2004

IEA SMALL SOLAR POWER SYSTEMS PROJECT

CENTRAL RECEIVER SYSTEM SOLAR POWER PLANT

ALMERIA/SPAIN

PLANT DESCRIPTION

PROJECT PERFORMED UNDER CONTRACT OF IEA-OPERATING AGENT
DEUTSCHE FORSCHUNGS- UND VERSUCHSANSTALT
FÜR LUFT- UND RAUMFAHRT

BY

INTERATOM INTERNATIONALE ATOMREAKTORBAU GMBH

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PREFACE

The main objects of the Small Solar Power Systems Project (SSPS) of the International Energy Agency, Paris (IEA) are detailed studies and demonstrations of the utilization of solar energy for power generation, in the interconnected grid as well as in isolated operation. Two different concepts of solar energy conversion have been considered in this project: the "solar farm" and the "solar tower". The object is to compare both concepts for the same design conditions, under the same ambient conditions for operation and evaluation by the same team.

The German aerospace research and test centre (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt in Cologne, DFVLR) served as the Operating Agent for the IEA in this project and has placed the orders for supply and installation of the power plants. The orders for the CRS Solar Power Plant were placed with INTERATOM as the main contractor as well as with Martin Marietta Corp., USA, (for the heliostat field) and SAIT electronics N.V., Belgium (for the data acquisition system). This paper contains the technical description of the CRS Solar Power Plant including technical data of subsystems and components.

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1 Plant Description

1.1 General Plant Overview

The Central Receiver System (CRS) solar power plant is one of the two Small Solar Power Systems (SSPS) promoted by the International Energy Agency (IEA) to demonstrate the technical feasibility of the generation of electrical power by the conversion of direct solar radiation (insolation) into thermal energy, and then, by conventional methods, into electrical power. It has been installed near Tabernas (Almeria-Spain) (see Figure 1.1).

An artist view of the plant can be seen in Figure 1.2.

The basic operation is as follows:

The direct sun radiation incident onto the heliostat field is reflected and concentrated into the receiver which absorbs and transfers the thermal energy to the sodium fluid. This energy is accumulated in a sensible heat storage and used to drive a conventional steam power generation system.

The overall system was designed to be able to deliver 500 kW_e to the grid, besides to supply its own internal electrical consumption, on March, 21, at noon, according to the specified insolation value of 920 W/m^2 (design point). The energy storage capability amounts to 1 MWh(e).

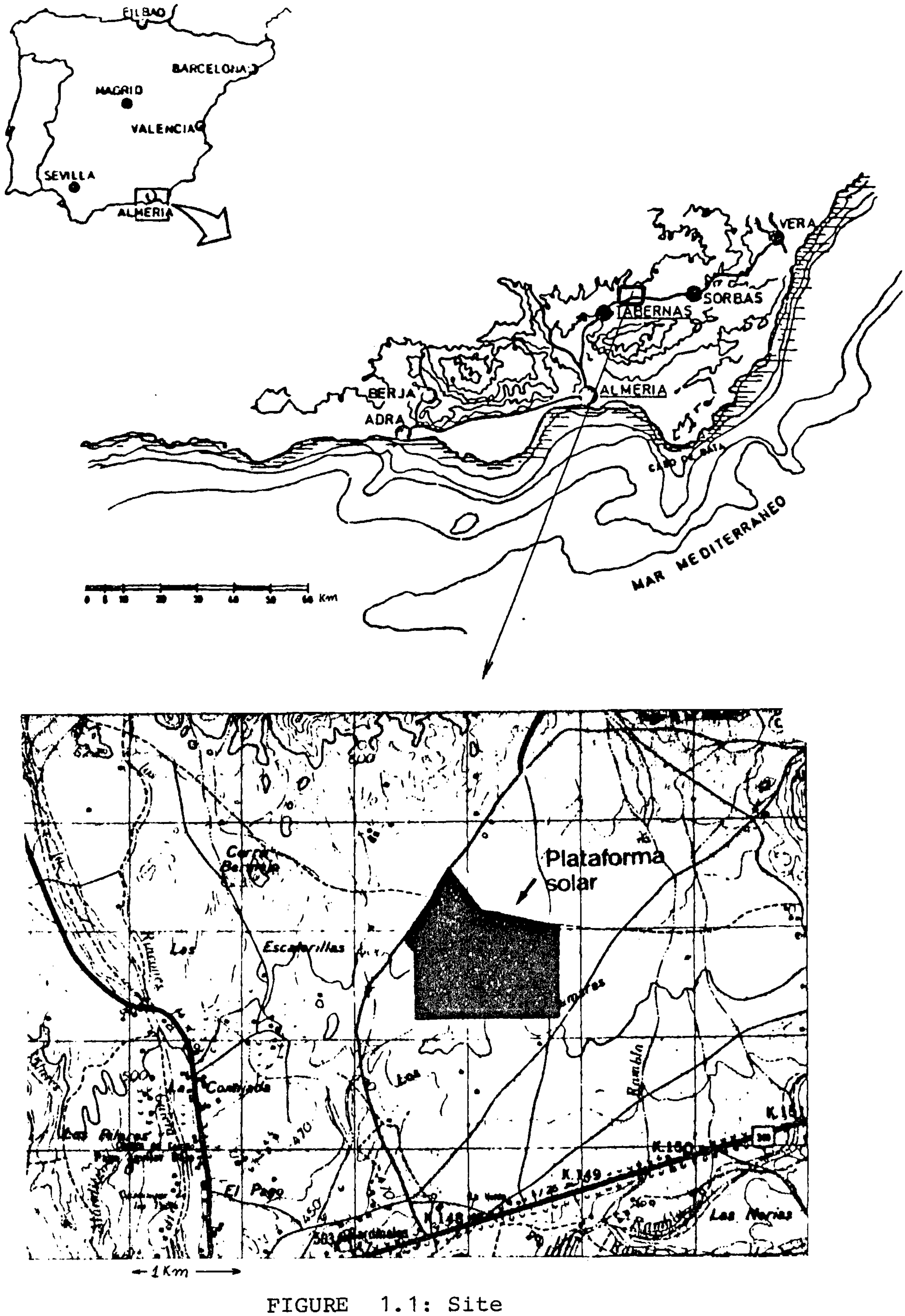

FIGURE 1.1: Site

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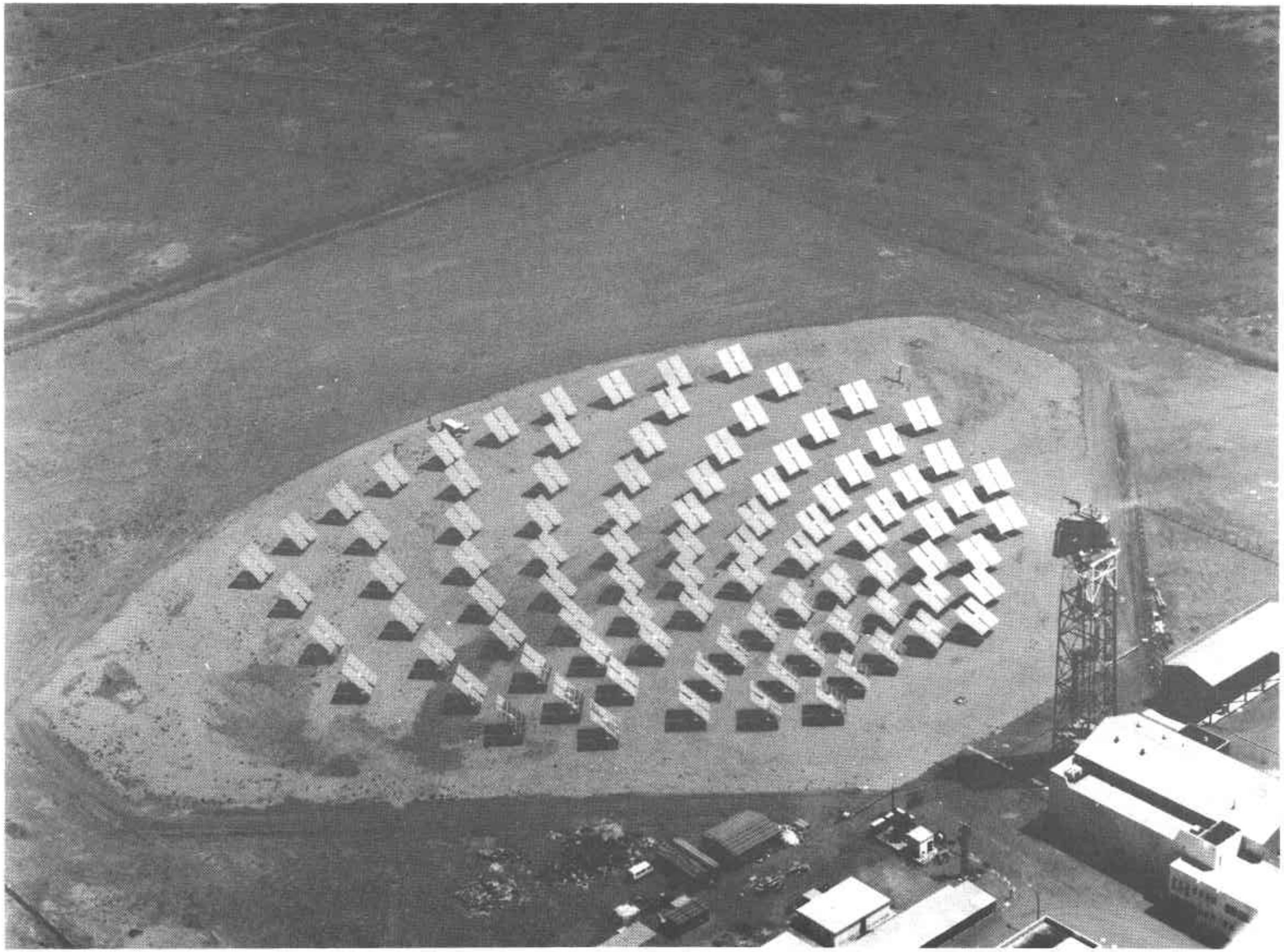

Fig. 1.2: General view of the CRS-Solar Power Plant

A functional schematic diagram of the plant is provided in Figure 1.3.

The main characteristics of the plant are -

- North-oriented heliostat field and a tower-mounted cavity receiver. One of the main differences in these types of solar plant is the whole energy collection system concept. For the relative small power output of this plant it is not effective to use a surrounding field. In order to increase the efficiency of the collecting process a cavity receiver with small aperture area is very suitable in combination with a heliostat field using focused facets.

- The use of sodium as primary coolant as well as energy storage medium. This is mainly due to the fact that liquid sodium has been found to be an excellent heat transfer medium. Due to its high boiling point, sodium can transfer thermal energy at high temperatures and at relatively low pressures. Therefore, the receiver surface can be built relatively samll, and the heat losses are relatively low. A remarkable efficiency when converting sunlight into heat can be obtained. Moreover, the sodium components are compact and have little weight.

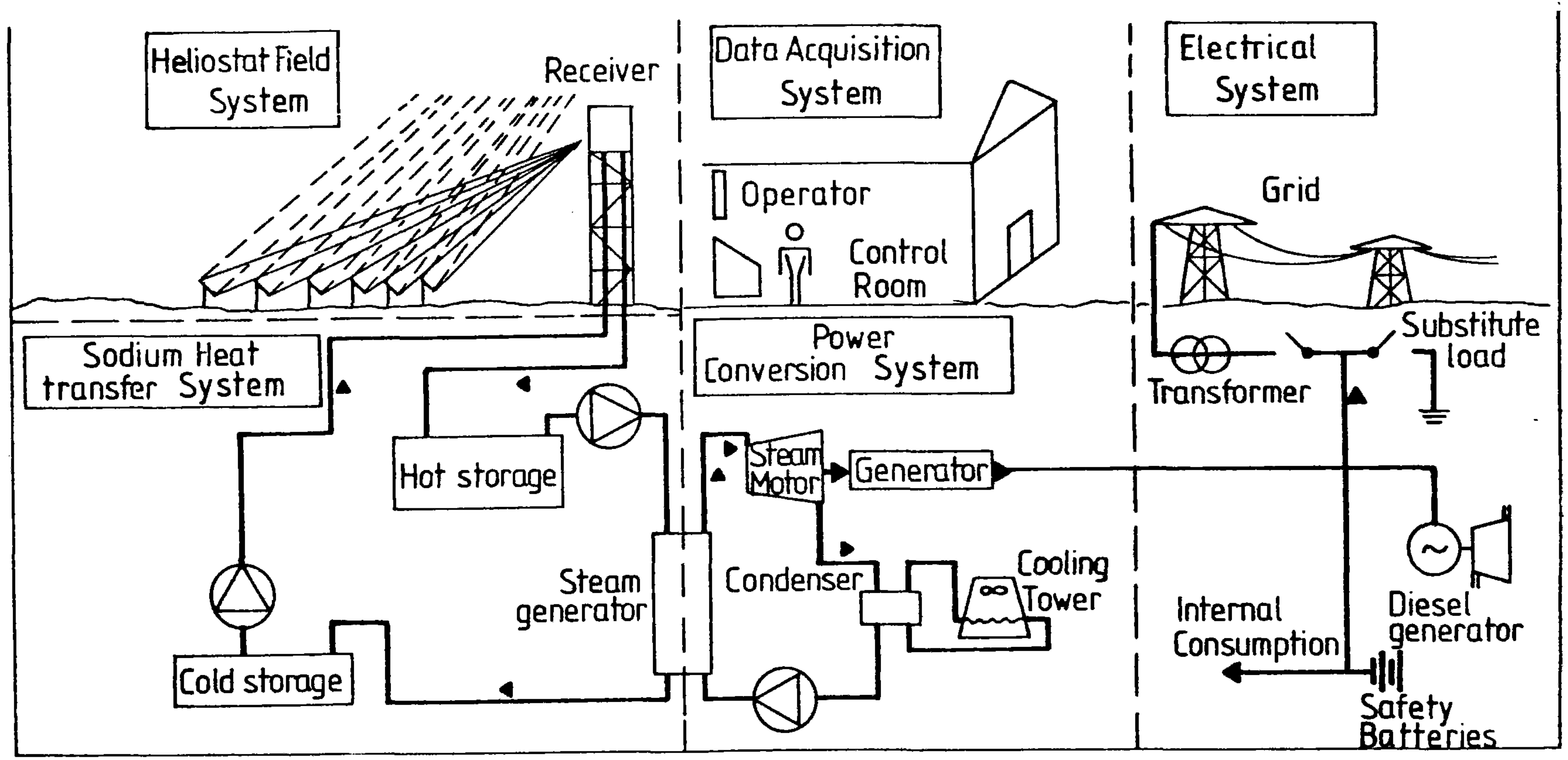

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FIGURE 1.3: Functional schematic

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Besides this, the sodium technology is today known and proven.

- The number of heliostats that results from the calculations regarding insolation conditions at the design point and the corresponding efficiencies of all the systems is 93.

The heliostat field layout was optimized taking into account the height of the tower and the required power into the receiver.
The aim was to minimize the number of heliostats and therefore to reduce the cost of the field. In determining this number, the mirror reflectivity plays an important role; in this case it amounts to 89.5%.

- The maximum sodium temperature was determined on 530°C because of technological and material problems associated with higher temperatures. Analyses have indicated that the overall system efficiency is only a weak function of the sodium temperature around 530°C because higher temperatures could theoretically increase the efficiency of the power ocnversion system and additionally reduce the storage volume, but the receiver efficiency would decrease due to higher thermal losses and also the piping thermal losses would increase slightly.

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- The lower minimun sodium temperature in normal operation (that influences the size of the storage vessels) was settled to 270° C because of the maximum temperature gradient through the receiver tubes and through the steam generator. This gradient is limited in the current technology in similar components to approx. 250 °C, as a result of the thermal transient induced stresses and the steam generator pinch-point limitation.

- The storage system is based on the two-vessels concept which provides a complete separation of the cold and hot sodium and therefore, optimum performance of the receiver and flexible operation of the sodium heat transfer subsystem.

- The power conversion system using a steam motor due to its relative high efficiency in this power range and with the steam conditions that are avilable after the steam generator.

- The control system's philosophy of the whole plant, is based at "the man in the loop" assumption, enabling the operator to run the plant by utilizing the separate control of the different systems. For safety reasons, however, in case of emergency, an automatic shut-down reaction of the plant is provided by the system. Besides of this the interlocking system will avoid wrong and dangerous commands to the plant.

The primary characteristic is that there is no computer which directly controls the system set points but rather this is accomplished by the operator in a manner similar to conventional control, except that the DAS-computer generated displays supplement analog displays. Each of the systems has its own autonomous control system such that each of the plant systems is independent, with the operator providing co-ordination between systems.

- Due to the demonstrative nature of the plant, all systems are combined and backed-up with a Data Acquisition System, (DAS), which will sample data of all interesting points of the plant any second, store them in an intermediate storage and provide all necessary calculations, curves and list to the operator.

In a summary way the main system data are related in table 1-1.

For a clear description, the plant can be divided in the following main systems or parts -

- Heliostat Field
- Sodium Heat Transfer System
- Power Conversion System
- Electrical System
- Data Acquisition System
- Site Facilities.

