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POWER PLANT OF CREYS-MALVILLE - OPTIONS AND DESCRIPTIONS

(Centrale de Creys-Malville - Options et Description)

By

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by

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1975 Conference of ANS at Paris France

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SUMMARY

The power plant of CREYS-MALVILLE is the third stage of a program which began with the experimental pile RAPSODIE and the demonstration power plant PHENIX. This is a first industrial realization in which the prime contractor will be NERSA and of which the steam plant will be supplied by the SUPER-PHENIX group under license of the Commissariat á l'Energie Atomique (CEA).

The power plant of CREYS-MALVILLE will be a base loaded power plant. The essential of the options which were taken for PHENIX, were preserved. (fuel UO 2-PuO 2, integral primary system, core instrumentation, handling mechanisms etc...). The principal modifications have to do with the number of secondary systems, the primary sodium purification system, and the steam generators etc. A general description of the power and its operation is given.

The preliminary excavation work has started. The preliminary safety report is being reviewed. The construction permit should be given this year.

(Translators note: report has no date)

I - INTRODUCTION -

France has been engaged for approximately 20 years, in the study and development of fast sodium-cooled reactors. This has been characterized in three stages:

- The realization by the Commissariat á l'Energie Atomique of an experimental reactor, RAPSODIE, started in 1967, at a power of 20 MWth, and increased to 40 MWth under the name of FORTISSIMO, in 1970. This reactor is actually an indispensable tool for performing experimental irradiations.

- The construction of a demonstration power plant PHENIX with a power of 250 MW electric by a joint team of Commissariat á l'Energie Atomique - Electricite de France - (E D F). This power plant allows testing of materials in large scale under representative conditions. Further, it allows performance of irradiations of important quantities of fuel under conditions of fluence as in a commercial reactor. Coupled to the French network since December 1973, it has, during its first performing year, a production of electricity quite comparable to that of a fissile power plant.

- The following stage, actually in progress, is the realization of a power plant at CREYS-MALVILLE with an electric power of 1200 MW, a stage that precedes that of the large commercial power plants. The question is to realize an installation able to generate electricity under conditions that may be compared with other power plants equipped with proven reactors, and especially with the light water nuclear plants, whether considered from the point of view of safety, reliability, construction or operation.

For this power plant, the prime contractor and operator is the Societe NERSA (Centrale Nucleaire Europeenne Rapide, Societe Anonyme) which combines the three large Europeans electricity producers: Electricite de France, (E.D.F.) ENTE NAZIONALE PER L'ENERGIA ELETTRICA (ENEL) and RHEINISCH-WESTFALISHES ELEKTRIZITATSWERK (RWE), their participation being respectively of 51%, 33%, and 16%.

The supply of the nuclear steam plant is assured in the framework of a unique responsibility, by the SUPER-PHENIX group which consolidates the Societes ALSTHOM-NEYRPIC, FIVES-CAIL BABCOCK, NUCLEARE ITALIANA REATTORI AVANZATI (NIRA) and TECHNICATOME. The Super-Phenix boiler is the object of a license, granted by CEA to the Groupement pour les Neutrons Rapides (fast neutrons), formed by ALSTHOM-NEYRPIC and FIVE-CAIL BABCOCK and NIRA. The necessary information is transmitted to these enterprises by TECHNICATOME acting in the name of CEA. The Groupement pour les Neutrons Rapides (GNR) has for its vocation the industrialization and commercialization of the fast-neutron steam plant regenerators in France. The Société NIRA plays the same role in Italy.

SUPER-PHENIX group has for its authorized agent, ALSTHOM, and has entrusted the engineering to a joint team, organized by agents of CIRNA (a subsidiary, consolidating in the field of fast neutrons, the means of the Societes TECHNICATOME and of the Groupement pour les Activitees Atomiques et Avancees (GAAA) and that of the NIRA.

The development of the three stages named above was assured thanks to the program of research followed by the Commissariat á l'Energie Atomique (CEA), and to which the Services de Recherches de l'Electricite de France, were closely associated.

2 - SPECIFICATIONS AND BASIC OPTIONS

The different characteristics of the power were established or selected from certain options, fixed from the beginning of the project study. These options themselves derive from the large characteristic choices of the type of channels, and the state of development of the particular characteristics of the structures planned for the project, etc....

2-1 - SPECIFICATIONS

The first concern of the designer was, no doubt, to assure the continuity with PHENIX, which has had satisfactory performance. The characteristics and new materials of the channels were thus tested at a representative scale. A pure and simple reproduction for CREYS-MALVILLE of the adopted solutions for PHENIX is the assurance of a satisfactory functioning of the installation. Of course, the acquired experience, allows management of those solutions. A second preoccupation was to conceive, within possibilities, a power plant able to operate as a "base load plant", which is to say, able to satisfy the demands of a national network in the manner as a nuclear plant of another type. It is in that perspective that primary concern was given to reliability of the installation, and that annual refueling was chosen.

