

The preheater 3 has a unique heat input in the shell side which is the steam from the fourth bleed of the low pressure steam turbine.

The preheated water is directed to the deaerator sited over the feed water tank.

5.9.- Feed water system

The preheated condensate is introduced into the deaerator. Make up water of the water – steam cycle may be introduced in the deaerator. This system consists of two parts: a deaerator head and a feed water tank.

In the deaerator head, the liquid (condensate and make up water) and steam phase are in turbulent contact, increasing the temperature of the liquid. Because of that, the solubility of the gases in the liquids decrease and a high stirring produce the remove the non condensable gases dissolved, in particular the oxygen and carbon dioxide. These gases are continually vented to the atmosphere together with a small part of steam.

The deaerated water is collected in the feed water tank located below. The feed water pumps deliver water to the steam generation train after flowing through the high pressure preheaters.

To the proper functioning of the pumps with the water near boiling temperatures, this equipment is installed in the necessary level in order to ensure the properly NPSH.

5.10.- Feed water preheating

The high pressure preheaters are shell and tube heat exchangers and heating the water from the feed water tank. The steam from the bleeds of the high pressure steam turbine flows by the shell side and the water by the tubes.

After that, feed water preheated is directed to the steam generation system.

6.- AUXILIARIES

The auxiliary systems of the thermo solar power plant are the following:

- Auxiliary Fuel System.
- Water Treatment to produce the necessary demineralized water for the steam cycle.
- Compressed Air generation and distribution for instrument and services.
- Nitrogen System.
- HTF Venting and Reclaim System.
- Cooling water system.
- Chemical Injection System.
- Sample System.
- Electrical transmission and distribution System.
- DCS System to register, evaluate and measure the relevant data in order to control and operate the power plant.
- Fire System.
- Waste Water Treatment System to fulfil the discharge limits. The generated effluents are divided depending on its nature into industrial water, rain water and faecal water.

6.1.- Auxiliary Fuel System

The functions of the Auxiliary Fuel System are the following:

- To storage auxiliary fuel and his distribution to the consumers.
- To channel the auxiliary fuel from the storage to the consumption points.
- To regulate the flow and the pressure of the fuel.
- The battery limits of this system are the following:
  - The connection valve of truck unloading.
  - Connection with each burner.

6.2.- Water treatment

At this facility the water supply is available of the public potable water network. For human consumption, it is not considered drinking water storage because it is considered a safe supply and will be connected directly to the buildings where it is necessary.

For industrial uses, the water is storage in a tank with a capacity for approximately 24 hours of autonomy.

To ensure that no biological growth occurs in the pond, sodium hypochlorite is dosed at the entrance. This will limit biofouling.

First step of the treatment shall be filtration in silex/carbon beds to remove traces of the chlorine.

After, shall be reverse osmosis modules and final refining in electrodeionization modules necessary in order to produce demineralized water in quality acceptable for the water-steam cycle.

The systems that establish the operational unit are the following:

- Bed filtration system

- Reverse osmosis system
- EDI system

6.3.- Compressed Air generation

In the power plant two different uses of compressed air exist, services air and instrumentation air.

Instrumentation air shall be necessary in order to all the electro-pneumatic actuators for plant automation (ISO 8573.1; -20 ºC of pressure dew point – at least).

Service air shall be used to maintenance operations (+3 ºC of pressure dew point).

The system consist of two (2) air compressors, 100% capacity, with integrated refrigerant dryer, an adsorption dryer and two receiver tanks.

Near major consumption points is possible to include other tanks to damp consumption peaks.

6.4.- Nitrogen system

In order to reduce oxidation of the HTF and consequent solids formation and fouling, nitrogen blanketing of the expansion vessels shall be provided. The purpose of the nitrogen gas is to maintain a non-reactive and pressurized atmosphere in the vapour space of the expansion vessel, preventing the entrance of air and moisture.

Also is necessary nitrogen supply to the thermal storage system, to prevent deterioration of the molten salts and as coolant pumps salts.

To this end, nitrogen cryogenic tanks, evaporators, gas filters, valves and piping connections shall be installed for its proper functioning (<u>note: Depending on the availability of liquid nitrogen supply may be interesting to install a nitrogen generation facility on site</u>).

In general, the system consists of the following elements:

6.4.1.- CRYOGENIC TANKS

They consist of inner container, which is made of stainless steel, and composed of a cylinder with two elliptical stamped bottoms. The material is austenitic steel al CR-NI that it is the appropriate one for operating at low temperatures. These temperatures may be until -196ºC.