TABLE 1 - 1

MAIN SYSTEM DATA

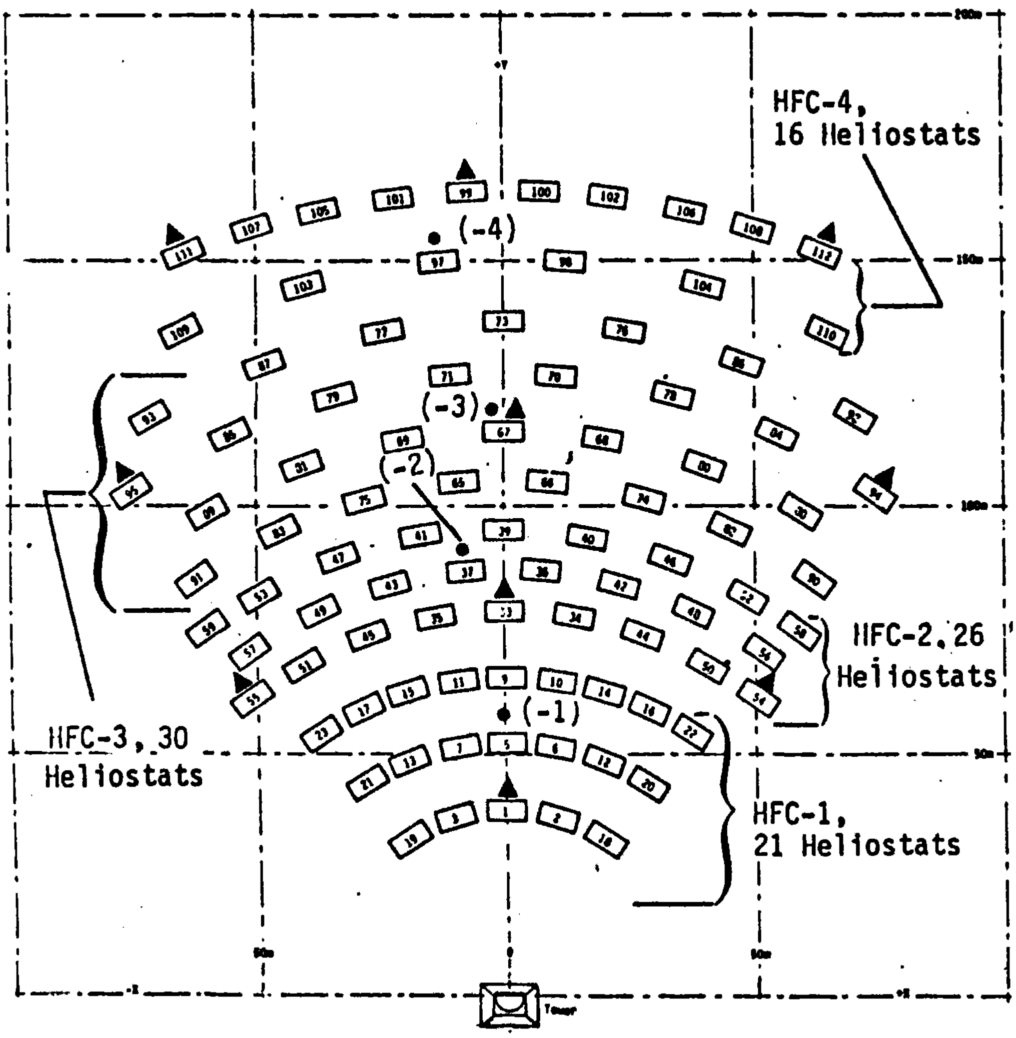
- Nominal output	- 500 kW
- Design point	- 12.00 March 21 (equinox)
- Direct Radiation	- 920 W/m^2
- Latitude	- 37° North
- Storage capacity	- 1 MWh_e
- Heliostat field type	- North field
- Number of heliostats	- 93
- Heliostat refl. surface	- 39.3 m^2
- Receiver C.P. altitude	- 43.25 m
- Receiver type	- Cavity
- Heat transfer medium	- Sodium
- Highest sodium working temp.	- 530°C
- Highest sodium working press.	- 8 bar
- Heat storage type/medium	- two vessels/Sodium
- Volume of each storage vessel	- 70 m^3
- Power conversion type	- Rankine cycle (steam motor)
- Live steam conditions	- 500°C, 100 bar
- Plant int. electr. consumption	- approx. 95 kW (Design point)
- Plant efficiency	- 16.1% (Design point)
- Average annual efficiency	- 11.4%
- Annual delivered energy	- 925,4 MWh

1.2 Heliostat Field

The heliostat field provides the controllable reflective surfaces to direct incident solar flux (insolation) as concentrated thermal energy into a 3.4 x 3.5 m octagonal shaped receiver aperture located 43.25 m high (centerpoint) on the facility tower.

a. Heliostat Field

The Heliostat Field Subsystem comprises ninety-three heliostats and controls located in a field north of the SSPS/CRS receiver tower (see Figure 1.4). In the north location, the heliostats reflect the sun's insolation back to the north-facing receiver aperture. The heliostats are located in the field on concentric-circle segments; the center of the circle segments is the projection of the receiver aperture on the ground below the tower. (This location is the origin (0, 0, 0) for location of all heliostats and for the receiver aperture center-point).
The heliostat field is symmetric about an imaginary line running north from the origin; seven heliostats are located on the line, and the other eighty-six are distributed symmetrically on either side of the line. Heliostats are staggered from each circle-segment radius to the next to minimize blocking of the reflected sun-flux from heliostat to receiver aperture. Shading of heliostats (by other heliostats) is minimized by location and separation.



• Location of Heliostat Field Controllers
(4 ea)

▲ Location of Sun-Presence Sensors
(10 ea)

FIGURE 1.4: Heliostat Field (plot plan)

The heliostat field subsystem was designed in conjunction with the location of the receiver to provide at least 2,700 kW input to the receiver cavity at the design point (equinox noon, 920 W/m^2).

The heliostats in the field have pre-focused mirrors to assure that the sun's reflected image is concentrated at the receiver aperture plane. The four focal lengths are 77 m, 101 m, 132 m, and 162 m; heliostats of these four focal lengths are assigned to focal zones (design assumption).
In addition, in order to further concentrate the sun's image at the aperture plane, each heliostat is pre-adjusted (canted) so that the reflected beams of all of its twelve mirrors converge at the slant range of the heliostat to aperture.

Other important data of the heliostat field as a whole are related below

- Aim point : 0, 0, 43.20 m
- Aperture area : 9.7 m^2
- Total reflective area : 3655 m^2
- Power inside the aperture: 2790 kW (design point)
- Peak flux density in the aperture : 277 W/cm^2
- Max. spillage flux around: 3.0 W/cm^2 the aperture
- Field area : approx. 15,000 m^2
- Field land use factor : approx. 0.25
- Field inclination : + 2.06 %, 15° NE

- Field efficiency (Design point)

. tower sway	: 1.000	
. tower shadow	: 1.000	
. consine factor	: 0.951	
. shading and blocking	: 0.999	
. reflectivity	: 0.895	(required minimum)
. tracking, atm. atenuation and aperture eff.	: 0.976	
TOTAL	: 0.830	

b. Heliostats

The components which comprise the heliostat (Figure 1.5) are shown in their respective relationships on Figure 1-6.

The heliostat has twelve mirror assemblies, (1.09 x 3.05 m), each with 1.079 x 3.035 m fixed-focus mirrors,having a reflective area of 3.275 m^2, for a total reflective area of 39.30 m^2 per heliostat.

The mirror assembly is a sandwich design of hot-bonded glass mirror, honeycomb core, and steel pan enclosure. The pan enclosure is formed from a single sheet of 0.58 mm thick cold-rolled steel. A single piece of aluminium honeycomb core fits into the steel pan. Core thickness is 66 mm.

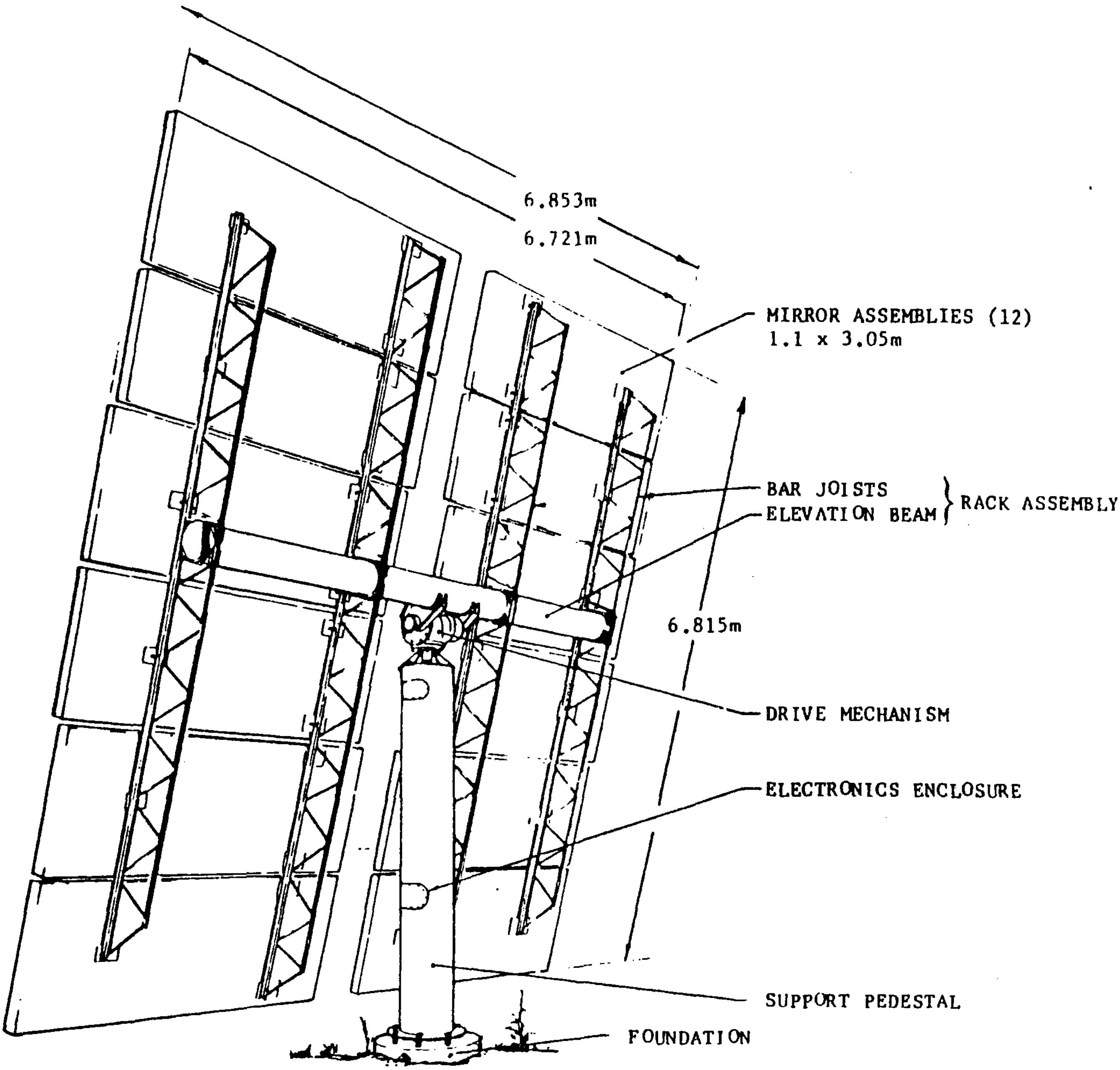


FIGURE 1.5: Heliostat

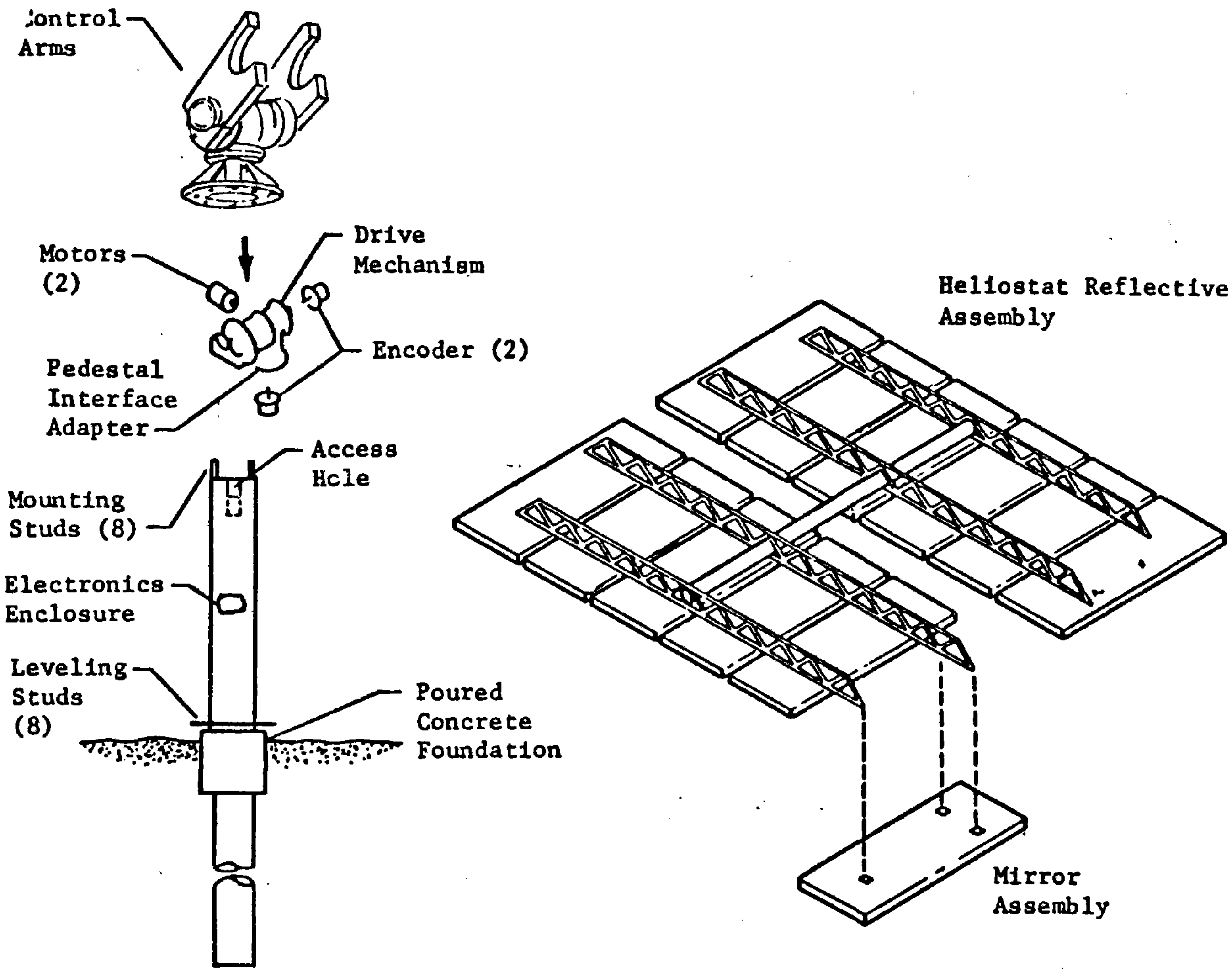


FIGURE 1.6: Heliostat Exploded View

The mirror assemblies are mounted to the rack assembly structure at three adjustable points each, two adjustable and one fixed, to provide for mirror module interalignment. (The rack structure with mirror assemblies mounted on it is designated "reflective assembly.") The support rack has four 35.6 cm deep bar joists mounted on elevation beam for mirror assembly attachment. The two support arms provide for attaching the rack to the drive mechanism. The drive mechanism contains azimuth and elevation gearing. The track/slew motors, one for each of the two axes, mount on the drive mechanism. The two encoders mount colinear with the two axes, elevation encoder at one of the support arms, azimuth encoder beneath the drive mechanism within the pedestal assembly enclosure.

The entire reflective assembly/drive mechanism assembly is supported by the pedestal assembly, which is a tube 53.30 cm diameter with 0.64 cm wall thickness. A bottom flange attached to the foundation mounting studs (which provide for leveling the entire assembly).
The drive mechanism is bolted rigidly to the top flange of the pedestal.

One heliostat controller is mounted on each heliostat, and receives commands and geometry data from the Heliostat Array Controller via the Heliostat Field Controller, and azimuth and elevation data from the heliostat encoders. These components are part of the Heliostat controls. Total weight of the heliostat, including the heliostat controller and cable assemblies is 1925 kg.

c. <u>Heliostats Control</u>

The heliostats are controlled by means of a main controller, designated Heliostat Array Controller (HAC), a mini-computer, located in the plant control room. The HAC transmits commands to the heliostats over command cables to four Heliostat Field Controllers (HFCs) (microprocessors) located at heliostats in the field.

The commands are retransmitted to microprocessors at each of the assigned heliostats (over cables). The microprocessors at each heliostat are a part of the Heliostat Controller (HC) which decodes the command and, based on data from position encoders on the azimuth and elevation axes of the heliostat, commands the motors in the desired direction at the proper rate; two rates are available - track (slow) and slew (fast). The HCs, upon proper command, transmit status data to the HFCs, which in turn reformats the data from its assigned heliostats and transmits it to the HAC.

Control equipment and software provide all necessary electronics, for a field of up to 256 heliostats, although only 93 heliostats are included in the field (four HFCs and 93 HCs). The system is designed to operate automatically or under direct control of the operator. The combined software and electronics provide the following capabilities.

1) Heliostat Array Controller. The primary functions of the Heliostat Array Controller (HAC) are:

a) Control operational-phase sequences as required for integrated control of a field of up to 256 heliostats;

b) Generate and transmit heliostat mode commands (by Group, Row, HC) as required by the phase sequences during either operational or maintenance phases while maintaining safe beam control;

c) Monitor the operational status of the heliostats as reported by the HFCs and report this status and detected irregularities in the form of displays and alarms;

d) Monitor and store the sum of the ten Sun Presence Sensors outputs;

e) Perform data packet transfer of heliostat field, relay contact and SPS data to the DAS computer;

f) Provide a stable time base using the WVTR trutime Receiver and Systron-Donner Time Code Generator input for HAC time;

g) Generate and transmit sun position information (once per second) to the entire field;

h) Transmit an analog signal to the SHTS for the sum of the ten SPSs and one contact closure signal to the SHTS indicating when heliostat beams are either on or off the receiver;

i) Transmit emergency defocus command upon receiver trip; and

j) Maintain safety through controlled beam movement.