Another specification quite in line with the above, is to prefer deliberately, when choice permits, tested materials and solution to others requiring preadjustment.

Last, a new and particular element at CREYS-MALVILLE has influenced certain basic options: the question of foreign partners participation in the project. If the power plant, built on French territory must satisfy all French regulation, particularly in matter of safety, it is indispensable that the chosen solutions conform to the foreign specifications Italian and German, whenever they exist. It is from those varied specifications that the following basic options were established.

2-2 - THE BASIC OPTIONS

The SUPER-PHENIX reactor of the CREYS-MALVILLE power plant, follows in the continuity of PHENIX, taking advantage of the knowledge acquired during the conception and building of the demonstration power plant, knowledge which completes and will complete little by little the experience of its operation. The wide fundamental choices and options of sodium as the heat transfer medium, and mixed oxides of plutonium and uranium for the fuel are repeated.

The principle used in PHENIX of the secondary circuit in sodium is conserved because that secondary fluid constitutes in itself a barrier between the active and contaminated primary sodium and the steam system. This leads only to a classic chemical risk of sodium-water reaction in the case of a rupture of the primary barrier within the heat exchangers. The number of secondary circuits is chosen equal to four, in order to favor the safety of normal reactor cooling and limiting as well the factors of extrapolation of the components, such as the pumps and intermediate exchangers on the one hand, and to simplify the design and installation and moreover by adopting the same design for all the circuits.

The concept of the integrated primary circuit in the reactor vessel is repeated, the experience of PHENIX having shown that:

- The compact implantation of the components of the reactor, (pumps and intermediate exchangers) is no particular design problem.
- The sodium circulation pattern in the reactor is now resolved and the natural convection makes a good guarantee of final cooling.
- The absence of pressure in the cooling circuits makes the components design relatively simple, allowing in particular an easy installation of the vessels and the internal structures of the reactor on the very site of the power plant. We remind that this concept, as for PHENIX, presents as well for SUPER-PHENIX the advantages of:
- Ease of confinement of the reactor unit, and afterwards, of the contaminated and active primary fluid, as well as the argon circuits.
- To ensure a large safety of core cooling even in case of rupture of the reactor vessel.
- To dispose of a large thermal inertia permitting easy removal of the decay heat in all cases.

In order to extend the integrated primary circuit principle to its maximum, the primary sodium purification system which was outside the reactor (which transports the active sodium out of the vessel) is placed inside the reactor vessel.

As for PHENIX, the core instrumentation consists of measurement of temperature at the exit of each fuel assembly, detection and localization of cladding failure by sampling of the sodium at the exit of each assembly and measures of variation of reactivity.

Bearing in mind the plant electric power of 1200 MW, the 17 MW steam generators used in large number for PHENIX, has not been retained because that solution becomes too expensive for SUPER-PHENIX. Thus it was decided to implant a steam generator in a loop; rough models of 45 MW were already tested successfully in the EDF installations, at RENARDIERES, during the year 1974. The handling of the core assemblies is accomplished with installations similar to that used for the PHENIX power plant. The transfer of an assembly in the reactor is obtained by means of two rotating plugs, and two transfer machines, a technique used for the RAPSODIE reactor, allowing vertical intervention of each assembly.

The assemblies are unloaded by means of a "SAS A TOURNIQUET"[*] without previous storage for decay in the core, then moved to a storage drum in sodium. They are afterwards released, complete, in casks filled with sodium, insuring a thermal joint, taking into account the high level of decay heat. These solutions allow reduction of quantities of plutonium immobilized at the power plant, and to reduce the cost of the fuel cycle.

Contrary to PHENIX, the steam cycle with reheating by the sodium was not retained. The reheat is accomplished with steam instead of sodium, which allows a simplification of the steam generators and associated circuits without a considerable reduction in the thermodynamic efficiency of the installation.

Keeping in mind the exposed specifications named above, the solution of two 600 MW turbogenerators groups has been retained using only materials which have been proven on other installations.

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[*] Possibly a chamber attached to a turnstyle. See Figures 6 and 7.

Last, handling installations were placed in the reactor building thus insuring the secondary confinement of the fuel assembly during handling. So all active products remain confined in one building.

3 - GENERAL DESCRIPTION

3-1 - SITE AND GENERAL IMPLANTATION OF THE POWER PLANT

The site of the power plant is on the territory of the community of CREYS-PUSIGNIEU (Isere) 60 km east of Lyon, and 32 km upstream on the Rhone, from the site of Bugey. It is located in an area essentially agricultural, having to keep away from large industrial sites.