The outer tank shell will be made of mild steel plate.

The chamber of each tank will be filled with perlite, which is flushed with hot nitrogen to remove the residual moisture. Then vacuum will be made lower than 30 thousandths of a millimetre of mercury column. That vacuum value is the one which the tank will operate. Each vessel shall be subjected to exhaustive helium leak tests.

Once the components are assembled, it shall be subjected to leak tests in pipes, sleeves, valves, etc.

The control panel, the suction and discharge lines, and the connections for the instrumentation will be installed on the outer shell.

6.4.2.- GASIFIER

Usually, each tank has one evaporator station with two evaporators in parallel.

These evaporators shall transform the liquid nitrogen of the cryogenic tank into gaseous nitrogen near to ambient temperature.

6.4.3.- HEATERS

In this facility kind is necessary to heat gaseous nitrogen at least to 5ºC to introduce them to the molten salts tanks.

6.4.4.- SAFETY DEVICES

According to the regulation, redundant safety valves are installed.

It will have a security vacuum system that ensures evacuation to the atmosphere if any eventual overpressure appears in the space between the outer shell and the inner container.

6.5.- HTF Venting and Reclaim System

The HTF system is a closed system which is subjected to at least one thermal cycle daily, expanding in the expansion vessels which have an inert atmosphere in order to avoid the oxidation of the thermal fluid.

During these cycles the vapours are pushed to the HTF Venting and Reclaim System (Ullage system), where the mix of nitrogen, HTF vapours, and the light product degradation are subjected to a double condensation to minimum temperature available.

After condensation stage, the effluent is passed through a activated carbon filter to adsorb traces of hydrocarbons which may be in nitrogen stream, before the final discharge to the atmosphere, in order to fulfil the allowable atmospheric discharge limits.

The ullage system has the following phases:

- First, vapours are condensed by an air cooled condenser and then the condensate is collected in the ullage vessel. This fraction of condensate is the HTF vapours that can be directed to the expansion vessels.
- The non condensing phase is forwarded to a water cooled condenser where vapours lighter than the HTF are condensed. These condensates are collected in the HTF light waste storage tank to be sent to a final authorized manager.
- Finally the nitrogen and non condensing boilers are directed to a carbon activated beds filters where traces of hydrocarbons are trapped.
- Additionally a tank with a heating coil is installed which are treated the bottom drains of the expansion vessels (where the heavy HTF wastes are accumulated). In this tank the HTF is evaporated and the liquid phase is directed to the heavy waste storage tank to be sent to a final

authorized manager. The HTF vapours are recovered in the air cooled condenser and collected in the ullage vessel in order to return to the system.

This system consists of the following elements:

6.5.1.- PRIMARY ULLAGE CONDENSER

This unit is based in a tubular beam with welded chambers in carbon steel, round shaped pipe with diameter of 1" in carbon steel and aluminium fins. The fan has fibreglass reinforced polyester blades.

The outlet temperature of the air cooled condenser is around 150ºC.

6.5.2.- ULLAGE VESSEL

This collects the vents of the HTF pumps seals system and the condensate from the primary ullage condenser.

The vent from the ullage vessel is directed to the secondary ullage condenser, while the condensing HTF of the bottom is returned to the expansion vessels.

6.5.3.- SECONDARY ULLAGE CONDENSER

This is a shell-tube heat exchanger. The vapours are directed to the shell side and the cooling water to the tube side.

The outlet temperature in the shell side is around 35 ºC

6.5.4.- ULLAGE DRAIN VESSEL

It is a tank which collects the condensate from the secondary ullage condenser. The stream of nitrogen is vented to the atmosphere through the adsorption filters, while the resulting liquid is directed again to the expansion vessels (if its quality is correct) or to the HTF light waste storage tank.

6.5.5.- ACTIVATED CARBON ADSORPTION FILTERS

These filters are based in a carbon activated as adsorbent material that collects the inlet light hydrocarbons. It consists of two adsorption filters with a set of valves which allow operated in series or in parallel.

6.5.6.- HTF RECLAMATION FLASH TANK

It is a tank with a heating coil using hot HTF from the solar field, wherein the drains of the expansion vessel are introduced. With the heat, HTF evaporates, leaving the heavy components in liquid phase.

This liquid is directed to the HTF heavy waste storage tank.