2) Heliostat Field Controller. The primary functions of the Heliostat Field Controller (HFC) are:

a) Maintain communications with the HAC computer;

b) Transmit the received commands for up to 32 HCs connected on the HFC and store the parameters for up to four corridors;

c) Poll the specified four HCs in response to a polling command from the HAC;

d) Transmit the status received from the four HCs to the HAC, upon request from the HAC;

e) Detect communication errors in messages from HAC and HC, and

f) On loss of communications with HAC computer, control stow of up to 32 heliostats using an approximate corridor walk (using last received sun vector).

3) Heliostat Controller. The primary functions of the Heliostat Controller (HC) are:

a) Maintain communications with the HFC, detecting communications errors;

b) Calculate the desired azimuth and elevation angles based on sun vector and operational commands from the HFC;

c) Control the azimuth and elevation motors to achieve the desired position;

d) Maintain the azimuth and elevation encoder interfaces to provide gimbal angle information;

e) Provide HC status information to the HFC upon a poll command;

f) Execute an automatic reset upon detection of major errors, and

g) Detect errors of heliostat operation (i. e., inoperative motors.

In Figure 1.7 can be seen the physical relation among these controllers.

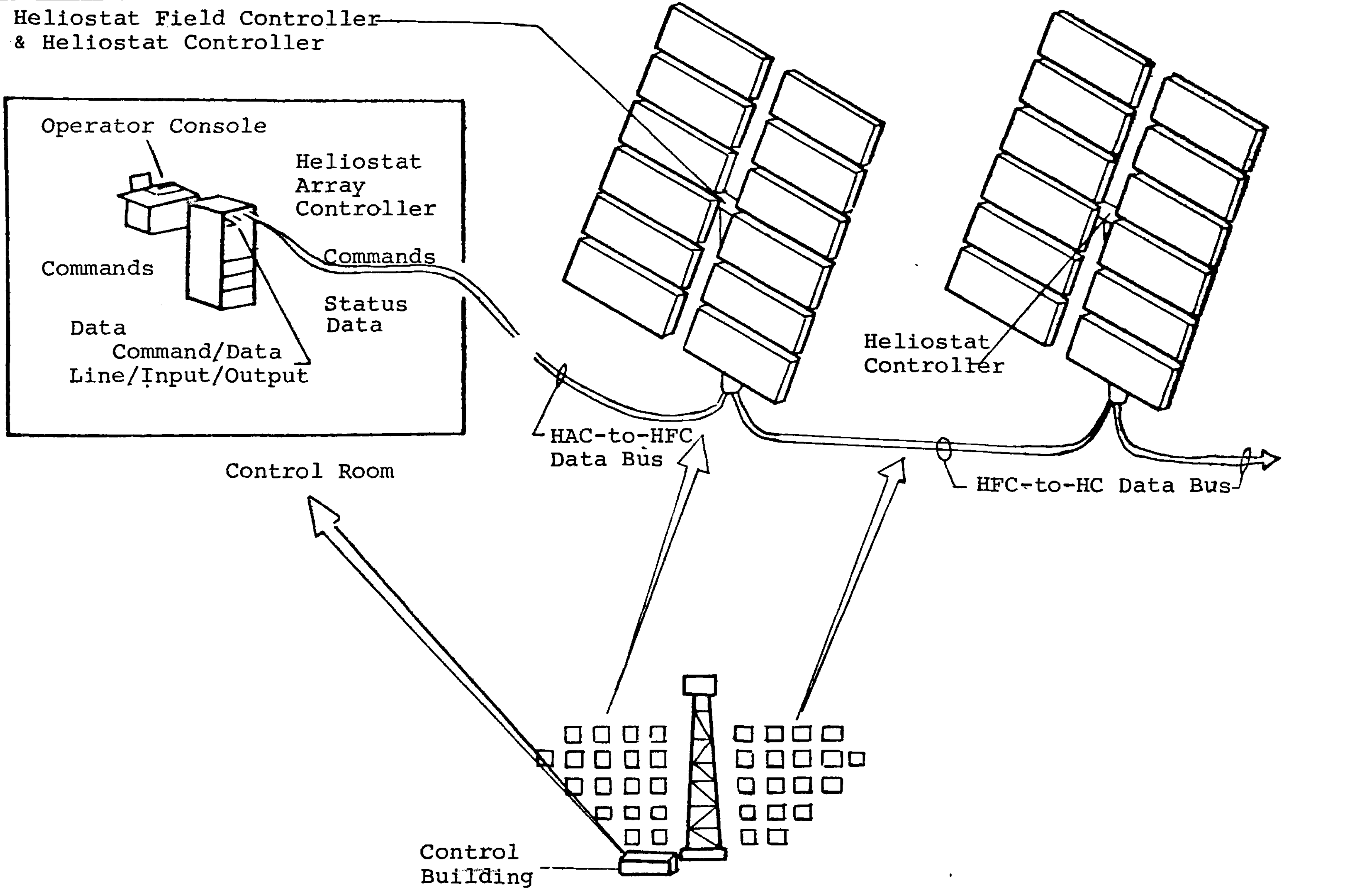


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FIGURE 1.7: Control of the Heliostat Field

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11211/10-79/2 (SSPS/002/4000)

1.3 Sodium Heat Transfer System

The task of the Sodium Heat Transfer System (SHTS) is to act as heat-transfer element between the receiver heated by solar energy and the steam generator of the electrical power conversion circuit. For a more flexible operation of the plant an energy storage system comprising two vessels is provided.

In order to achieve a most favourable efficiency, the sodium heat transfer circuit is designed as single-circuit system, (no intermediate heat exchanger is provided for) including one part loop for the receiver and the other one for the steam generator. Both part systems are hydraulically independent and due to this, the operation of one loop can be performed and controlled without any disturbing effects and influences from the other loop.

During normal operation conditions there will be two nearly constant temperature levels, one upper level of approx. 530 °C (receiver outlet - hot storage-pump-steam generator inlet) and one lower level of approx. 275 °C (steam generator outlet - cold storage-pump - receiver inlet).

All parts or equipment of this system which will work at the highest temperature level (approx. 530 °C) are made of austenitic steel while those which normally work at approx. 275 ° are manufactured of ferritic steel (for instance cold storage, cold trap regeneration vessel etc.).

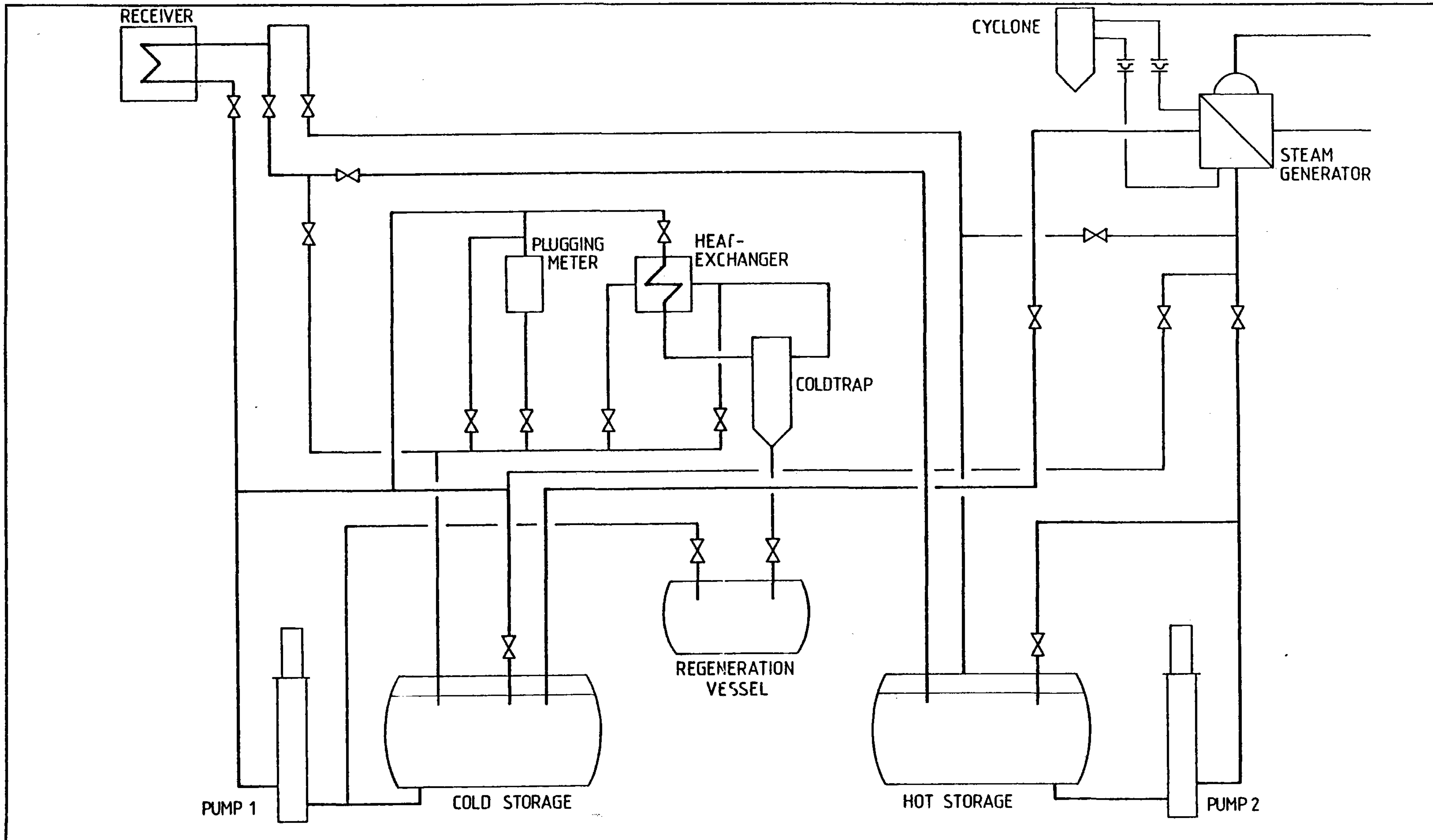

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FIGURE 1.8 : Sodium Heat Transfer System Diagram

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In figure 1.8 a simplified diagram of the Sodium Heat Transfer System (SHTS) can be seen.

The main elements or parts of the SHTS are the following:

a. Receiver:

This is a cavity receiver with a north-oriented 3.4 x 3.5 m octogonal shaped with 9.7 m² of aperture area in a vertical plane. The center of it is located 43.25 m above the ground (Fig. 1.9). The absorbing surface is formed by a part of a straight cylinder on which six parallel sodium carrying tubes are mounted and directed in a serpentine way from the bottom to the top (repetition fourteen times). The ceramic back wall enables a short time heat storage.
The main characteristics of the receiver are related below.

Type of heat exchanger surface:	vert. 120 degree cylinder bundle tube
Dimensions of tube bundle :	Radius: 2.25 m Arc length: 4.71 m (active) Height: 3.61 m
Weight of tube bundle :	1000 kg (full), 630 kg (empty)
Tube dimensions :	38 x 1.5 mm
Number of parallel tubes :	6 horizontal
Number of slides :	14
Peak heat flux (design point) :	60.0 W/cm² (tube bundle)
Average heat flux (des. point):	16 W/cm²

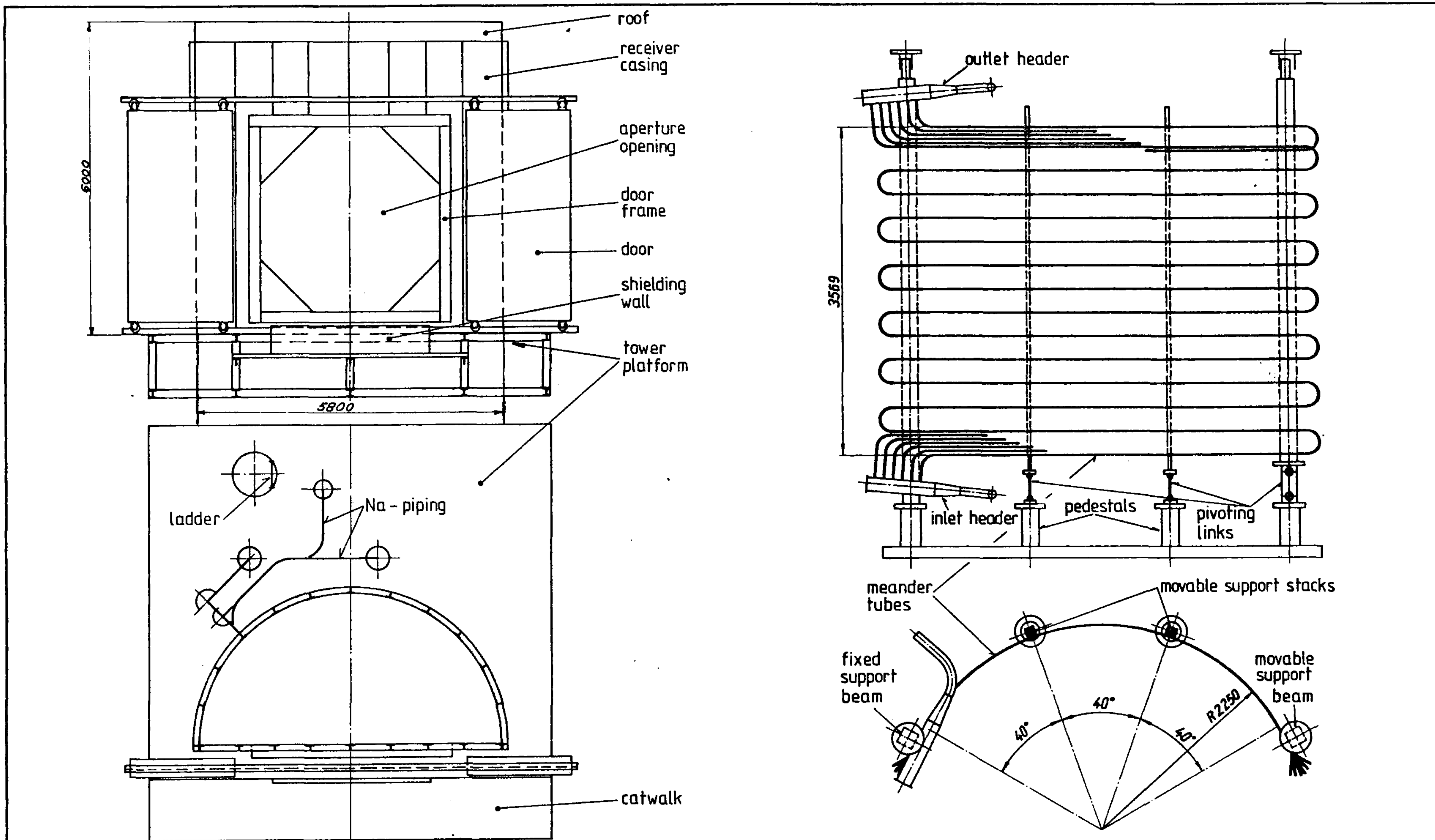

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FIGURE 1. 9: Receiver

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Active area	- 17.01 m^2
Absorptivity of tube coating	- approx. 0.95
Receiver output power	- 2464 kW (Design point)
Receiver efficiency	- 88.3% (Design point)
Sodium inlet temperature	- 270°C
Sodium outlet temperature	- 530°C
Sodium mass flow	- 7.3 kg/s (Design point)
Flow velocity	- 1.5 m/s
Pressure drop	- 0.5 bar (Design point)
Total receiver weight (full)	- approx. 25 t.

b. Steam Generator

This is a helical-tube-type once-through operation mode. The three heating tubes are coiled around a central displacement tube and are housed in a cylindrical shell. The sodium will flow downwards between shell and displacement tube around the heating tubes whereas the water and steam will flow upwards.
In order to cope with a severe sodium-water reaction two rupture disks are installed and connected via pipes with a cyclone.
A drawing of the steam generator is shown in figure 1.10.
The main data of this equipment are related below.