The density of the population around the site is light: 31 inhabitants per square kilometer within a 10 km radius. Large agglomerations (BELLEY, LA TOUR DU PIN, BOURGOIN, AMBERIRU EN BUGEY, AIX LES BAINS, CHAMBERY) are all situated at least 20 km from the site. The future planning of the LYON-ST-ETIENNE-GRENOBLE metropolis does not foresee any considerable increase in the population within a 20 km radius around the power plant.

The power plant is situated 40 km from the LYON-BRON airport, and 30 km from the future international airport of LYON-SATOLAS which will open between 1975 and 1980. It will be outside of any "airport zone" where statistically, most accidents occur at take-off and landings, and outside of LYON-SATOLAS approach patterns. The subsoil is formed by sandy-gravelly clay in large thick layers with sufficent permeability, allowing for adequately foundation to support the buried parts.

The Rhone, until site level, has an ice-level with low water during the winter months. The annual average flow is 443 m3/s. Once in a thousand years, the flow could be as high as 3.500 m3/s. The dam at Genissiat situated 90 km upstream, stabilizes the river flow, which is sufficent for 3000 MWth power plant cooling by connection and direct rejection of the cooling water.

The site of Creys is situated in a province withe a seismic classification of zone VI on the MSK scale, bordered by the Jura province classified in zone VII intensity. The strict application of the geological information leads to a paired assignment (VI, VII) for the maximal probable earthquake, and the major earthquake of safety. The horizontal, maximal calculated values of acceleration on the ground, (0,10 g and 0,20 g) correspond in fact at a superior classification for matter of safety.

3-2 - BUILDINGS - CIVIL ENGINEERING

The group of buildings is situated on a platform of about 600 x 300 m at an elevation of 208 NGF, or 1 meter above the flood level of the Rhone. This platform is made of an embankment with materials taken from the terrace west of the site, light structures located on the bank, the heaviest (reactor, turbo-generators groups) resting on the land. The structures on the site include from north to south, a group of nuclear plant buildings described as follows (Figure 1):

- A reactor building formed by a circular enclosure in reinforced concrete of 64m inside diameter, 1m thick, and a height of 80m. It shelters the nuclear installations which are: the reactor unit, surmounted by its metallic dome (primary enclosure); the active auxiliary circuits; the handling of new and irradiated assemblies by the special handling mechanism; a part of the secondary sodium circuits, (intermediary exchangers, secondary pumps and connecting piping). This building rests on a natural bed with a surface at the level of the platform, 208 NGF (Figures 2 and 3).

- Four steam generator buildings placed radially in the periphery of the reactor building. They each shelter part of a secondary loop exterior to the secondary confinement formed by the concrete enclosure of the reactor building (Figure 4). Each building has an excavation device in the ground of 25 x 25m and of about 50m in height.

- It is formed by a reinforced concrete infrastructure resting on a natural floor, and of a height of +13m. This infrastructure bears in metallic support superstructure of the steam generators and piping.

- Three buildings of nuclear auxiliaries -The non-active nuclear auxiliaries are contained by these three buildings, placed at the periphery of the reactor building in 3 of the 4 free sectors delimited by the steam generator building. These three buildings are founded on a natural floor and are separated from the reactor building by an annular zone of 2.50m through which pass most of the connections between the reactor building, the nuclear auxiliaries, the steam generators and the rest of the power plant.

- A sodium storage building for the first filling of the reactor as well as for nitrogen and argon storage situated west, and detached from the main buildings.

- The engine room which contains both groups of turbogenerators and associated water supplies. It is separated from the reactor building by an intermediary bay. 6m in width, used for circulation and passage of pipings and cables. The civil engineering design of the engine room building consists of reinforced concrete, from its foundation up to the machinery floor, and steel frame structure above. The connections with the control building are in the basement for the cables, with a footbridge for the personnel. Connected to the engine room building are:

-West, general auxiliaries buildings (auxiliary boilers, raw water storage, demineralization station, compressions).

-South, the platforms of the main transformers.

The control building - This reinforced concrete building is built parallel to the engine rooms, on the Rhone side, and at a total height of 13m. Conceived in order to realize a geographic separation of two redundant routes for power supply and control circuits for the reactor equipment; it consists of:

-A north aisle and a south aisle, each containing a cable way for each electric auxiliary.

-A central nucleus, separated from the aisles by anti-missle and fire proof concrete walls, preventing the simultanecus loss of both redundant routes contained in the aisles in case of fall of a small plane, and reducing the risk of general fire in the building. This central nucleus contains in particular the control room and its annexes (local and operations offices). The electric connections between the control building and other buildings proceed into underground galleries, respecting the total separation of both routes. To both north and south extremities are joined to each aisle two reinforced concrete buildings, each, containing two emergency generators.

In the extention of those buildings, we find:

-North: the building of offices, shop and workshop.

-South: the platform of both auxiliary transformers 225, 000/6, 600V.