6.5.7.- HTF LIGHT WASTE STORAGE TANK

This is a storage tank of light compounds of the HTF degradation. Beside this tank is the HTF load pump in order to load out to truck and sent to a final authorized manager

6.5.8.- HTF HEAVY WATES STORAGE TANK

This is a storage tank of heavy compounds of the HTF degradation. The HTF load pump is the same as the light compounds load pump and also is sent to a final authorized manager.

6.6.- Auxiliary Cooling System

Besides condensing the outlet steam of the steam turbine with an air cooler condenser, it is necessary to cool other auxiliary systems or equipments of the power plant.

The auxiliary cooling system chosen in this project is an air cooler.

The systems or equipments that needing cooling are the following:

- Lube and control oil system.
- Generator.
- Sample system.
- Feed water pumps.
- HTF pumps.
- Secondary ullage condenser.
- Vacuum system.

The auxiliary cooling system consists of the following equipments or systems:

- Air cooler.
- Closed cooling pump.
- Expansion tank.
- Chemical injection to close cooling system.

6.7.- Auxiliary steam boiler

It is necessary to have a reliable source of steam supply to the seals system of the turbine. Since this type of facility is discontinuously operated, is necessary to have an extra steam generator.

The main features of this equipment are the following:

- Steam flow: 6.000 kg/h
- Working pressure: 6 - 10 bar(a)
- Working temperature: About 180 – 200 ºC (minimum +20ºC superheated)

6.8.- Chemical Injection System

To maintain the water quality inside the pipelines and conserve the integrity of the different systems, chemicals have to be injected in order to remove the oxygen dissolved, adjust the pH above the corrosion values and avoid incrustations and salt deposits.

Chemicals shall be injected in the following systems:

- Water-steam cycle:
  - Deaerator (Oxygen scavenging – pH adjustment)
  - Condenser (pH adjustment).
  - Steam generator (pH adjustment).
- Closed cooling water system:
  - Corrosion inhibitor – antiscaling and glycol.

6.9.- Sample system

The power plant is provided of a continuous analytical control system of the water-steam cycle quality, according to the standards. The sampling points shall be the following:

- Feed water
  - Specific conductivity
  - pH
  - O_2
- Blow down of the steam generator
  - Specific conductivity
  - pH
- Saturated steam in the steam generator
  - Acid conductivity
- Superheated steam
  - Acid conductivity
  - Sodium
  - Silica
- Reheated steam
  - Acid conductivity
- Condensate
  - Specific conductivity
  - pH
- Make up
  - Specific conductivity
  - Sodium
  - Silica

The sample system is integrated in a skid which samples are taken. The temperatures and pressures are adjusted before being directed to each analyzer.

6.10.- Electrical system

The electrical system shall provide all the necessary elements to carry out the following functions:

- Transport the generated electrical energy in the steam turbine-generator to the grid.
- Provide electrical power to the main and auxiliary services of the power plant at different voltage levels.

It shall consist of at least the following systems:

- 132kV high voltage grid connection system: Consist of a transformer, which will raise output voltage from the generation voltage (15 kV) to grid voltage (132kV).
- High voltage generation system: The 15 kV High Voltage System will allow distributing the generated electrical energy to the grid and will have the possibility of supplying to the auxiliary systems.
- Medium voltage system: The aim of the 5 kV system is to supply power to the main pumps with higher power consumption of the plant.
- Low voltage system: The aim of the low voltage system is to distribute the electrical energy from the auxiliary services transformers to final consumers of the plant. It will be supplied distribution panels at 400Vac voltage level.
- Uninterruptible Power Supply (UPS): The aim of this system is to provide AC power to the critical services that require high reliability and stability for safe operation of the plant.
- Diesel Emergency Genset: The emergency system will consist of two diesel gensets (one for the Salts and HTF system and one for the BOP) will serve as a back-up power for critical loads in the 3-phase 400V Distribution System.

6.11.- Control system

The Distributed Control System (DCS) shall consist of the set of hardware, software, wiring and communication networks that constitute the man-machine interface for control of the plant under all operating conditions and safety, including the control of packing units (or subsystems) that must be fully integrated into the system.

The functions of the control system shall be the following ones:

- Supervising and monitoring of all the processes
- Performing its automatic control logics
- Performing its protection of equipments logics
- Interface to the plant operating
- Manage historics
- Manage alarms
- Manage reports

This system consists of an electronic control system where collect all the signals and the operating conditions of the plant in order to a proper operation.