Heat transfer area	- 14.7 m^2
Heat transfer tube dimensions	- 25 x 3.2 mm
Tube length (3 tubes)	- 62.2 m
Thermal power	- 2203 kW (Design point)
Feedwater temperature	- 193°C
Outlet steam temperature	- 500 - 525 °C
Outlet pressure	- 105 bar

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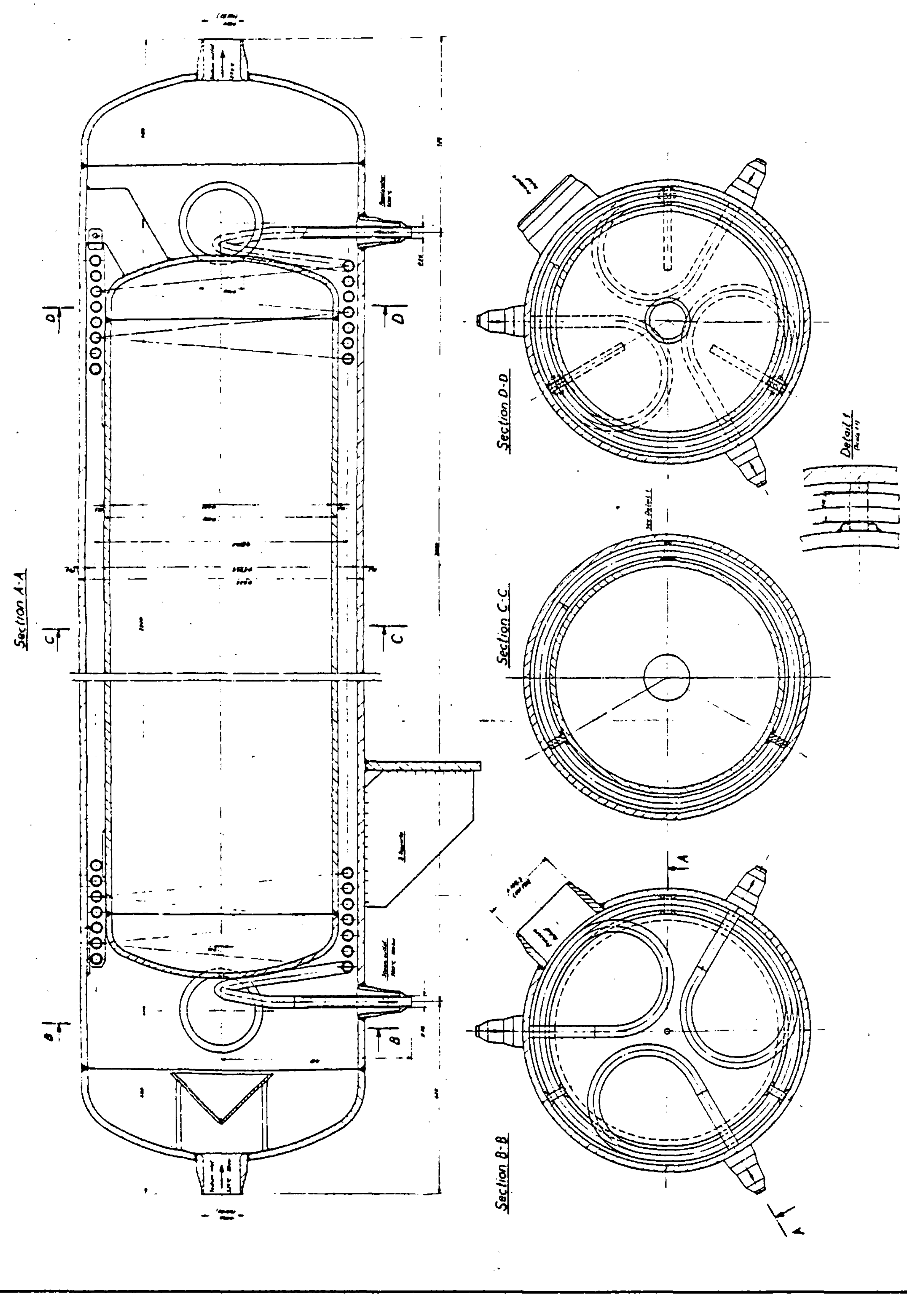
Figure 1.10 - Steam generator



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Steam flow	: 0.86 kg/s (Design point)
Pressure loss water/steam side	: 10 bar
Sodium inlet temperature	: 525 °C
Sodium outlet temperature	: 275 °C
Max. pressure on the sodium side	: 8.0 bar
Sodium mass flow	: 6.9 kg/s (Design point)
Sodium volume of the steam generator	: 1.05 m^3
Water/steam volume of the steam generator	: 50 l
Partial load	: Range of 25 % to 100 % load
Overload capacity	: 110 %
Load change rate	: 5 %/min
Volume of cyclone	: approx. 2 m^3

c. Sodium pumps

Two centrifugal pumps are arranged beside the storage vessels, one to feed the receiver, the other to supply the steam generator. Their sodium overflow pipes and covergas equalizing pipes are connected directly with the corresponding vessels.

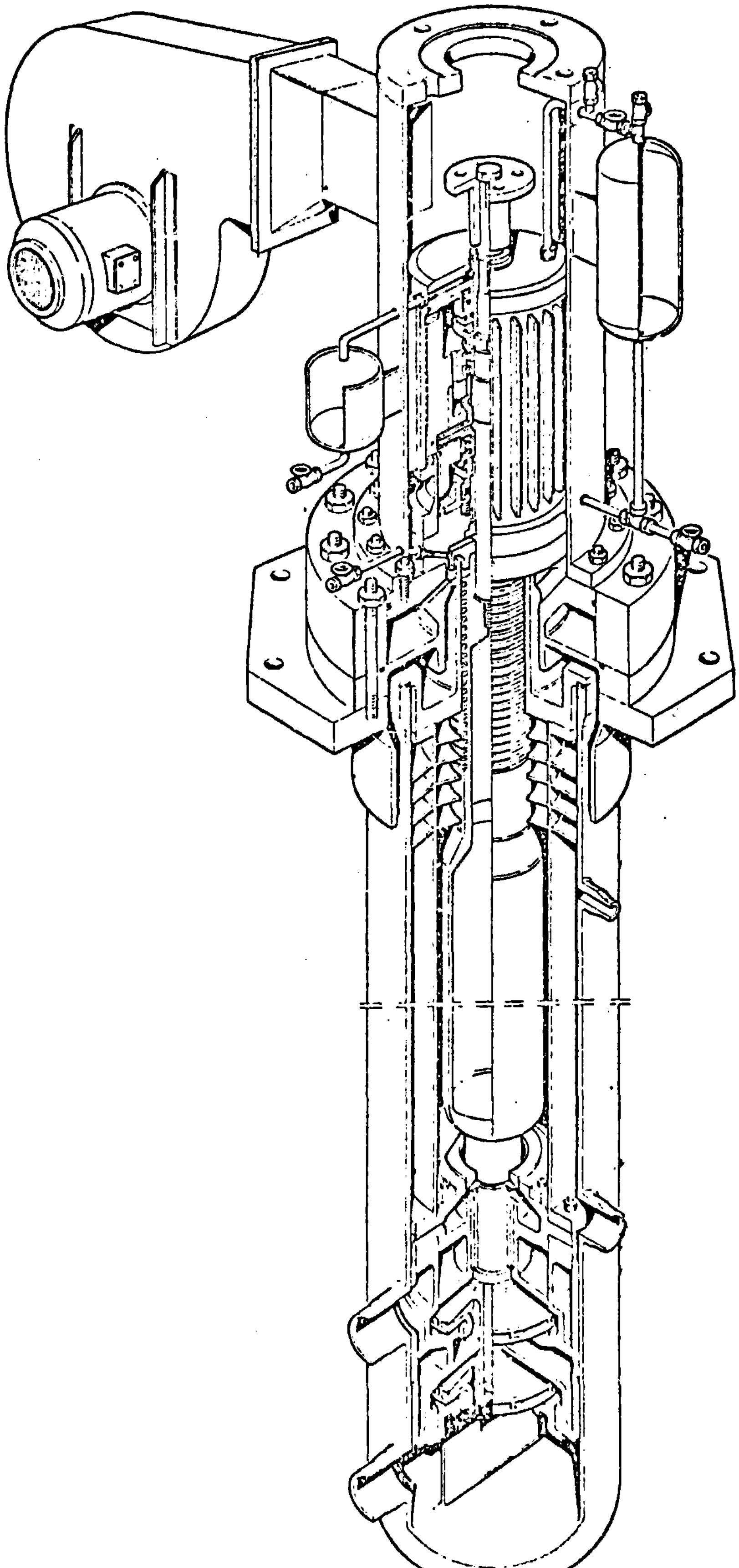
The main design features are described below:

The forced draft air provides effective oil and thermal barrier cooling and idle hot stand by capability. The axial contact double mechanical-face pressurized oil-lubricated seal keeps the atmosphere out and the argon gas in. Seal and bearing heat dissipation is provided with an integral heat exchanger and oil circulating impeller. The argon cover gas provides an inert blanket over the sodium, separating the liquid sodium from the seal area. The free surface overflow design acommodates 3100 mm sodium level fluctuation. Two-stage arrangement allows low operating speed and good dynamic characteristics. Large diameter evamated hollow shaft provides rigidity. Symmetrical multivolute design minimizes loads on the submerged hydrodynamic bearing.

A drawing of the pumps is shown in figure 1.11.
The main characteristics of the sodium pumps are related below.

		Receiver loop	steam gen.loop
Normal operating temperature	:	275 °C	530 °C
Max. operating temperature	:	530 °C	530 °C
Max. flow rate	:	48 m^3/h	35 m^3/h
Max. pressure difference	:	3.5 bar	1.8 bar
Design flow rate	:	30 m^3/h	30 m^3/h
Sodium flow rate range	:	10 - 155%	10 - 110%
Design point electr. cons.	:	4.3 kW	2.8 kW
Length	:	approx. 5m	approx. 5m
Weight (empty)	:	approx. 3t	approx. 3t

FIGURE 1.11: Sodium Pumps



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d. Storage equipment

It consists of two separate vessels: one cold storage vessel and one hot storage vessel. Both vessels are cylindrical. The cold vessel serves in addition as a draining capability for all the sodium of the SHTS.

The size of these two vessels storage system has been calculated in order to provide 1 MWh (electrical) after 24 hours of the filling, having taken into account the thermal losses, plus a safety operation margin.

The main characteristics of the vessels are related below.

	Hot Storage	Cold Storage
Operating temperature	: 530 °C	275 °C
Diameter	: 3.3 m	3.3 m
Length	: 9.8 m	9.8 m
Volume	: 70 m^3	70 m^3
Design pressure	: 8.5 bar	8.5 bar
Weight (empty)	: 20.5 t	15 t
Weight (full) + support + insolation	: 90 t	85 t

e. Purification equipment

It basically consists of a heat exchanger, a cold trap, a regeneration vessel and a plugging meter. The tube-in-tube heat exchanger has capacity enough to cool the sodium down to almost the plugging temperature. The cold trap is equipped with a cooling air blower to cool the sodium further down in order to ensure the uniform precipitation of the impurities. The regeneration vessel is the place where the sodium will be conducted after the cleaning of the cold trap and the impurities will be afterwards definitively separated of the SHTS. To monitor the sodium purity a plugging meter is provided.
The main characteristics of this equipment are related below.

Tube-in-tube heat exchanger:

- Thermal capacity : 230 kW
- Sodium throughput : 1.23 kg/s
- Inlet temperatures : 120/300 °C
- Outlet temperatures : 258/160 °C

Cold trap:

- Plugging temperature : 150 °C (required)
- Operational temperature : 160 °C
- Max. operational temp. : 400 °C
- Max. operating pressure : 10 bar

- Max. precipitation rate : 16 g O_2/h
- Sodium velocity : 2.5 mm/s
- Precipitation volume : 1 m^3
- Dimensions : ∅ 1.3 m, length 3.5 m
- Weight : 3000 kg

Cooling air blower:

- Flow rate : 6000 m^3
- Inlet temperature : 35 °C
- Air outlet temperature : approx. 120 °C

Regeneration vessel:

- Volume : 4.5 m^3
- Dimensions : ∅ 1.8 m, length 4 m
- Design pressure : 8.5 bar
- Design temperature : 450 °C
- Weight : 2800 kg

f. Sodium piping system

All the above-mentioned parts of the SHTS are connected by the corresponding pipes in which the necessary valves (shut-off, check, safety, control and pressure reducing) to perform all the operation capabilities are installed.
In figure 1.12 one can see the main sodium loops inside the building.
The main characteristics of the piping are related below.

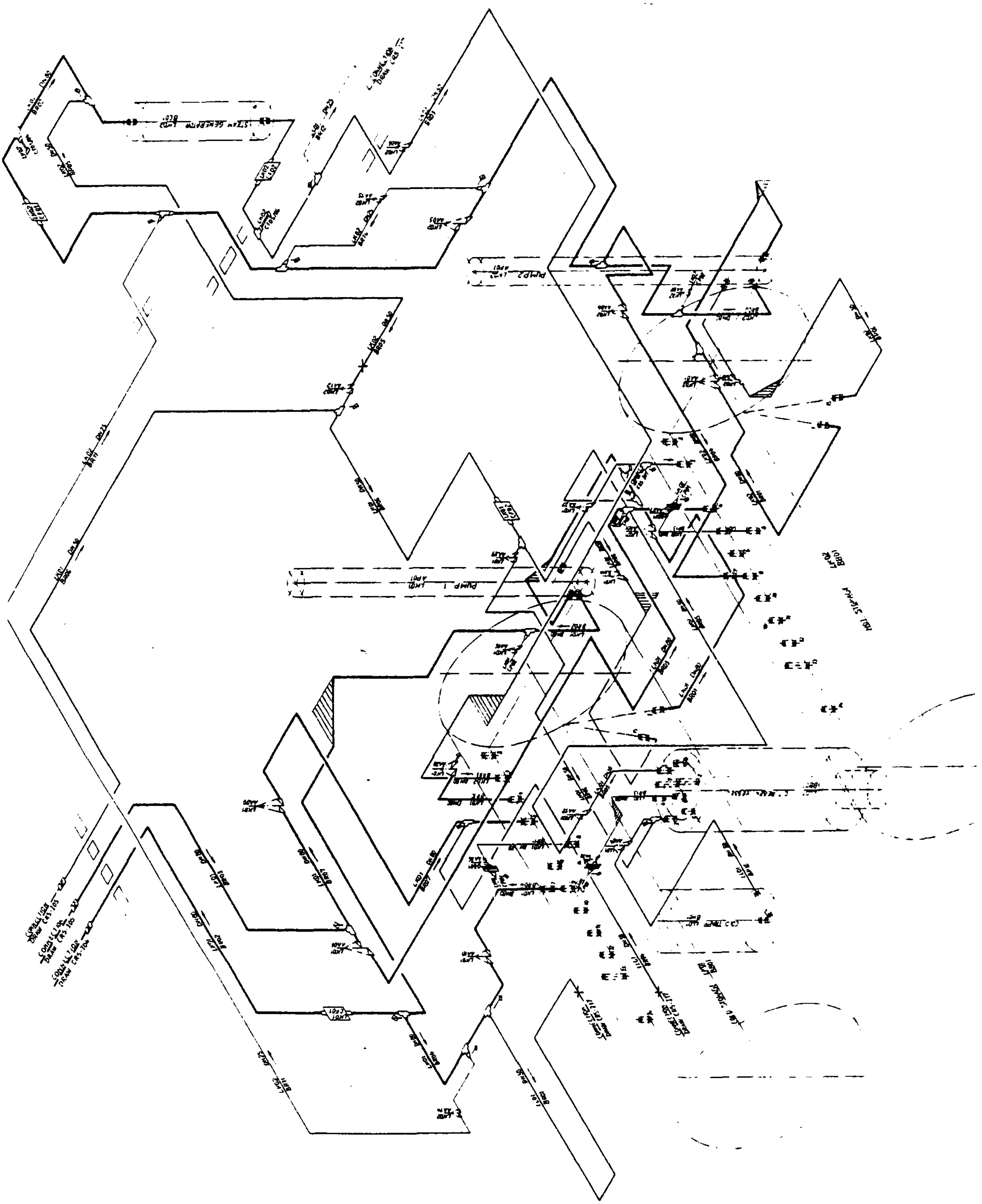

FIGURE 1.12: Main Sodium Loops (Isometrie)

- Main pipe diameter : DN 80/50
- Secondary pipe diameter : DN 25
- Type of shut-off and check valve : cone type, bellow sealed
- Type of safety valve : spring loaded,bellow sealed
- Type of control or pressure reducing valve : cone type, bellow sealed

g. Cover Gas System

This is provided for supplying pressurized inert gas to the whole Sodium Heat Transfer System in order to fill the system with sodium, to preserve a definite Na-level and to cover all free sodium surfaces with inert gas during all operation and shutdown phases. For all these purposes Argon gas will be used.

In figure 1.13 an isometric view of the cover gas system can be seen.
The main characteristics of this system are related below.

- Nominal design pressure : 16 bar
- Range of operating pressures : 8.5 - 1.5 bar
- Max. operating temp. : 400 °C
- Vapor trap type : SINTERMETAL

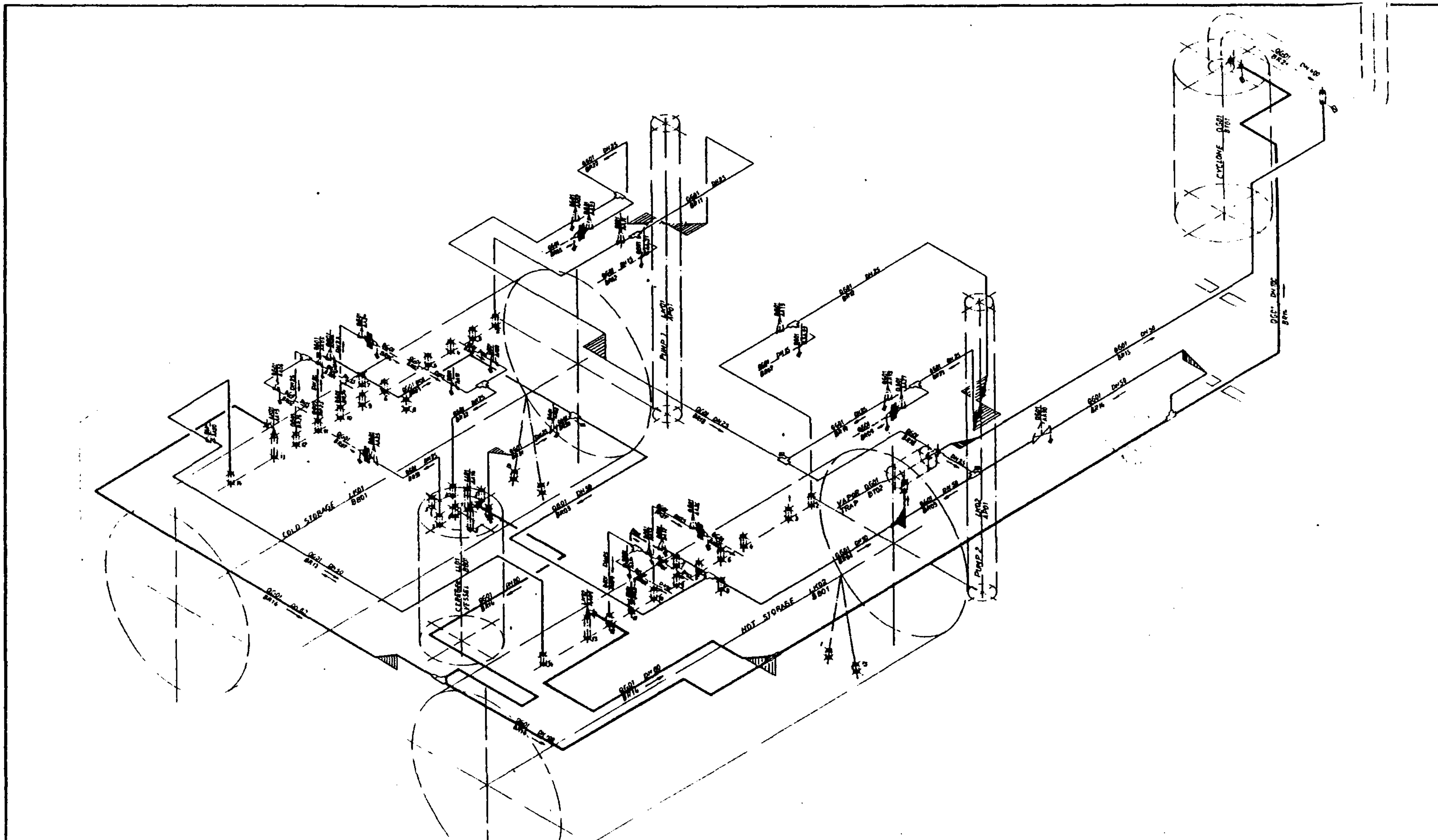

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FIGURE 1.13: Cover gas system (Isometrie)

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h. Trace heating

All sodium components and piping (except the receiver) are provided for with an electrical trace-heating system. By means of this the preheating of the complete HTS up to approx. 200 °C will be performed. Then any freezing of the sodium will be avoided. Besides of this, all the a. m. sodium elements are covered by an adequate thermal insulation consisting of mineral wool with cover sheet.