-The pumping station situated at the edge and upstream of the Rhone, includes;

-The circulation pumps

-The raw water cooling pumps of the safety system, (2 groups of pumps and 2 well separated circuits).

-Fire pumps.

The circulation water, after its passage through the condensers of the turbogenerator groups and diverse cooling systems is emptied into the Rhone at a reject station situated slightly downstream of the engine room. All water pipes are buried.

3-3 - NUCLEAR REACTOR

With a power of 3000 MW, it includes essentially a reactor of the type "integral primary system", connected to the steam generators by four secondary loops.

At the center of the cover slab are two rotating plugs, one excentric in relation to the other, permitting removal of all fissile and fertile assemblies, safety assemblies, as well as part of the protective rods, implanted in the false grid (Figure 5).

The reactor scram system includes 21 control rods, three of which insure core regulation by adjusting reactivity, constituting the main scram system on one hand, and three particular safety rods forming the complementary scram system, on the other hand. The control rod units and their mechanisms are supported by the "core cover plug," implanted in the small rotating plug. This structure also supports 3 plugs "local rupture sheath." Besides, 2 thermocouples for each assembly allows surveillance of the sodium temperature at the exit of each assembly.

The cover slab carries the four primary pumps, the 8 intermediate exchangers, a purification system for the integral primary sodium, and the loading-unloading installation for the reactor assemblies. The integrated primary sodium purification system includes an electromagnetic pump, and a cold trap submerged in the hot sodium of the primary vessel. The loading-unloading installation, consists of a "SAS A TOURNIQUET" (Figures 6 and 7), extending into the reactor by a handling ramp. A valve, at the end of the reactor unit insures tightness of the latter, in periods of operation. An enclosure around the reactor unit insures the primary confinement. At a lower part, it is formed by the safety vessel completely surrounding the reactor main vessel which is welded to the slab. At the highest part this confinement is insured by a metallic enclosure with a cylindrical barrel surmounted with a dome (Figure 6). An ultimate emergency circuit, composed of two networks of tubes traversed by water and implanted around the safety vessel and under its own bottom, is able to release the reactor decay heat after a full power operation.

Handling of the assemblies - (Figure 7) It includes a unit of apparatus and installations to handle fuel assemblies, blanket and control assemblies, and a part of the safety assemblies as follows:

-The transfer from one location to another in the reactor by means of the two rotating plugs and of the two transfer machines.

-Reactor unloading and loading from storage, by means of two carts circulating on inclined ramps, connecting the reactor unit to the storage by a sealed "SAS A TOURNIQUET" (Figures 6 and 7); a pot filled with sodium placed on each cart insures the removal of the decay heat from the assemblies. The storage allows a certain decay of the assemblies before their removal thanks to the "BARILLET" (Figure 7) made of a carrousel placed in a vessel filled with sodium and which receives the bare assemblies. The decay heat brought by the assemblies is removed by means of 2 independent sodium systems connected to air cooling systems; the transfer of the assemblies into the "BARILLET" at the bottom of the ramp to the different rings of a carrousel is accomplished by a rotating plug and a transfer machine:

-the extraction from the "BARILLET" and introduction of the removed assemblies into the conditioning room is done via the handling passageway.

-assemblies conditioning and removal; at this point, each assembly is lead inside a cask which is then filled with sodium and sealed. The casks are then placed into a transport tower placed under the room.

-storage and conditioning of new assemblies in a special room where the assemblies are placed in pits.

-introduction of the new assemblies into the "BARILLET" by means of a hood which insures the transport of each assembly separately from the conditioning well located in the new assemblies room, until it reaches the storage barrel.

The main secondary circuits (Figure 8) - They are essentially made of 4 independent loops, each, made of 2 exchangers, implanted into the reactor main vessel, a main secondary pump with a vertical axis placed at the bottom of a spherical expansion reservoir, and a steam generator unit.

Each intermediate heat exchanger receives the sodium discharged by the secondary pump into a vertical collector going through the exchanger center. The sodium circulates afterwards from bottom to top inside the bundle of tubes. The hot primary sodium current coming from the core penetrates through the upper window of the exchanger then circulates from top to bottom parallel to the tubes and exits radially. The upper window can be sealed by lowering a cylindrical ring when the loop is out of service.

Steam generators are unitary and of the "once through" type. The secondary pumps are activated by a variable speed motor. They also have an emergency motor of reduced power. In case of simultaneous failure of all steam generators, the power plant is stopped and installation consisting essentially of 4 sodium-air exchangers connected in parallel with the 4 steam generators allows release of decay heat even with natural convection of air.

The auxiliary circuits - The auxiliary circuits of primary sodium are reduced because the purification installation is integrated into the reactor. They include essentially the piping and the electromagnetic pumps permitting the transfer of sodium between the three storage reservoirs of the reactor building and the reactor itself.