6.12.- Fire system

The fire system shall guarantee enough water reserve (generally with 120 minutes range) and supply, at least operating at required flow and pressure. The system shall be in accordance with the local fire Code rules and NFPA rules. The fire water will be stored in a tank.

The pump unit consists of an electrical pump, a diesel pump and a jockey pump to maintain the pressure in the pipelines.

The active fire system consists of the following subsystems:

- Electrical system of fire system having own power supply.
- Fire detection and alarm with alarm buttons and loss energy supply pushbuttons.
- External network hydrants and hose reels for the inside of buildings.
- Foam monitors extinguishing system in HTF
- Spray water system for oil filled transformers, expansion vessels and buffer tank.
- Foam-Water system to protect the HTF pumps and the steam turbine oil system
- The possibility of installing a preaction system for electrical rooms, control and rooms with flammable products shall be examined.
- Portable fire extinguishers
- Vehicle equipped with tools and generator for lighting

The fire system is completed with the detection and alarm system, sending the electrical signals to the fire control panel.

6.13.- Waste Water Treatment System

6.13.1.- INDUSTRIAL WASTE WATER

The plant will generate the following industrial effluents:

- Water-steam cycle drains.
- Water treatment drains.
- Effluents polluted by oil.

These different flows are collected in homogenization pond before discharge.

6.13.1.1.- Water-steam cycle drains

This drain is due to the salt concentration because of evaporation produced in the system, which content must be controlled in order to avoid incrustation inside the pipelines.

Nevertheless, the removed water has lower salt contents than the raw water. In essence, it is osmosis water with decaling products. This stream contributes to dilute the salt concentrations of the total discharge of the plant.

6.13.1.2.- Water treatment effluents

The water treatment system will generate the following effluents

- Discharges by cleaning bed filters.
- Discharges of rejects of reverse osmosis.
- Discharges by cleaning of the EDI system.

Reverse osmosis rejections reaches 25% (approx.) with respect to the inlet flow of water. This discharge has the same type of raw water salts, but four times more concentrated.

6.13.1.3.- Effluents polluted by oil

The effluents polluted by hydrocarbons could come from areas of the transformers, steam turbine oil system and HTF system. These effluents shall be treated by a oil separator with coalescent plates. The sediments and the hydrocarbons collected during maintenance and cleaning are stored in containers and handled by an authorized waste manager.

The treated effluent shall be collected in a sump (1 m^3 approx.) where the presence or absence of HTF dissolved in water will be checked. In case the HTF will not be detected or its concentration will be less than 1 ppm, the effluent will be pumped to the homogenization pond. Otherwise, the effluent shall be handled by an authorized waste manager.

6.13.2.- RAIN WATER

The plant will be provided channels and underground ducting system to direct rain water to the discharge point.

6.13.3.- FAECAL WATER

A treatment system by a biological filter shall be installed in order to treat this kind of water. This system consists of glass-fiber reinforced polyester (GRP) compact construction. The maximum flow of sewage discharges is estimated to be 6.3 l/s and the average daily 0.27 m^3/h of flow.

The capacity of this system will be of 70 inhabitants and is divided in the following parts: a decanter, a clarifier and a biological filter. The system reduces the DBO_5 efficiency to 75% and the sedimentable solids to 80%. After the treatment the clarified water will be filtered to the ground.

7.- RAW MATERIALS AND CONSUMABLES

THE DATA PRESENTED BELOW SHOULD BE CONTRASTED DURING THE PROJECT AND SHOULD BE CONSIDERED AS PRELIMINARY STIMATIONS AND THEY ARE ONLY FOR INFORMATION.

7.1.- HTF

The HTF is supplied by lagging trucks, which unload in the expansion vessels. To this end, the truck is fed with nitrogen under pressure in order to get out the transporting HTF and direct to the expansion vessels by a flexible hose. Once the expansion vessels are filled, begin the filling of the other parts of the HTF system.

To avoid freezing, the HTF must be flowing continuously. For security, the minimum temperature of the HTF must not drop under 65ºC.

The total mass of the HTF in the system is approximately 7,845 Tn (a 25 ºC).