The main data of the trace heating are related below.

- Connection	: main diesel busbar
- Installed power	: 135 kW
- Voltage	: 380 V/220 V
- Average power (Design point)	: 12.8 kW

i. Control

The control of the SHTS consists of three independent circuits

- control of the receiver loop:

  The outlet receiver temperature is the reference variable and it is controlled by changing the speed of the receiver loop pump. For quick changes a follow-up controller is provided of which the disturbance input variables are: the sodium flow rate, tube bundle temperatures (three thermocouples divided over the tube bundle) and solar insolation (ten sun sensors divided over the heliostat field).

- control of the steam-generator loop:

  The sodium outlet temperature at the steam generator is defined as the control variable while the sodium/feed water flow rate ratio acts as command value. Any variations of these values act on the correcting element which is either the variable pump speed to vary the sodium flow or the control valve at the steam-generator outlet to vary the steam flow.

- control of the purification system:

  This automatic system controls separately the sodium flow rate through this system, the cold trap inlet temperature and the purification temperature.

- safety interlocks:

  Besides of the a. m. controls a safety interlock system is provided. This system takes into account not only sodium variables but also other ones coming from the heliostat field and P.C.S. and drives the sodium elements in safety operations in order to avoid big damages in case of any corresponding malfunction.

j) Fire protection equipment

This consists of passive precautions, like the sodium leakage collecting pans, including a sufficient passive extinguishing system, and active precautions like fire detecting and extinguishing equipment. It could be also included here the sodium leakage detecting system.

The main characteristics of this equipment are related below.

Sodium leakage collecting pans :

Location	:	Bottom SHTS-hall - Bottom steam generator room, bottom receiver and bottom of the receiver tower (+ 6.25 m level)
Material	:	Steel
Area of the plates	:	approx. 300 m²

Leak detection system :

Location : Inside receiver cavity, pump suction and overflow pipes, sodium leakage collecting pans

Smoke detection system '

Control areas: 1 suction device for 30 - 60 m^2

Sodium fire-extinguishing equipment '

- Antisodium trays: 10
- Graphex powder: 470 kg (in baskets with pils)
- Fire extinguishers: 35 of 6 kg each (Graphex CK 23 powder)

1.4 Power Conversion System

By means of the Power Conversion System (PCS) the energy that has been collected and stored in the storage system as sensible heat is transformed into electricity.

The PCS basically consists of one conventional steam motor, with the necessary auxiliary equipment, which is fed with the steam produced in the steam generator, directly coupled to a synchronous alternator.
In figure 1.14 a simplified diagram of the PCS is shown.
The main parts are described below.

a. Steam motor equipment:

The superheated steam, which has been produced in the steam generator, feeds a five-stage steam engine. In the bypass line of the steam engine a cross-over valve protects the engine against over pressures. A superheated steam cooler with the same capacity of the total boiler output also mounted in this bypass protects the system against too high temperature. In the steam engine the pressure drop between inlet steam and condenser pressure will be expanded in five stages. The second and the third stage supply the required steam for the two steam heated feed-water preheaters,whereas the fourth stage supplies the degasifier of sufficient steam.

A drawing of the steam motor can be seen in figure 1.15.

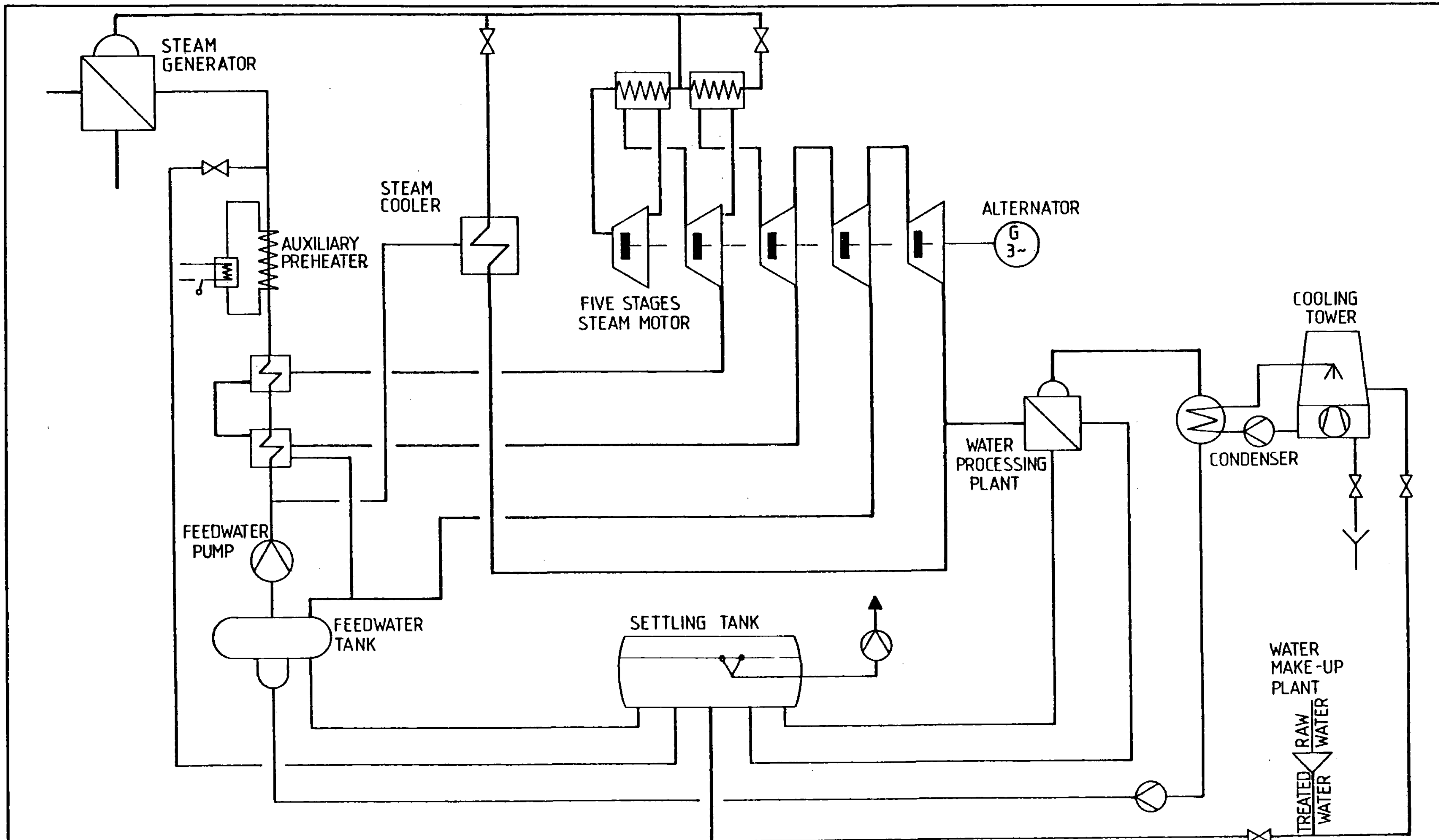

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FIGURE 1.15 Power Conversion System Diagram

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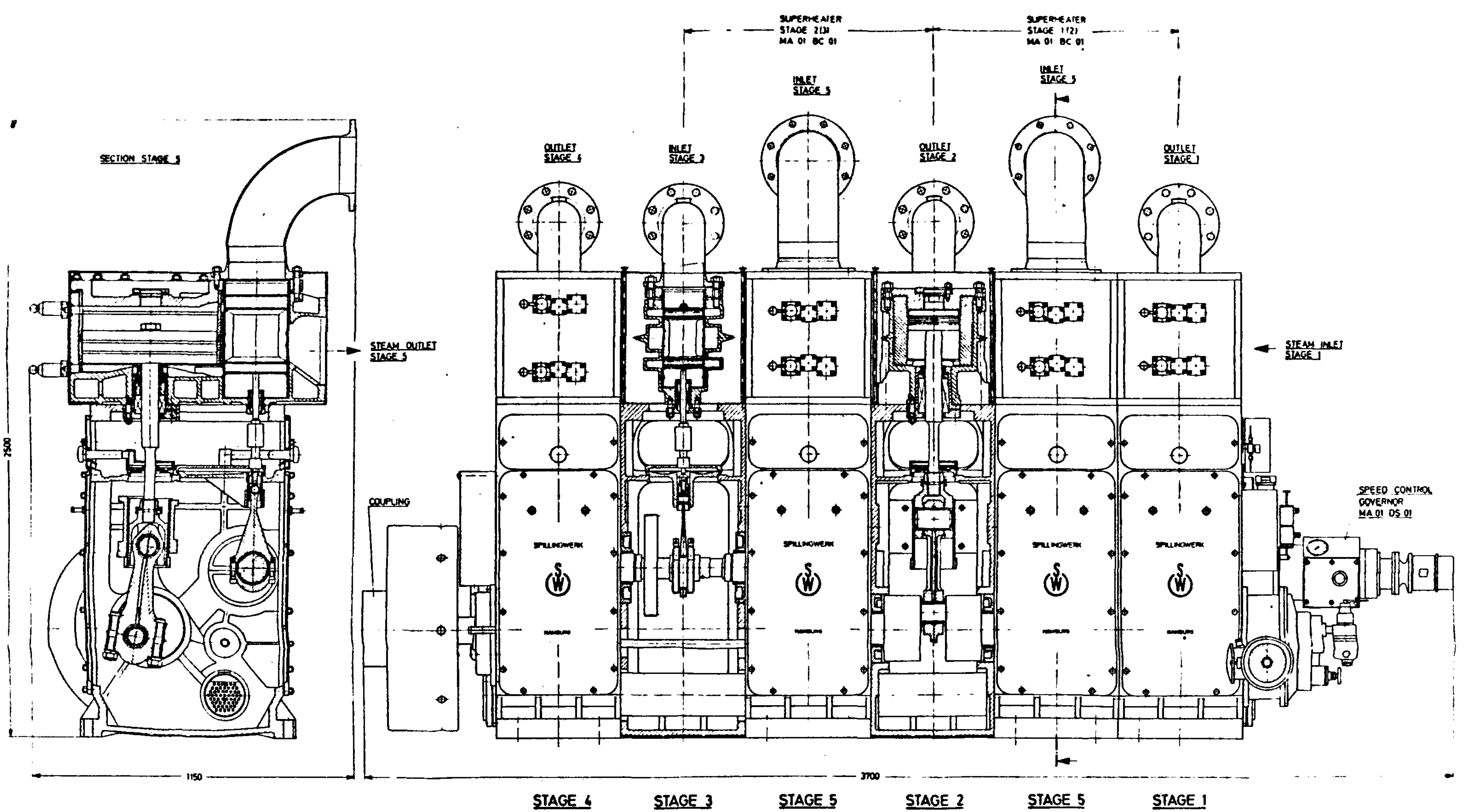

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FIGURE 1.15 Steam motor

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In order not to exceed the maximum allowed steam temperature at the inlet of the steam-motor (approx. 400 °C) as well as for reheating purposes at the second and the third stage, two steam to steam heat exchangers are provided. A hydraulic temperature governor controls the steam flow to these heat exchangers. The exhaust steam of the steam motor will be condensed in a surface condenser which is equipped with a condensate pump and a vacuum pump for the removal of non-condensable gases and for maintaining the required low pressure.

The condensate pump feeds the condensate from the main condenser to the combined degasifier feed-water tank.

The degasifier will be heated through a surface heat exchanger with steam that is extracted behind the fourth stage. A level control device assures, that as soon as the level in the feed-water tank decreases below the allowed level, additional water is be fed from the evaporating plant (water separator) to the main condenser.

The feed water flows through two feed-water preheaters to the steam generator. The required operation pressure is delivered by the feed-water pump, which is a steplessly speed controlled piston pump. The control parameter is the live steam pressure, measured in the superheated steam line.

Some special valves to act during the start-up and shut-down periods only are also incorporated in the water/steam system.

One of them is the overflow valve before the steam generator that must avoid flooding the steam generator during start-up with relatively cold water.
Other special valves to be mentioned are the valves in the inertisation system of the steam generator that must prevent oxygen corrosion overnight when the water-steam side of the steam generator is drained.
The main characteristics of this equipment are related below.

- Nominal output : 617 kW
- Inlet pressure : 100 - 102 bar
- Inlet temperature : 500 °C
- Outlet pressure : 0.3 bar abs.
- Speed : 1000 rpm
- Overload capability : up to 110 % continuous
- Operating life time : 90,000 hours

b. Water processing equipment:

In a two-stage water evaporating plant the steam from the steam engine will be condensed and evaporated and the additional water from the settling tank and water make-up plant will be evaporated. This evaporation process guarantees the quality of the feedwater, that should be in accordance with the VGB (1972) standards for high pressure once through boilers. The condensate of the first stage, enriched with oil and salts is

pumped to a separation tank (settling tank from where a part of the water is discharged via a waste pipe whilst the separated oil will be discharged through an overflow into a disposal barrel. Water from the water make-up plant is fed to this settling tank in order to balance the drained quantities.
The main characteristics of this equipment are related below.

Separator 1st stage

- Type : totally closed cylindrical tank
- Operating pressure : 0.2 bar
- Operating temp.: 60 °C
- Length/Height : approx. 2500 mm
- Diameter : approx. 2000 mm

Evaporator stage 1

-	Heat transfer rate		: 1500 kW
-	Flow rate	shell side	: 0.6 kg/s
		tube side	: 1.1 kg/s
-	Pressure/temp.	shell side	: 0.3 bar/60 °C
		tube side	: 0.2 bar/60 °C
-	Pressure loss on both sides		: 0.08 bar

Separator 2nd stage

- Type : totally closed cylindrical tank
- Operating pressure : 0.15 bar

- Operating temp. : 50 °C
- Length/Height : approx. 2000 mm
- Diameter : approx. 1600 mm

Evaporator stage 2

-	Heat transfer rate		: 700 kW
-	Flow rate	shell side	: 0.3 kg/s
		tube side	: 0.5 kg/s
-	Pressure/temp.	shell side	: 0.2 bar/60 °C
		tube side	: 0.15 bar/50 °C
-	Pressure loss on both sides		: 0.05 bar

Settling tank

- Type : rectangular plate tank
- Operating pressure : 1 bar
- Operating temperature:80 - 100 °C
- Dimensions : 3500 x 2500 mm
- Height : 1500 mm

c. Recooling equipment:

For the recooling of the cooling water a wet cooling tower with an electrically driven fan has been considered, equipped with a salt drainage device and a feeding device which provides additional

water from the water make-up plant. A sufficient drainage of salt is of importance as to reduce the water-side corrosion of the condenser and thus prevent the intake of salts into the feed-water to the steam generator.
The main data of the cooling tower are related below.

- Max. operating pressure	: 1 bar
- Max. operating temp.	: 50 °C
- Heat transfer capacity	: 1500 kW
- Rate of flow	: 24.4 kg/s (88 m^3/h)
- Inlet temperature	: 45 °C
- Outlet temperature	: 30 °C
- Drainage quantity	: 150 kg/h
- Make up water consumption	: 3 m^3/h

d. Water make-up plant:

One of the aims of this plant is the chemical treatment of additional water for the recooling system. Another task is the supply of additional water for the water steam system.

The treatment is made by the neutral ion-exchange system i. e. reactivation of the exchanged elements by common salt. The plant is designed as a double-unit system, one unit in operation, the second one to be reactivated by salt-water at the same time.

The change from one unit to the other one takes place automatically. The common salt tank has a capacity of one week.
The main data of this plant are related below.

-	Nominal output	: 3.5 m^3/h
-	Max. output	: 11 m^3/h
-	Output between two regenerations	: 35 m^3
-	Hardness of raw water	: approx. 29 dH
-	Water pressure	: min. 3 bar, max. 6 bar
-	Water temperature	: min. 12 °C, max. 30 °C
-	Salt tank capacity	: 2000 kg (12 regenerations)

e. Electrical feed-water pre-heating equipment:

This equipment assures that under off-normal operation condition such as starts and stops of the plant the feed water temperature will not fall below 175 °C . This equipment consists of a thermo-oil circuit with electrical heater, pump and heat exchanger and functions fully automatically.