The argon auxiliary circuits of the reactor allow the reactor argon atmosphere to communicate with the three reservoirs of the primary sodium. Some filter-condensers placed between the reactor and its reservoirs allow the trapping of aerosols and sodium vapor, and cooling of the argon. The reservoirs insure the decay of the short lived products. Passage through active charcoal traps with liquid nitrogen cooling, removes the gaseous products. The argon, then purified, is reused for the barrage circuits of the reactor unit mechanisms.

The auxiliary sodium circuits of the "BARILLET" consist of two independent decay heat removal circuits by some sodium-air exchangers of which the exchanger tubes are rolled inside of the barrel vessel. They also include an installation of sodium purification.

The argon secondary auxiliary circuits are made to regulate the cover gas pressure in the expansion reservoirs of the secondary pumps, the storage reservoirs of each loop, and to regulate the sodium level in the steam generators.

The secondary auxiliary sodium circuits include a purification installation by loop and a discharge circuit which receives the products from a sodium-water reaction in the highly improbable case of a leak occurring in the steam generators. They also include by loop, an installation of hydrogen detection composed of an electromagnetic pump with a selection of several sampling channels and one analyzer using the principle of hydrogen diffusion across a wall of nickel.

The annex circuits - For its normal operation the reactor must have several annex circuits, the main ones being as follows:

-The cooling circuit of the cover slab and the rotating plugs (independent double supply).

-The completely redundant ultimate emergency system;

-The organic liquid circuit insuring the cooling of the cold traps of purification, sodium and argon;

-The steam circuit and the auxiliary boiler for the preheating of several reservoirs;

-The nitrogen circuit for filling and regulation of the intervessel atmosphere.

3-4 - ENGINE ROOM

Conceived for 2 turbogenerators groups of 620 MW, the engine room is divided in two identical parts deducting each other by translation and each corresponding to a group and its auxiliaries.

-The turbine is made of a high and medium pressure (HP-MP) section, and two low pressure (LP) double flow sections.

-The steam admission to the HP-MP section is effected by two pipes coming from a "barrel of banalization" (moisture separator ?) at the exit of the steam generators.

-Five drain points (3 on the HP section, 2 on the LP section take the steam to be used for reheating the feed water.

-The alternator has the following characteristics:

. Electric power: 690 MVA

. Power factor: 0.9

. Nominal voltage: 20 kV ± 5%

. Nominal frequency: 50 Hz ± 1%

The stator windings are cooled by a demineralized water circulation. The rotor and the stator magnetic circuit are cooled by circulating hydrogen. The excitation is of the static type with thrystors.

-A bypass circuit capable of at least 60% of nominal flow, and including isolation valves, some expansion valves and a desuperheating system, allows the steam produced by the steam generators during the starting phases to pass directly to the condenser.

-A water station is associated with each turbogenerator group.

It includes the following installations:

. Two full flow extraction pumps.

. A station for continuous treatment of the condensate, able to insure treatment of the total water flow.

. Two rows of reheaters fed by the two low pressure (LP) drains.

. A degassifier tank fed by the steam coming from:

-either, the drawoff, placed at the turbine HP (high pressure) exhaust.

-either from the barrel of live steam.

-either from the "balloon d'eclatement" (literally: bursting balloon; see Figure 9) used during the phases of startup and shut down of the steam generators.

-either from the auxiliary boilers.

. A full flow turbo-feed pump drawing from the degassing feed tank and flowing back into the high pressure (HP) station. Its driving turbine is fed either by drawn steam coming from the superheater dryer (main feed), or by live steam, or the steam from the "balloon d' eclatement" or the auxiliary boilers.

Two motor-driven feed pumps without Diesel power and each likely to assure 25% of the nominal flow. These pumps are used during the phases of startup and shut down of the power plant. They draw from the degassifier tank discharging directly to the entrance of the steam generators.

. A high pressure (HP) water station made of two rows of 2 reheaters fed with HP steam drains.

. At the exit of the HP station, the feed water coming from the two water stations, comes into a common header before being sent to the 4 GV (steam generators).

3-5 - ELECTRIC DISTRIBUTION

The produced energy is released for each group through a 20/400 kV transformer of 500 MVA and 400 kV toward a 400 kV station placed at the edge of the site. This center made of two 400 kV will be connected as a first stage, to the 400 kV EDF network through two lines going to the station of St-VULBAS, and two lines going toward the station of GENISSIAT. Each group is coupled to the network through a circuit breaker placed in the engine room, a 20 kV coaxial cable and a 400 kV circuit breaker placed at the interconnection station. The auxiliary electrical supply to the site comes from the following sources:

-Two sources external to the site independent from each other, and consisting of:

a) the 400 kV network materialized by the interconnecting station; this source feeds the auxiliaries through two transformers called "drawoff" 20/6.6kV of 50 MVA with 2 secondary windings, each derived from the main alternater-transformer connections downstream of the circuit-breaker and placed on the energy release platforms.