The physical and chemical properties of HTF are:

Product	Heat Transfer Fluid	
Composition	Eutectic Mixture of Diphenyl Oxide/Biphenyl	
Chemical Formula	$C_{12}H_{10}O/C_{12}H_{10}$	
Product Comercial Names	Dowtherm A, Therminol VP1 or Diphyl	
Application	Indirect Heat Transfer	
TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES		
PROPERTY	**UNITS**	
Color	-	Clear to light yellow
Max. Allowing Working Temperature	ºC	400
Freeze point	ºC	15 °C
Atmospheric Boiling Point	ºC	257.1
Flash Point	ºC	113 (SETA)
Fire Point	ºC	118 (C.O.C.)
Autoignition Temperature	ºC	599 °C (ASTM E569-78)
Density @ 25°C	kg/m3	1056
Average Molecular Weight	g/mol	166

7.2.- Molten salts

In order to stored thermal energy, molten salts are used. These salts consist of a mix of sodium nitrate (60%) and potassium nitrate (40%).

A tank preheating and a salts treatment and melting provisional systems shall be provided in order to charge the salts into the system. Through this system, the temperature of the tank increase.

Sodium and potassium salts shall be supplied in solid phase and separately.

The total mass of the molten salts in the system shall be approximately 56,455 Tn.

The physical and chemical properties of Salts are:

Product	Molten Salts		
Composition	Sodium Nitrate and Potassium Nitrate mixed 60%/40% by weight ratio		
Chemical Formula	$NaNO_3/KNO_3$		
Product Comercial Names	Thermo-Solar Salts or Hitec Solar Salts		
Application	Thermal energy storage		
TYPICAL PHYSICAL, CHEMICAL AND THERMAL PROPERTIES			
PROPERTY	**UNITS**	**KNO3 Potassium nitrate**	**NaNO3 Sodium nitrate**
Appearance	-	Solid, crystalline	Solid, crystalline
Color	-	White	White
Appearance	-	Odourless	Odourless
pH value	-	6-9 (5% aqueous solution)	6-9 (5% aqueous solution)
Melting point / melting range	ºC	333 °C at 1013 hPa	308 °C at 1013 hPa
Flammable solids	-	Not flammable	Not flammable
Density (at ambient temperature)	kg/m3	2190	2260
Solubility	g/L	> 100 g/L at 25 °C (water)	> 100 g/L at 25 °C (water)
Decomposition temperature	ºC	> 600	> 600
Oxidising properties	-	Oxidising	Oxidising
Purity	(%)	99.6	99.5
Heat Capacity (Cp) near the melting point	J/kgºC	1160	1820
Heat of Fusion (based on average heat of fusion of each component)	kJ/kg	161	
Moisture (H_2O %)	%	max 0.1	max 0.1
Chlorine, Cl	%	max 0.1	max 0.1
Magnesium, Mg	%	0.01	0.02
Nitrite, NO_2	%	0.02	0.02
Sulfate, SO_4	%	0.05	0.10

7.3.- Water

The water supply is available of the public potable water network.

- Potable water for human consumption.
- For industrial uses.

The water consumptions are the following ones:

- Drinking water (150 l/day/hab equiv. and 70 hab equiv.): 3,840 m^3/year
- Raw water for demi water production: 140,000 m^3/year (30 m^3/h)
- Services water: 200 m^3/year (0.02 m^3/h)

Demi water properties shall be according to VGB-R 450Le.

7.4.- Fossil fuel

To maintain the temperature of the HTF higher than the freezing temperature during non productive time is necessary to install heaters with fossil fuel. The fossil fuel could be LNG or oil.

Additionally,the melting salts temporary system will consume fossil fuel for:

- Heating of tanks during 7 – 10 days (each tank; 24 hours a day).
- Melting salts during 13 weeks (24 hours a day).

7.5.- Nitrogen

The purpose of the nitrogen gas is to maintain a non-reactive and pressurized atmosphere in the vapour space of the expansion vessel, preventing the entrance of air and moisture.

Also is necessary nitrogen supply to the thermal storage system, to prevent deterioration of the molten salts and as coolant pumps salts.

The estimated consumptions are:

- HTF system: 4,890 Ton/year.
- Ullage system: 390 Ton/year.
- Molten salts tanks: 681 Ton/year.
- Molten salts pumps: 495 Ton/year.

7.6.- Activeted carbon

As filler material in the adsorption filters is used active charcoal to retain traces of light hydrocarbons that may remain in the final stream.

- Quantity per filter: 9000 kg active charcoal.
- Estimated change: Each 20 or 30 days.

7.7.- Lubricants

The most demanding lubricant is the one of generator. It consists of a tank of 15,000 liters of capacity. To check its properties samples are taken every three months (depending on the manual of the supplier).

Other equipments shall be needed lubricating oil with local dispensers or lubricating grease.