The installed power of this equipment is 30 kW.

f. Alternator:

The steam motor is elastically connected to a brushless self-controlled three-phase current generator.

The generator is equipped with an automatic voltage control device for isolated (non-parallel) operation and a reactive current control for parallel operation.
The main data of this alternator are related below.

- Protection : IP 23
- Frequency : 50 cycles
- Voltage : 400 volts, star, 4 terminals
- Output : 700 kVA or 600 kW at power factor from 0.85 to 1.00
- Operating life time : 90,000 h

g. Control:

The control of the PCS enables to run under different ranges of power as well as in the stand-by state when no electrical output is delivered.

During the parallel operation with the public grid the control will be effected in the following manner:

- the reactive power will be controlled automatically via the electrical reactive power control device of the constant voltage generator

- the boiler pressure will be controlled via the speed of the thyristor-controlled feed pump

- the inlet steam temperature is limited to the upper level by the uncontrolled sodium inlet temperature (530 °C)
- the heat supply (sodium) follows fully automatically the feed-water quantity
- the heat supply loop (sodium) will be controlled separately.

The output of the generator set in isolated operation can be varied continuously within the limits of 2 to 100 % of the gross output whereby the maximum variation speed of appr. 5 % per minute is to be taken into consideration.

The steam motor is equipped with a mechanical speed governor which controls the frequency of the generator set in times of isolated operation (non-parallel operation).

The motor is equipped with a fully automatic start-up, self-acting supervision and fully automatic stop device.

The main supervising and stop impulses will be indicated in the engine room and electrically transmitted to the remote control panel of the control room as well as to the Data-Acquisition System (DAS).

1.5 Electrical System

The electrical system includes all central devices for power supply and distribution of the electrical power produced in the alternator.

After the 3phase (400 V, 50 Hz) current has been produced a part of electricity is tapped off to cover the own requirements of the plant (internal consumers). This is performed via the low-voltage switchgear. The remainder is fed into the grid via the transformer or into an adjustable substitute load in a simulated stand-alone operation. The connection to the grid is via a high-voltage switchgear.

In case of no operation of the PCS the energy required by the different internal consumers will be supplied by either the interconnected grid or the emergency diesel generator which is provided for.

In the single wiring diagram (figure 1.16) the electrical relation of these items and the different consumers is shown.

Besides of this the electrical system includes the earthing and lightning protection system and as a particular item of this type of plant all the heliostat field cabling.
The main elements' description is indicated in the following paragraphs.

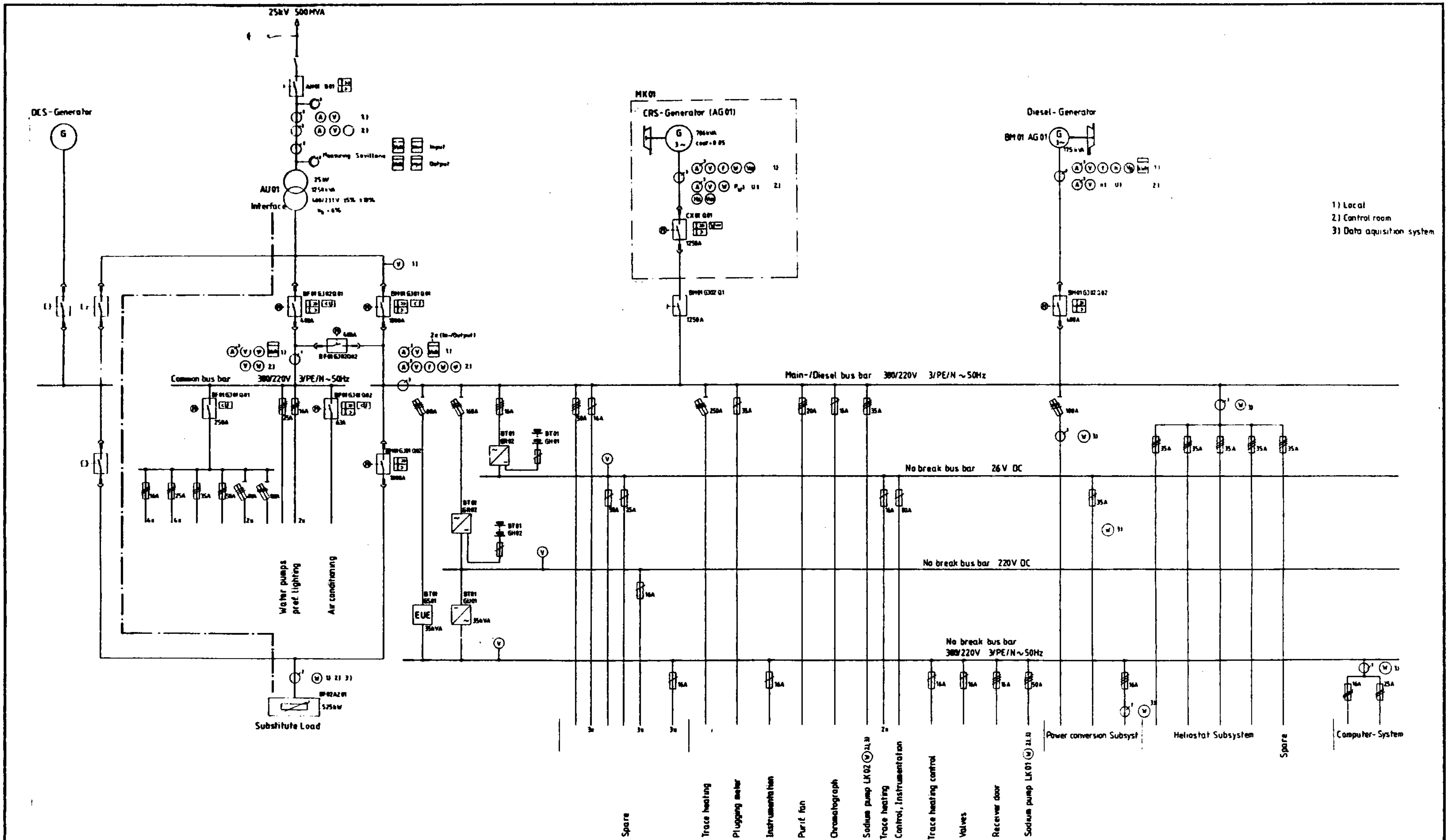

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FIGURE 1. 16: SINGLE WIRING DIAGRAM

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a. High-Voltage Switchgear:

The swichgear unit is fitted with non-drawout equipment and single bus bars supplied in metal-enclosed design.

The breaking capacity amounts to 1500 kVA. The cubicle is suited for making up switch-board with circuit-breaker. Adequate space is provided for accommodating instruments, relays and terminal blocks for measuring and control circuits.

b. Transformer:

As well as the high-voltage switchgear this equipment is used for both currents, one produced in the CRS-plant and the other produced in the Distributed Collector System (D.C.S) plant. The transformer is clophen-cooled and designed for the installation inside the building. The design power is 1250 kVA and the corresponding voltages on both sides are respectively 400 V and 25 kV.

c. Low-Voltage Switchgear:

This comprises the panels to feed into the substitute load, into the transformer, to control the generator and to supply all the auxiliaries internal consumptions of the plant. All the required switches for individual functions are completely wired and interconnected. The interlocks required for operation are also included.

d. Substitute load:

It is a high-capacity load resistor type, air forced ventilated and designed for outdoor installation.
The resistor is adjustable by contactors in 35 steps from 16,66 kW to 525 kW.

e. Emergency Power System:

In case of power failure at the main bus the auxiliary power is supplied automatically after max. 15 seconds by the Diesel Generator with 380/220 V AC.

The motor includes all the normal devices, including speed regulation, motor-mounted control units, battery start-up system, automatic switchgear, cooling fan and day tank.

From this main bus bar the different safety no-break bus bars are fed. They are:

- No-break bus bar 380/220 V, 50 Hz, which consists of an AC/DC converter and battery charging a 220 V DC battery set and a permanent operating 220 V DC/380-220 V AC converter.

- No-break bus bar 24 V DC, which consists of an AC/DC converter and battery charger and a 24 V battery set.

- No-break bus bar 220 V DC which is direct connected to the 220 V DC battery set mentioned above.

f. Heliostat field cabling:

It includes all equipment, which is necessary for the distribution cabling and connection of the consumers within the field, the main ones are the low-voltage cables between the central power supply and the heliostat tracking units, the computer cables between the heliostat array control system and the heliostat field controllers, the instrumentation cables, e. g. for the sun presence sensors and all local panels required for fuses and distribution.

Inside the buildings the heliostat field cabling for the power-supply cables are on cable trays. Those cables used for control and measurement are mounted on cable ducts.

Outside the buildings the cables will be conducted in the ground ducts.

All energy cables are laid using the sand-bedding method. The laying of the cables of the control circuitry will be done in the same way.

All cables are directly conducted from the ground into small distribution panels located at each heliostat.

g) Earthing and lightning:

The earthing system basically consists of an iron grid laid out inside and surrounding the building area, in the foundations level, connected to its steel structure. In addition a separate cupper wired earthing system is provided for in the heliostat field.

The lightning system is completely separate as required by the Spanish regulations and consists of a radioactive system with alpha emitter, situated in the top of the tower, which protects all the plant facilities.

1.6 Data Acquisition System

The data acquisition subsystem performs the monitoring of the CRS-plant information. This subsystem is comprised of a digital computer with its associated peripheral equipment and acquisition subsystem, located in the computer room of the plant. In the CRS control room, semigraphic color CRT's and printer-plotters are available as man-machine interfaces.

The plant operating data, alarms and statuses are collected every second during plant operation. Analog measurements are displayed in real time on request. Pending alarms are listed on the screen for operator facility. Average values or snapshots are recorded on disc and saved on magnetic tape for historical filing. Data summaries and plant performance reports are computed and edited on printer-plotters.

The DAS is connected to following other subsystems:

- the sodium heat transfer subsystem (SHTS)
- the power conversion subsystem (PCS)
- the meteorological station (MET)
- the heliostat array control computer (HAC)
- the time code generator (TCG).

In figure 1.17 one can see the relaction between the control scheme of the plant and the data acquisition system.

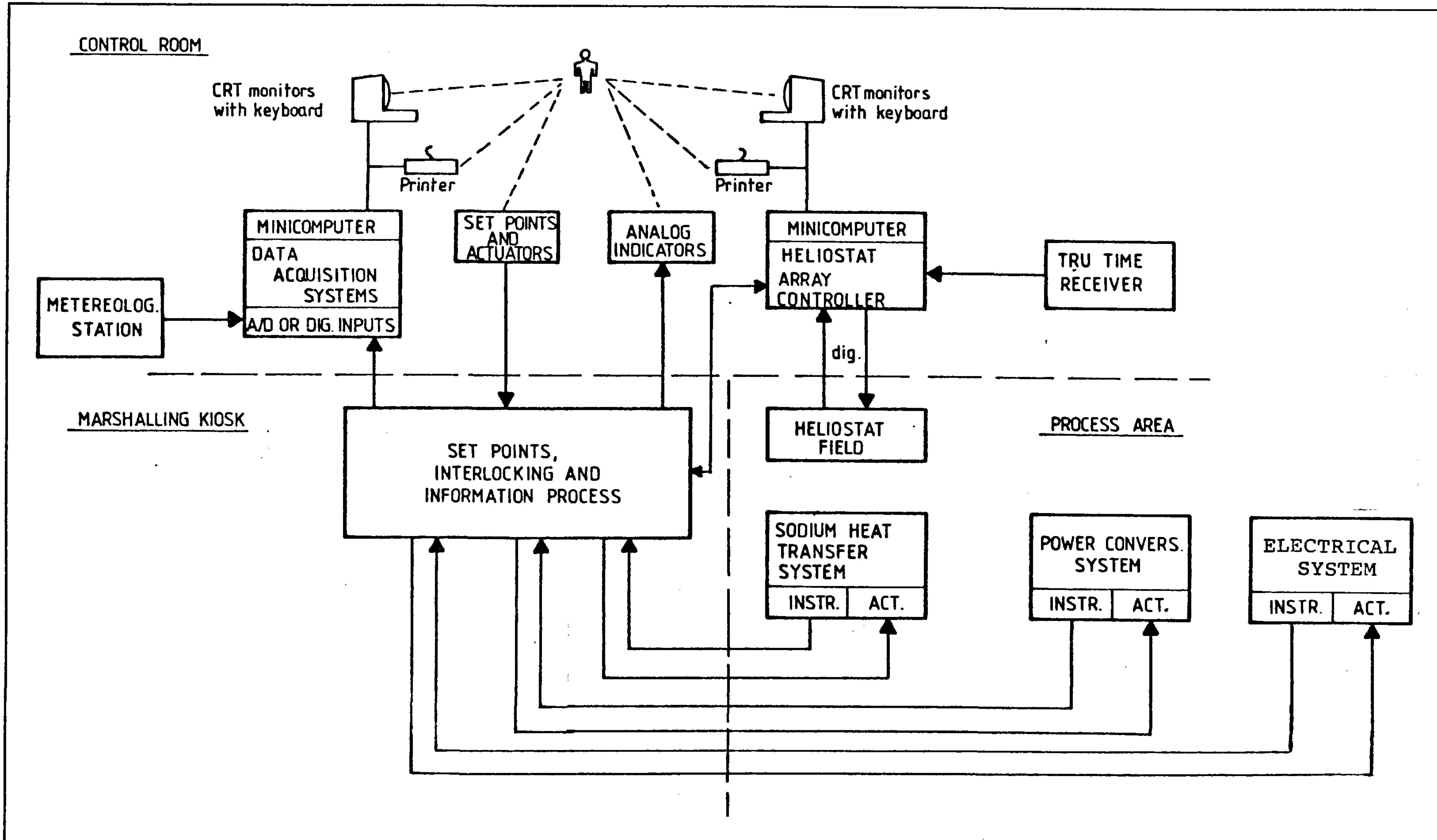

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FIGURE 1. 17 Control and Data Acquisition schematic

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The output signals of the various subsystem instrumentation sensors are transmitted to the Marshalling Kiosk and then to the DAS computer where they are converted from analog to digital format. These signals are also displayed as analog meter indications and discrete indicators on the operator's control console; these indicators are independent of DAS operations. The SHTS, PCS and MET analog signals are connected to the DAS acquisition subsystem via 240 current input channels (4 to 20 mA). The digital alarms and statuses are sent to the DAS by relay contact closure (1024 channels available).

The HAC computer transmits heliostat field data to the DAS computer on 1 asynchronous line at 9600 bauds.

Time and data generated by the TCG device is sent to the DAS through another RS232 asynchronous line.

- Hardware description:

  The Nucleus of the system is a MODCOMP 7835 mini-computer with 256 Kbytes of central memory, fast hardware floading point and FORTRAN accelerator.

  The 10 Mbytes disc is used for storage of programs, parameters and collected data during on line activities.

Historical filing of data and plant performances calculations is performed on a 800 BPI magnetic tape unit.

Communication with peripherals, HAC computer and TCG is performed through the Asynchronous Terminal Controller (16 full-duplex channels available).

The analog and digital acquisition is accomplished through MODACS III hardware (MODULAR ACQUISITION SUBSYSTEM), connected to the CLASSIC CPU by Direct Memory Access channels.

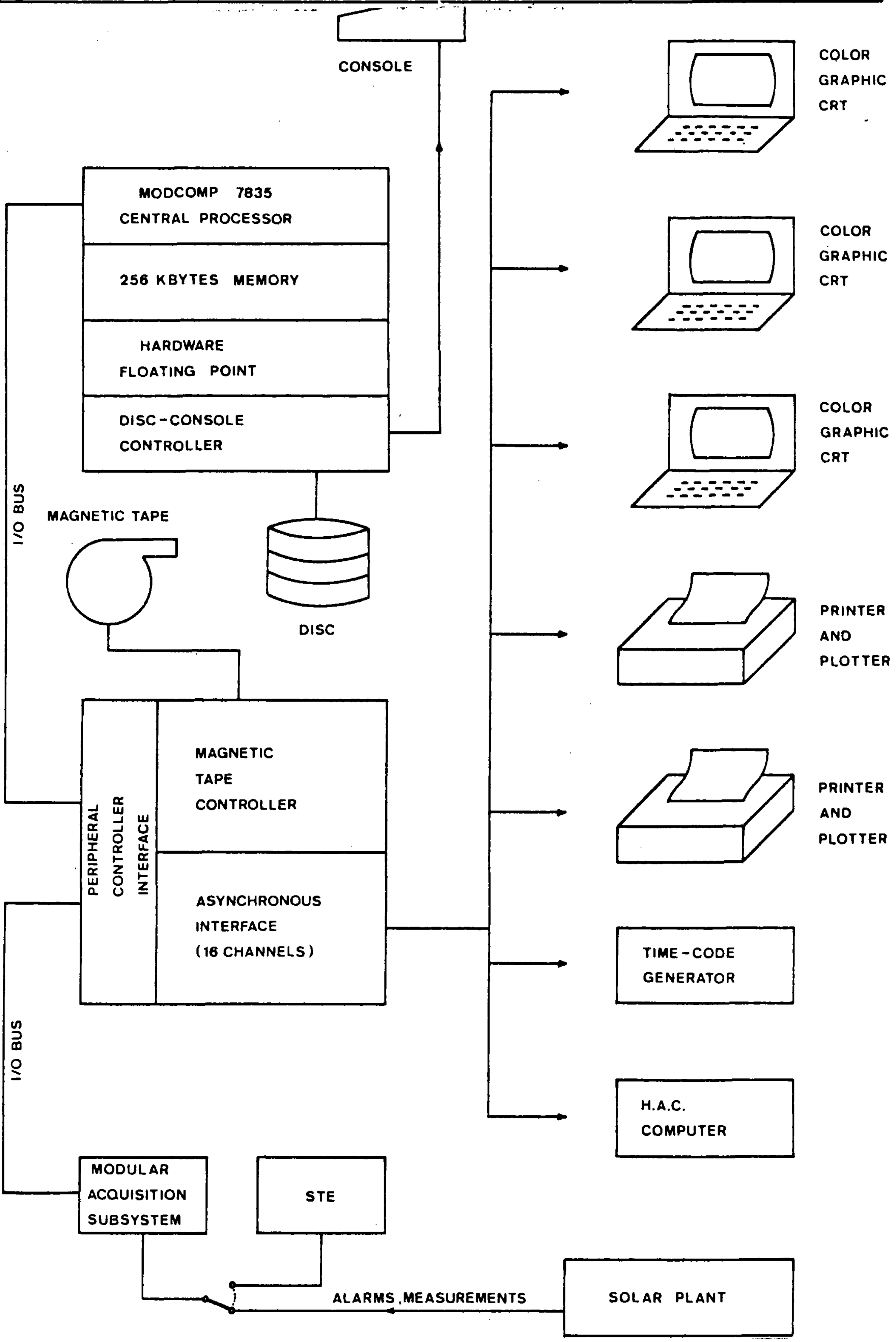
The analog (15) and digital (32) input cards, located in 3 files, are supported by 1 MODACS controller which performs the interface between the PROCESS input-output bus and the CPU I/O bus.