-The 225 kV network reattached to the power plant by an antenna of the line 225 kV VULBAS-SERRIERES feeding in parallel two transformers called "auxiliaries" 225/6.6kV of 50 MVA, each with secondary windings installed on the platform south of the control building.

These auxiliary transformers are permanently energized, ready to respond instantly to the entire power plant auxiliaries, normally assured by the drawoff transformers in case of incident of the latter or on the 400 kV network.

b) Two sources, internal to the site, independent of one another, made by two distinct units each including two Diesel generators of 2000 kV. Those two units are completely separated geographically and functionally (north and south from the control building). These two internal sources will feed, in case of loss of the two network sources a certain number of standby auxiliaries indispensable to the power plant safety and to the protection of important material.

The distribution network consists of two distinct half-networks, forming an extension of two redundant routes (A and B) of command control. Each half-network includes two sets of buses 6.6kV normal, each fed by the two external sources to the site, on one hand, and two sets of buses 6.6kV standby supplied each by the two sources external to the site and also by a diesel. As well as for the normal set of buses as for the standby set of buses, the 6.6kV and 380 V penetration panels of the two half-networks are installed in each of the two routes to the control building, thus separated geographically. The electrical connections between panels and sources and between . . . (bottom of page 15 missing).

3-5 - <u>GENERAL OPERATIONS</u> (Figure 9)

Operation vis-a-vis the network

The power station is controlled from one control room only, where are centralized all the means of choice of emission of command, and the necessary information to its control. The operator in the control room has the following computers:

-Two computers of treatment of core temperature (TRTC) insuring core surveillance, and providing reactor protection.

-A computer of detection and diagnosis of core defects (DDDC) giving information on the core physical control and associated circuits, without input to the safety system.

-A computer of complementary treatment of informations of the whole power plant. These two computers are not indispensable to the immediate operation of the power plant.

In case of unavailability of the control room, the operator has at his disposal, the necessary controls and information to control the shut down of the reactor and maintain it in a safe state, grouped in two half-panels, each placed in one aisle of the electric building.
The fuel handling is done when the reactor is shut down, and is controlled from a decentralized control station in the reactor building.

General controls and modes of operation

The regulation is conceived to allow the power plant to assume the network demands as named above. This operation must then be adapted . . .
(bottom of page 16 missing)

The variables which are subject to automatic regulation, the controlling variables and the regulating units are as follows:

Controlled Variables	Controlling Variables	Regulating Units
Sodium temperature at steam generator exit	Steam generator feed flow	Turbo-feed pump (speed + control valve)
Steam pressure	Steam flow	Turbine throttle valve
Electric power	Secondary sodium flow	Secondary sodium pumps (variable speed)
Average temperature at core exit	Reactivity	Control rods (3)

For the reactor itself reactivity must be adjusted by three regulating rods (automatic action). For safety reasons, there is no automatic action on the primary sodium flow. The operator adjusts this flow manually after a variation in the power plant load.

Possible operating states of the power plant

Besides the states of normal operating at nominal power or at partial power, a certain number of exceptional states were planned.

-Operating on the bypass circuit of the turbines.

-Operating with a stopped primary pump (limited power at 70% of nominal power).

-Operating with a secondary circuit out of service (limited power at 70%).

-Operating with a turbo-generator group out of service (limited power at 50%).

-Operating with a feed turbo-pump out of service (power limited at 75% if the electric feed pumps are available).

Shut down states

Three states of shut down have been planned:

-hot shut down or, of short duration for which the hot primary sodium temperature is maintained in the vicinity of 330°C. This state corresponds to a position of reduced power after an incident or after an unplanned scram.

-semi-hot shut down or, of average duration, during which, the hot primary sodium temperature is maintained at 250°C; this state corresponds at a week-end type shut down or "handling shut down" for debugging.

-cold shut down or, of long duration, for which the hot primary sodium temperature is equal to 180°C; this state corresponds to "fuel handling", "insertion of equipment" or "shut down for cleaning".

Extraction of the decay heat is then assured by:

-either the steam generators fed by water and the associated circuits of startup-shut down for the states of hot shut down and eventually semi-hot.

-either by the sodium-air exchangers for the cold states and eventually semi-hot.

4 - CONCLUSION

In this report were presented the main features and the general characteristics of this project which is an important step toward the realization of "commercial" power plants.

The first preparatory excavation work on the site began in December, 1974, and the decision to build must be made jointly by the three partners (EDF, ENEL, RWE) this year.

At the same time, various authorizations will be given by NERSA. In particular, examination by competent authorities of the preliminary safety report has been accomplished according to the previously set schedule, and the construction permit should be granted before the end of the year. (report not dated).