The annual consumption of the lubricants are estimated in 2,300 liters of oil and 400 kg of grease (if the steam turbine oil is not polluted)

7.8.- Chemicals

7.8.1.- WATER TREATMENT

For water demineralization treatment is necessary to use the following chemicals:

- Sodium hypochlorite: 130 m^3/year of commercial product (15%).
- Sodium metabisulphite: 30 m^3/year of commercial product.
- Disperser: 5.5 m^3/year of commercial product.
- EDI cleaning additives: HOLD
- RO membrane cleaning Additives: HOLD

7.8.2.- WATER-STEAM CYCLE

To ensure the quality of the water and the steam, the plant will be provided of a low pressure chemical injection system and high pressure chemical injection system. In the feed water system, oxygen scavengers (carbohydrazide) and products for controlling the pH (volatile amines) shall be injected in order to adapt the characteristics of the feed water.

Also alkalinizing agent shall be injected (phosphates) in the steam generator in order to control the water pH and maintain the value of the phosphates in safety parameters to pipelines protection.

The estimated annual consumptions are:

- Carbohydrazide: 2,850 litres of pure product/year.
- Volatile amines: 23,700 litres of pure product/year.
- Phosphates: 9,000 litres of pure product/year.

7.8.3.- CLOSED COOLING WATER SYSTEM

A corrosion and antifouling inhibitor (NALCO 73360) in the initial filling is added in order to maintain the conditions in the closed cooling water system. In the initial filling, needs to add the concentration of 3000 ppm of product in the system. The concrete quantity depends on the volume of the system. The annual consumption in normal conditions is estimated to be 70 liters.

To avoid freezing into the water closed circuit shall be necessary to additive antifreeze (e.g. glycol) in winter, when the temperature goes below zero.

Every month the presence of waste products is checked by an analysis. In case of leaks, reparations or pollution, additives will be added as necessary.

8.- WASTE MATERIAL, EMISSIONS AND DISCHARGES

THE DATA PRESENTED BELOW SHOULD BE CONTRASTED DURING THE PROJECT AND SHOULD BE CONSIDERED AS PRELIMINARY ESTIMATIONS AND THEY ARE ONLY FOR INFORMATION.

8.1.- Activated carbon contaminated

The activated carbon retains hydrocarbons and it saturates. At that point, is necessary to replace the fill and send the contaminated product to an authorized agent.

- Quantity per filter: 12,240 kg active charcoal contaminated (estimated).
- 219,000 kg/year of material contaminated.

8.1.1.- CONTAMINATED LAND

When a leak of HTF in the solar field occurs must be removed the contaminated soil to prevent contact with water and that pollution could spread.

This land can be sent to an authorized agent for treatment or may be located within the plant in a bioremediation area until soil bacteria eliminate such contamination.

It is not possible to estimate the annual quantity.

8.1.2.- LUBRICANT WASTE

Waste contaminated with oil or grease, should be collected in closed containers and from time to time (depending on local regulations) be removed by an authorized agent for treatment and/or elimination.

8.1.3.- EMISSIONS OF HTF HEATERS

HTF heaters emissions shall fulfill the local regulation and EIA requirements.

8.1.4.- WATER-STEAM CYCLES DRAIN

The estimated drain flow of the water-steam cycle is 51,000 m^3/year.

8.1.5.- WATER TREATMENT EFFLUENTS

During the demineralized water production the following dumps are generated:

- Discharges by cleaning silex filters (7,500 m^3/year)
- Discharges of rejects of reverse osmosis are estimated in 42,900 m^3/year

- Discharges by EDI and membranes cleaning are estimated in 300 m^3/year

8.1.6.- EFFLUENTS OF POLLUTED WATER BY HYDROCARBONS

Because this effluent comes from accidental spills, not foreseeable, it is not possible to estimate the annual discharge quantity.

8.1.7.- FAECAL WATER

It is considered that the potable water consumption average is 150 liters/person and day. It is estimated 70 habitants per day, so the annual water consumption shall be 3,840m^3.

9.- BATERY LIMITS CONDITIONS

9.1.- Electrical grid

There will be one electrical connections to the main grid of the country:

- Electrical grid connection to 132kV.

9.2.- Water supply

There will be a connection to the public drinking water supply. Pressure supply To Be Defined).

Analytical of water supply: TBD.

9.3.- Waste water

There will be a discharge point of waste water. The wastewater disposal shall fulfill the local regulation and EIA requirements.