Three graphic color CRT's (INTECOLOR) with keyboard are used for interactive operator communication and real-time data display.

For hard-copy outputs and reports, 2 PRINTRONIX printer-plotters provide fast alphanumeric and graphic editing possibilities.

In figure 1.18 one can see the DAS-configuration.

FIGURE 1.18 D.A.S Configuration



1.7 Site Facilities

This includes all the necessary infrastructure for the plant components and the utilities and services required for a proper operation of the plant.

The plant is installed in the provided 300x300 m square as shown in figure 1.19

In figure 1.20 the site plan of both plants (CRS and DCS) with the shared site facilities can be seen. In this report however only the CRS-part is described.

a. Site preparation:

The greater part of the site area is occupied by the heliostat field. To allow easy maintenance of the heliostats and avoid unexpected shadowing and blocking effects due to terrain irregularities the heliostat field area has been graded according with the natural slope of the terrain. In order to avoid as far as possible dust in the mirrors, the complete surface of the terrain is covered by gravel. The building and common services area is levelled to a horizontal flat surface.

Because of the natural slope of the field, a heavy-rain-water drainage protection was made at the North side to avoid streams of water through the heliostat field in case of raining. This drainage is discharged near the north-east corner just outside the plant limits.

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FIGURE 1.19 Almeria Solar Platform

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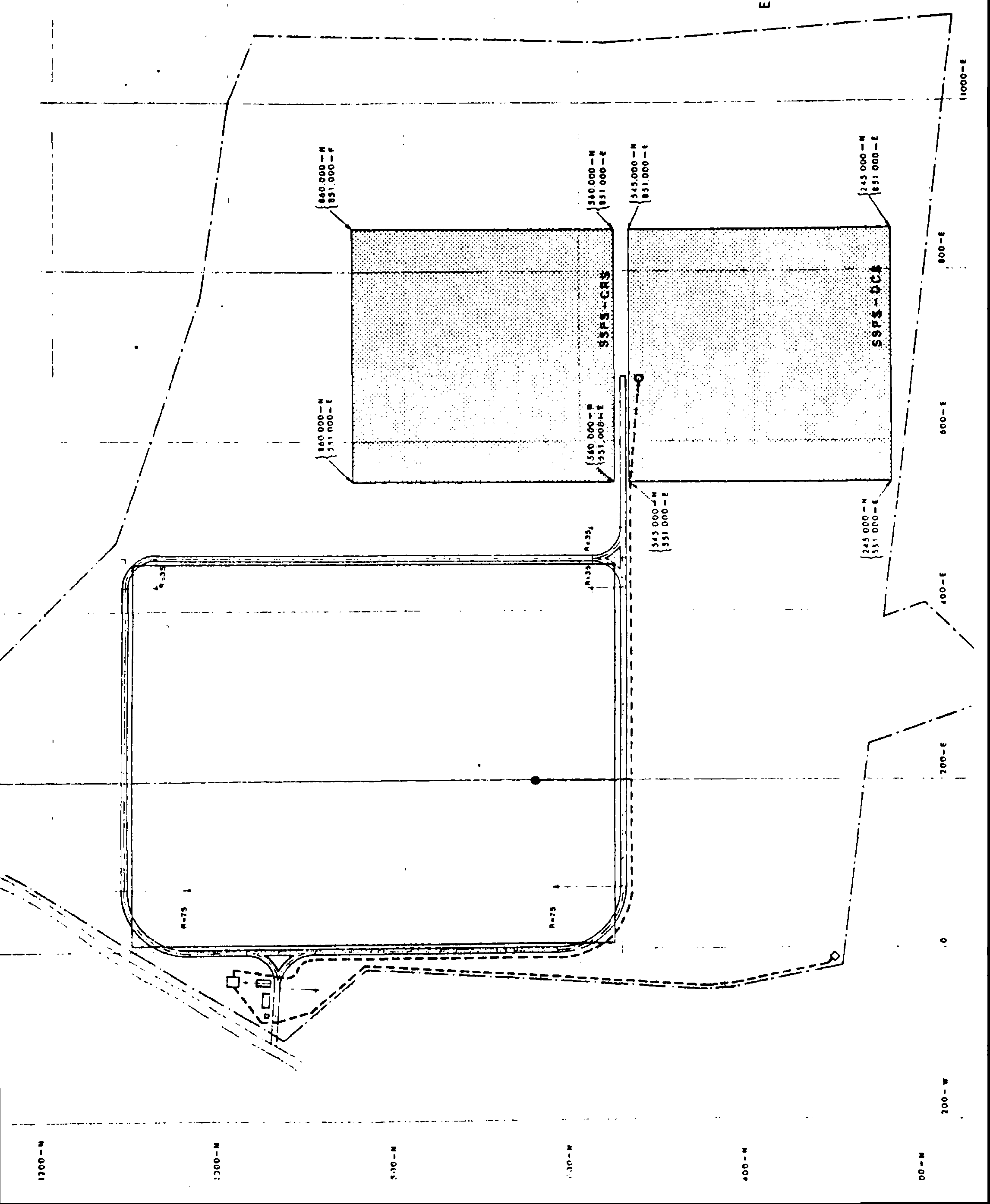

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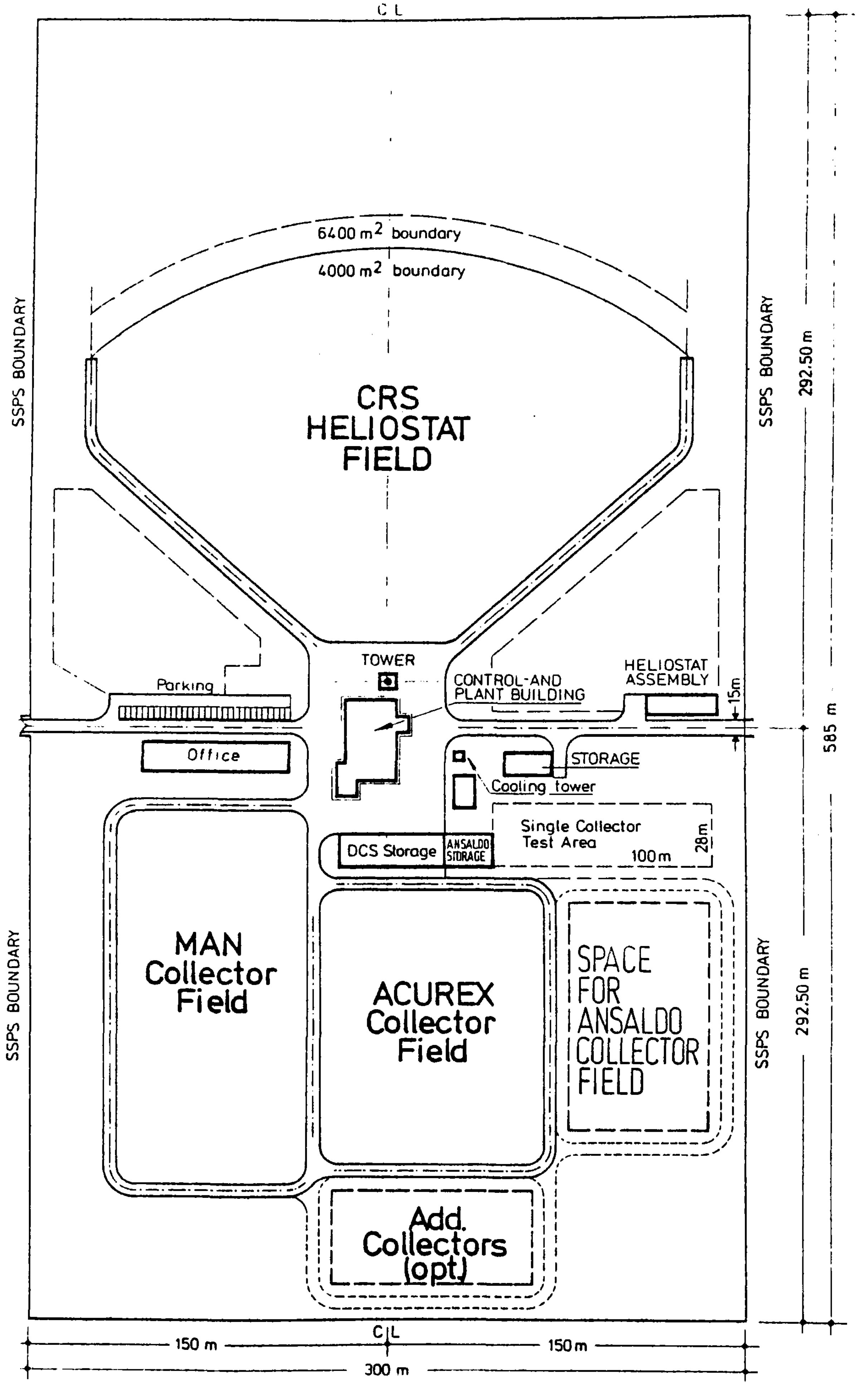
FIGURE 1.20 SSPS Plant Layout



At the south side of heliostat field a field drainage line discharges the collected rain water to outside the west boundary of DCS square.

In the heliostat field the tranches to arrange the heliostat cabling as well as the heliostat foundations are provided.

b. Tower

The tower consists of a free-standing steel structure to withstand on the top the receiver, its supporting frame and the associated equipment such as piping systems, electrical wiring, etc. The design is of such a quality that the functional requirements as well as the aesthetic requirements of the facility are met.

For accessibility, easy maintenance and installation of the tower itself, receiver and associated elements, a stairway has been provided from the corridor, connected with the main building, to the top platform.

The tower is erected on a reinforced concrete foundation.

In figure 1.21 a view of the tower and the connection with the sodium process area of the building is shown.

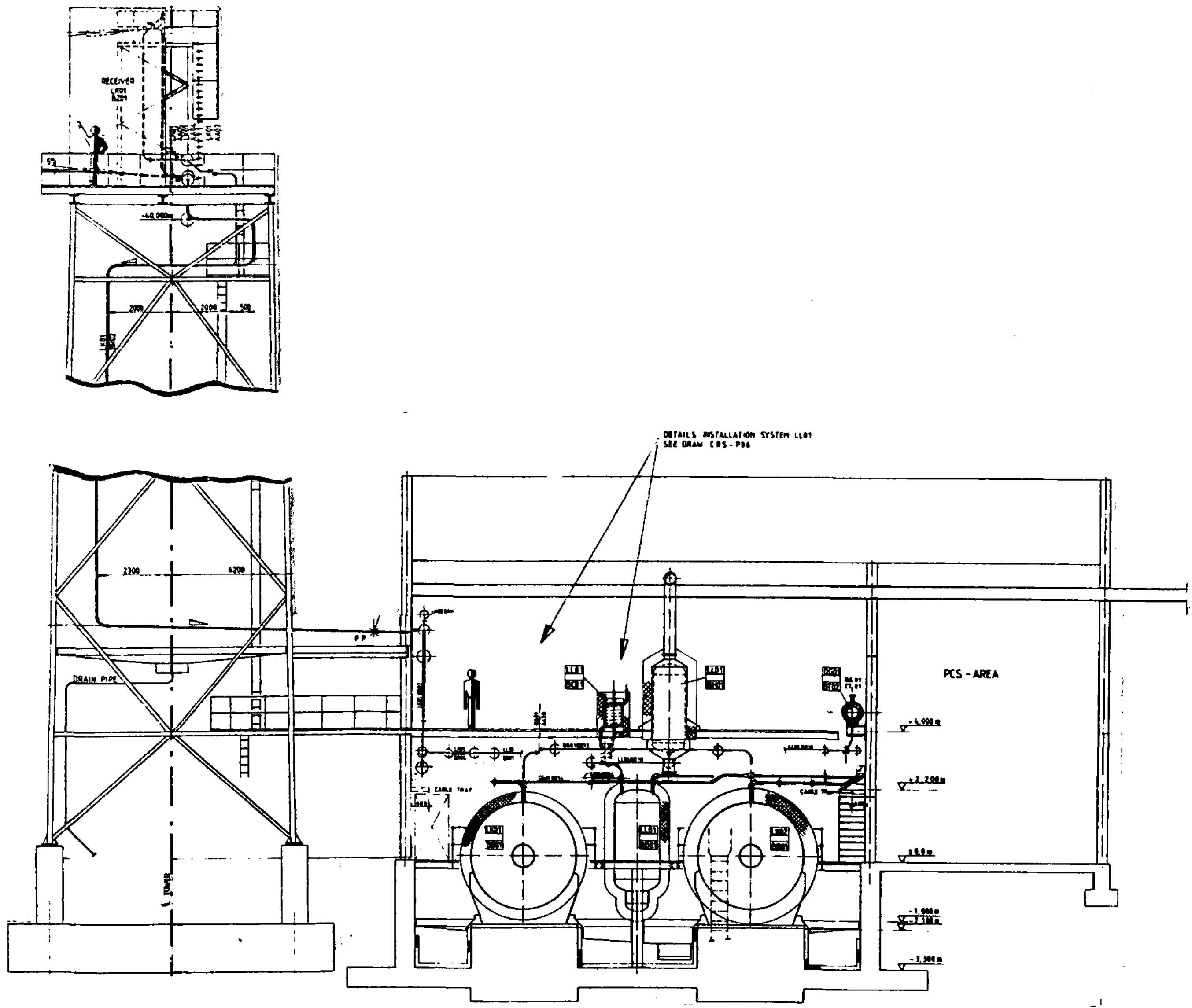


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Fig. 1.21 Tower and Building Process Area

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c. Main building:

The main building is designed for the common use of CRS-DCS plants and includes two separate well-defined zones, one connected to the other:

- building process area and
- administration, control and maintenance zone.

Inside the general building process area the CRS-plant comprises of:

- <u>SHTS-Hall; Steam-Generator Room - Sodium Heat Transfer System</u>

  The SHTS-Hall has a free inside floor space of 15.60 m x 14.40 m whereas the STG-room has one of 4.80 m x 7.20 m.

  The inside roof height is 15.50 m for the SHTS-Hall. For the STG-Room, the inside room height is 9.80 m; this makes a total of approx.4000 m^3 interior space. The floor levels are defined to - 3.30 m for the SHTS-Hall and to ± 0.0 m for the STG-room.

  The separating walls between the SHTS-Hall and the steam-generator room and the PCS-Hall respectively, has been designed as fire protection walls in solid-brick lining; this is also applicable to the wall to the supply and social buildings.

A bridge-crane unit is installed in a way that, after crossing the fire protecting wall, the PCS-Hall can also be attended.

Doors and gates are designed as single steel gates in double-wall version (fire-protection) according to the relevant rules.

A building heating is not necessary, only fresh-air supply is to be provided for via installed roof fans.

Daylight lighting by corresponding facade structure is foreseen.
The floor in the entire building part is covered with a sheet-steel cladding (sodium collecting pan). For the purpose of protection of the floor concrete against eventually appearing high temperatures, a space with insulation is provided below the sodium collecting pans.
Platforms, catwalks, stairs, covering and railing are adequately provided.

- PCS-Hall - Power Conversion System

For the PCS-Hall a free inside floor space of 15.60 m x 7.20 m is foreseen. The inside roof height here is 12.20 m, the floor level $\pm$ 0.0 m. The entire construction volume amounts to approx. 1400 m³ interior space whereby standardized grid sizes are taken as basis. This building part is separated from the SHTS-Hall by a fire-protection and splash-protection wall.

The wall to the supply and social buildings is also designed as fire protection wall.

Doors and gates are to be laid out similar to the ones of the sodium hall.

Similar to the SHTS-Hall and STG-Room, no heating is necessary here; also the fresh-air supply is provided via installed roof fans.

- Supply and Social Building - Electrical System

The electrical parts are located in the following areas:

Ground floor

	for
Marshalling Kiosk	(only CRS)
Battery Room	CRS/DCS
Emergency Diesel Rooms	1 for CRS & 1 for DCS
Transformer	CRS/DCS
H.V. Switch Room	CRS/DCS

The total area is approx. 101.0 m^2.

At a room height of 3.80 m, this gives a total space of approx. 384 m^3.

First floor

Main Control Room	CRS/DCS
Computer Room	(only CRS)
L.V.Switch Room	CRS/DCS

The total area is approx. 82.8 m².

This gives, at a room height of 3.40 m, an interior space of approx. 281 m³ (total).

Doors and gates are to be laid out as before.

The floor in this building part is to be provided for as hard-cement layer with a concrete-seal coating.

In the control, computer and L.V. switch-gear rooms, a double floor is provided.

In the rest of the building light floor incline to a pump sump is available for the purpose of collection of the leakage water. Several ground channels for the location of the electrical cabling are to be provided for.

The floor of the electrical rooms at the ground floor is made of hard cement with a concrete seal coating; only the battery room with its lock must be provided with a floor base of acid-proof ceramics plates.

The oil-tank part is equipped with a collecting pan floor with oil-resistant coating.

The computer room, main control room and marshalling kiosk are air-conditioned.

Emergency diesel and transformer have inlet- and outlet-air openings.
The battery room is equipped with a separate inlet- and outlet-air unit (acid-proof) and is provided with an eye-wash accomodation.

A plot plant of the main building is given in figures 1.22 and 1.23. Representative views of the process area provided in figure 1.24. The equipment layout in the control room can be seen in figure 1.25.

d) Utilities and services:

The major needs covered by this point are the following ones:

-
- Signalisation for air navigation
- Plant ventilation and air conditioning system
- Domestic water system
- Sanitary drainage system
- Sewage system
- Conventional fire protection system
- Raw-water system
- Maintenance workshop.

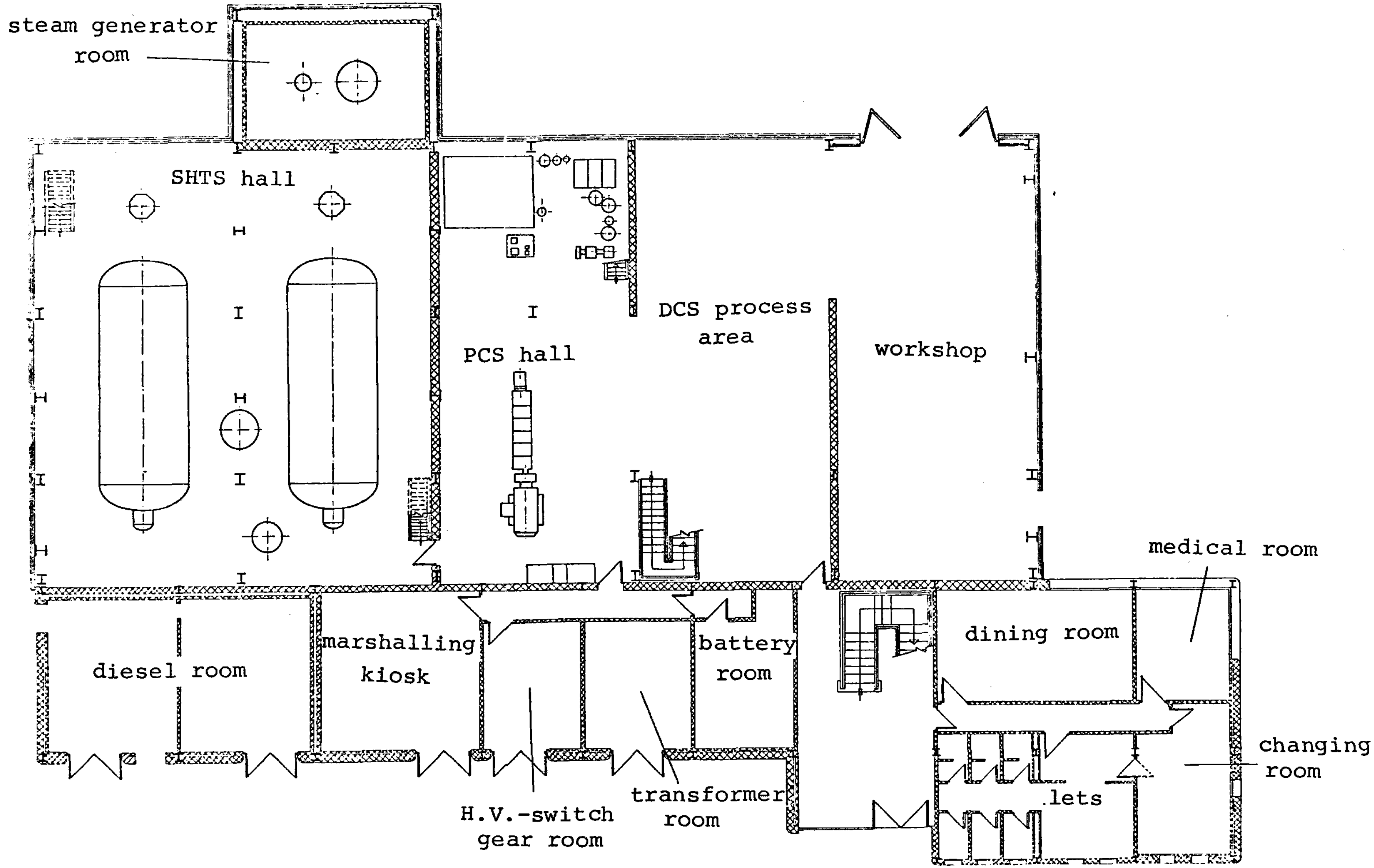

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FIGURE 1.22: 0.0 m Level Main Building Plot Plant

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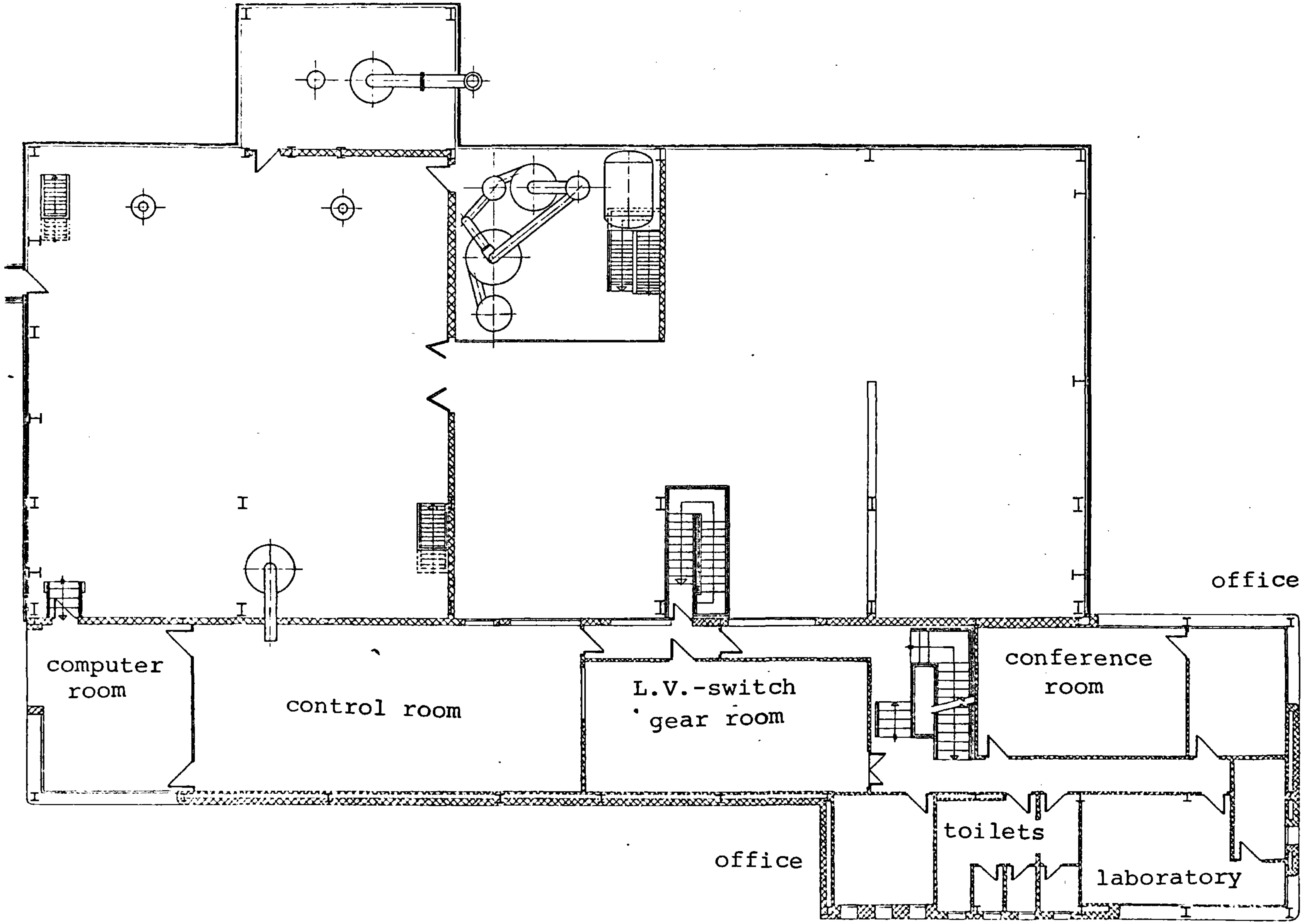

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FIGURE 1.23: 4.0 m Level Building Plot Plan

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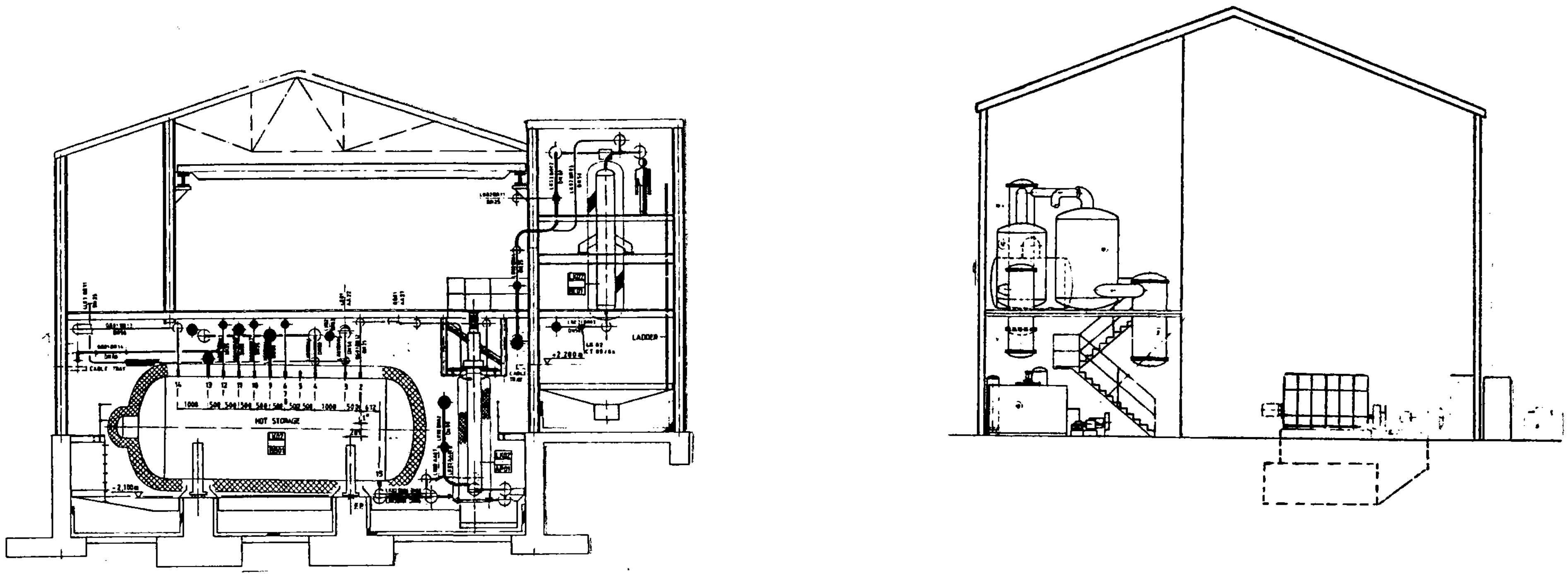

SSPS

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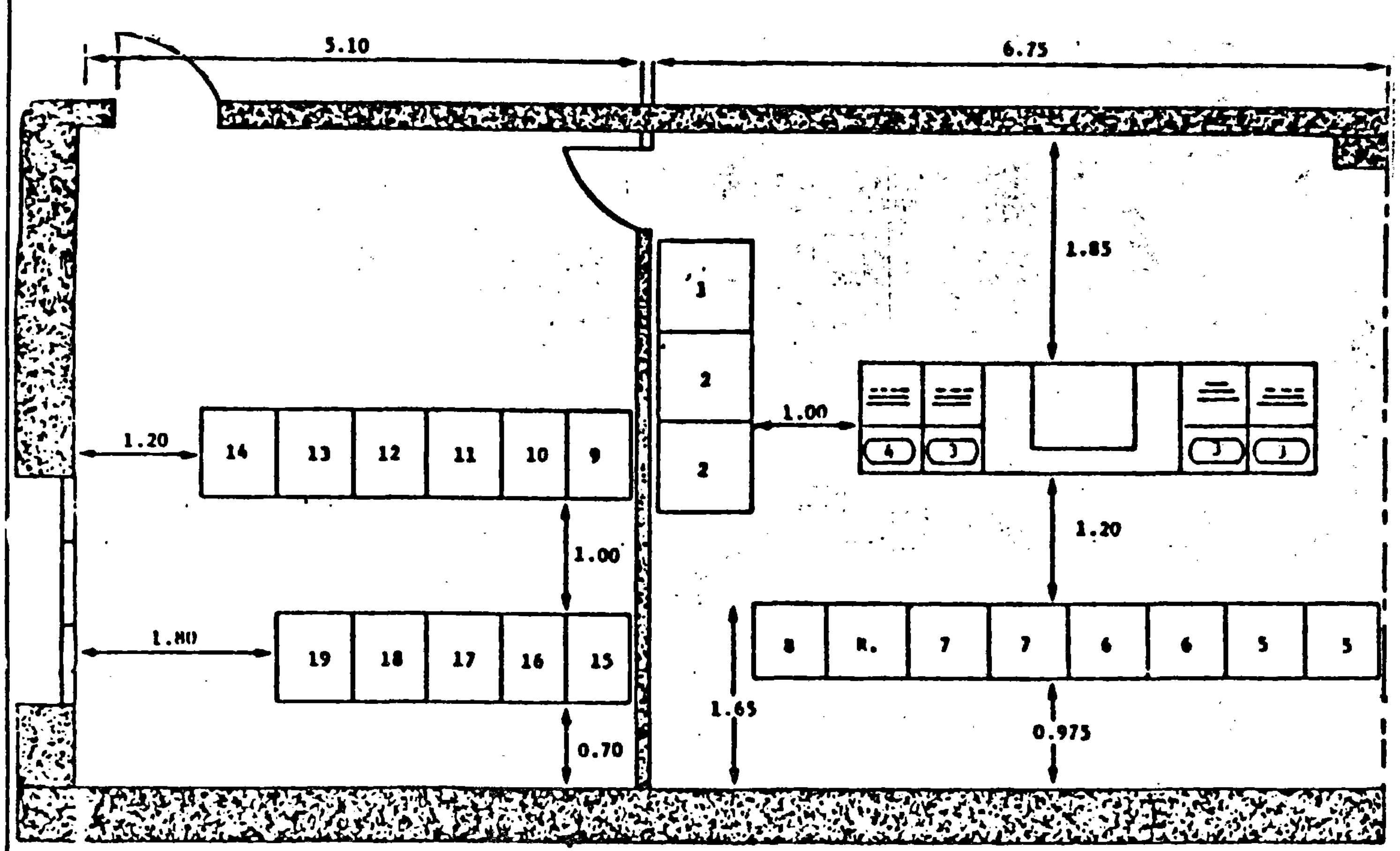
Fig. 1.24: SHTS and PCS Process Area Views

INTERATOM
INTERNATIONALE ATOMREAKTORBAU GMBH

11211/10-79/2 (SSPS/002/4000)



1 HAC Printer

2 DAS Printer

3 DAS TV Monitor with Keyboard

4 HAC TV Monitor with Keyboard

5 Wall Panel CPS

6 Wall Panel PCS

7 Wall Panel HTS

8 Recorder for Plugging Meter and Gas Chromatograph

9 DAS Computer Cabinet

10 DAS Magnetic Tape Unit Cabinet

11 DAS MODACS Cabinet

12 DAS Disc Cabinet

13 DAS MODACS Cabinet

14 DAS Connections Cabinet

15 HAC Analog-to-Digital Conversion Cabinet

16 HAC Magnetic Tape Unit Cabinet

17 HAC Disk Unit and Controller Cabinet

18 HAC Computer Cabinet

19 HAC Operator Console Modcomp TI-820

R. Reserved for additional equipment

SSPS

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Figure 1.25.: Control Room Equipment Layout

INTERATOM

INTERNATIONALE ATOMREAKTORBAU GMBH

ANNEX

CRS MAIN CONTRACTOR	KIND OF CONTRIBUTION
INTERATOM	- PLANT ENGINEERING
SUBCONTRACTORS	
- CASA	
- JUNTA DE ENERGIA NUCLEAR	
- B.V. NERATOM	- ENGINEERING SERVICES
- BELGONUCLÉAIRE	
- SULZER AG	- RECEIVER, STEAM GENERATOR
- VOEST ALPINE AG	- SODIUM STORAGE TANKS
- DEGUSSA AG	- SODIUM METAL
- P. KAHLE	- PIPING SYSTEM
- BYRON JACKSON	- SODIUM PUMPS
- F.S. STÖHR	- SODIUM AND GAS VALVES
- DR. STARCK & CO.	- INSULATION, TRACE HEATING
- E. GESSNER KG	- COLD TRAP, HEAT EXCHANGER
- SPILLING CONSULT KG	- POWER CONVERSION SYSTEM
- SIEMENS AG	- POWER SUPPLY, INSTRUMENTATION AND CONTROL
- ZIEGLER GMBH & CO. KG	- FIRE FIGHTING SYSTEM
SUBSYSTEM CONTRACTORS	
MARTIN MARIETTA	- HELIOSTAT FIELD SYSTEM AND CONTROL
S A I T	- DATA ACQUISITION SYSTEM

1192/10-79/2 (SSPS 009/4000/B)