Thus, the conditions today seem joined to insure progress of the project in a satisfactory manner. They seem equally encouraging to consider the development of other projects in France or abroad.

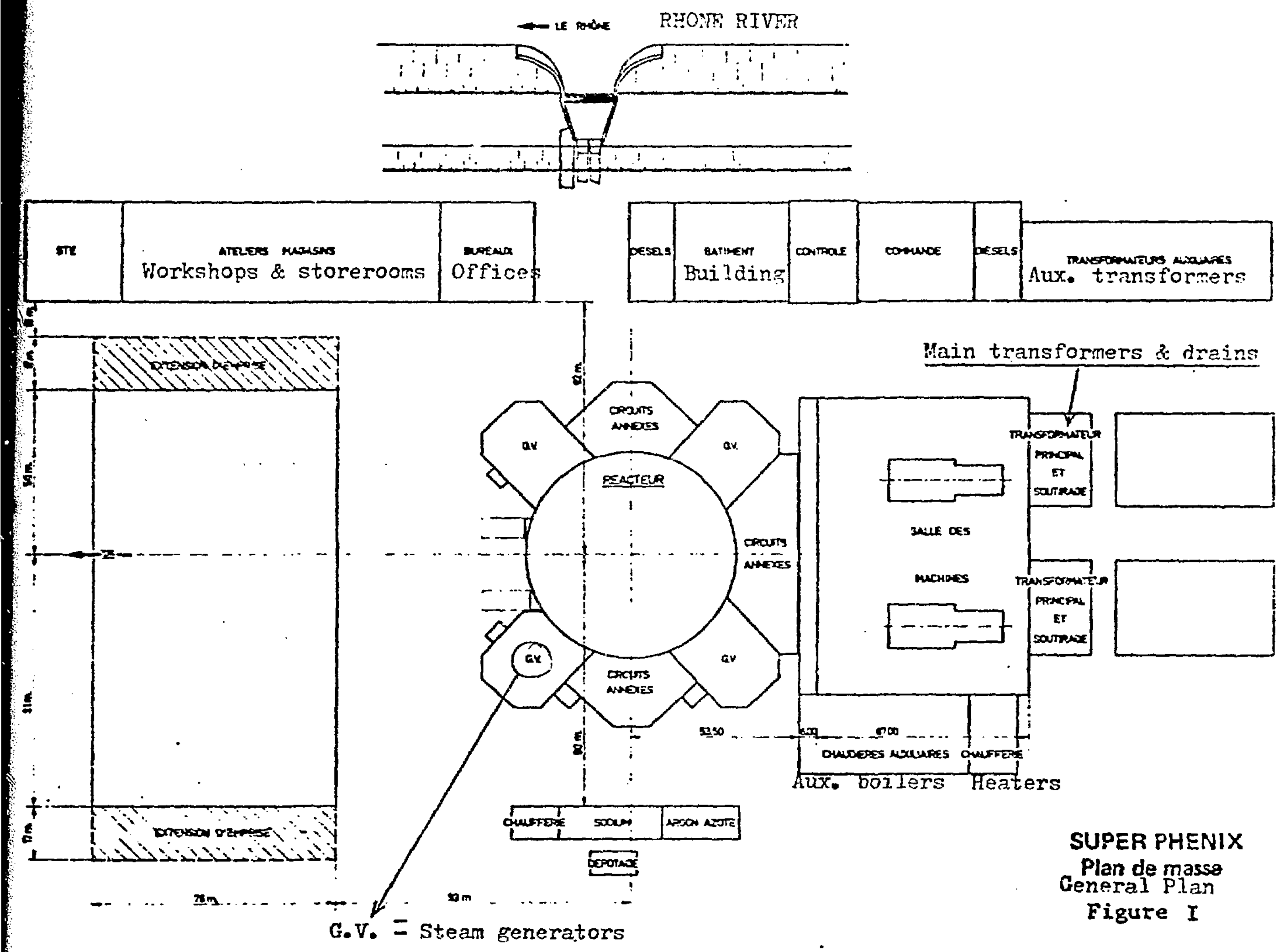
MAIN CHARACTERISTICS OF THE POWER PLANT

THERMODYNAMIC CHARACTERISTICS

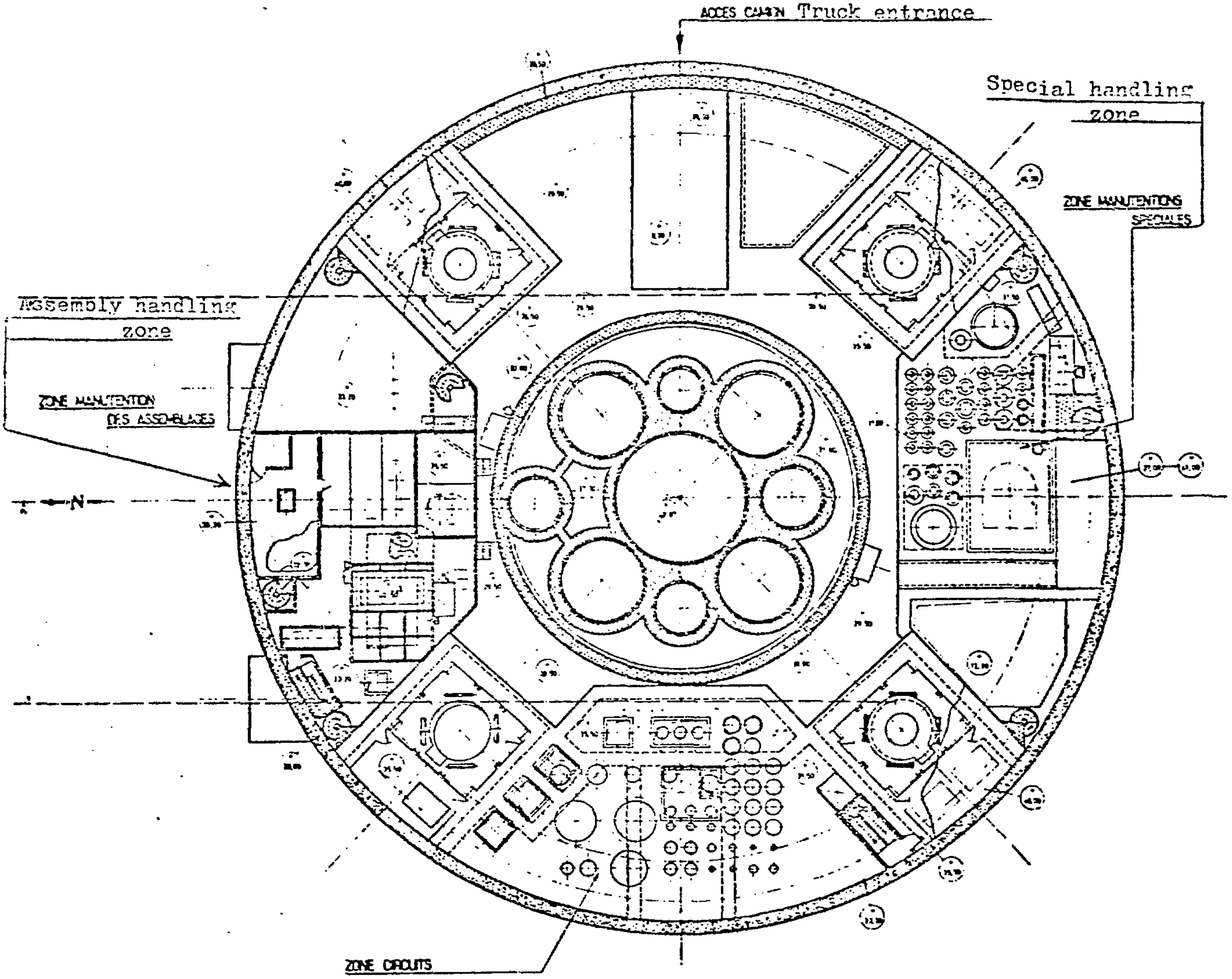
-Thermal power	3000	MW
-Electric power	1200	MW
-Efficiency	40	%
-Primary system: Nature/Type	Sodium	Integral
. Mass of sodium	3300	Tons
. Number of pumps	4	
. Temperature at core entrance	395	°C
. " at core exit	545	°C
. Total flow	16,400	kg/s
-Secondary system: Nature/Type	Sodium	Loops
. Number of loops and pumps	4 - 4	
. Number of intermediate exchangers	8	
. Temperature at entrance of intermediate exchangers	345	°C
. Temperature at exit " " "	525	°C
. Total flow	13,200	kg/s
. Total mass of sodium in the 4 loops	1,700	Tons
-Tertiary circuit: Nature	Water - steam	
. Number of steam generators	1 per secondary loop	
. Temperature of superheated steam	490	°C
. Pressure of superheated steam	180	bars
. Total steam flow	1360	kg/s

CORE CHARACTERISTICS

-Maximum neutron flux	6.1×10^{15}	$n/cm^2/s$
-Maximum power density	0.30	MW/l
-Length of the core	1	m
-Fuel assemblies		
. Number	364	
. *Length of an assembly*	5.4	m
. Nature of the fuel	UO2 - Pu O^2	
. Number of pins	271	
-Nominal maximum clad temperature	620	°C
-Maximum rate of combustion	70,000	MW/days/ton
-Core life with a 0.85 load factor	850	Days
-Time between fuel handling	12	Months
-Breeding gain	0.2	



SUPER PHENIX
Plan de masse
General Plan
Figure I

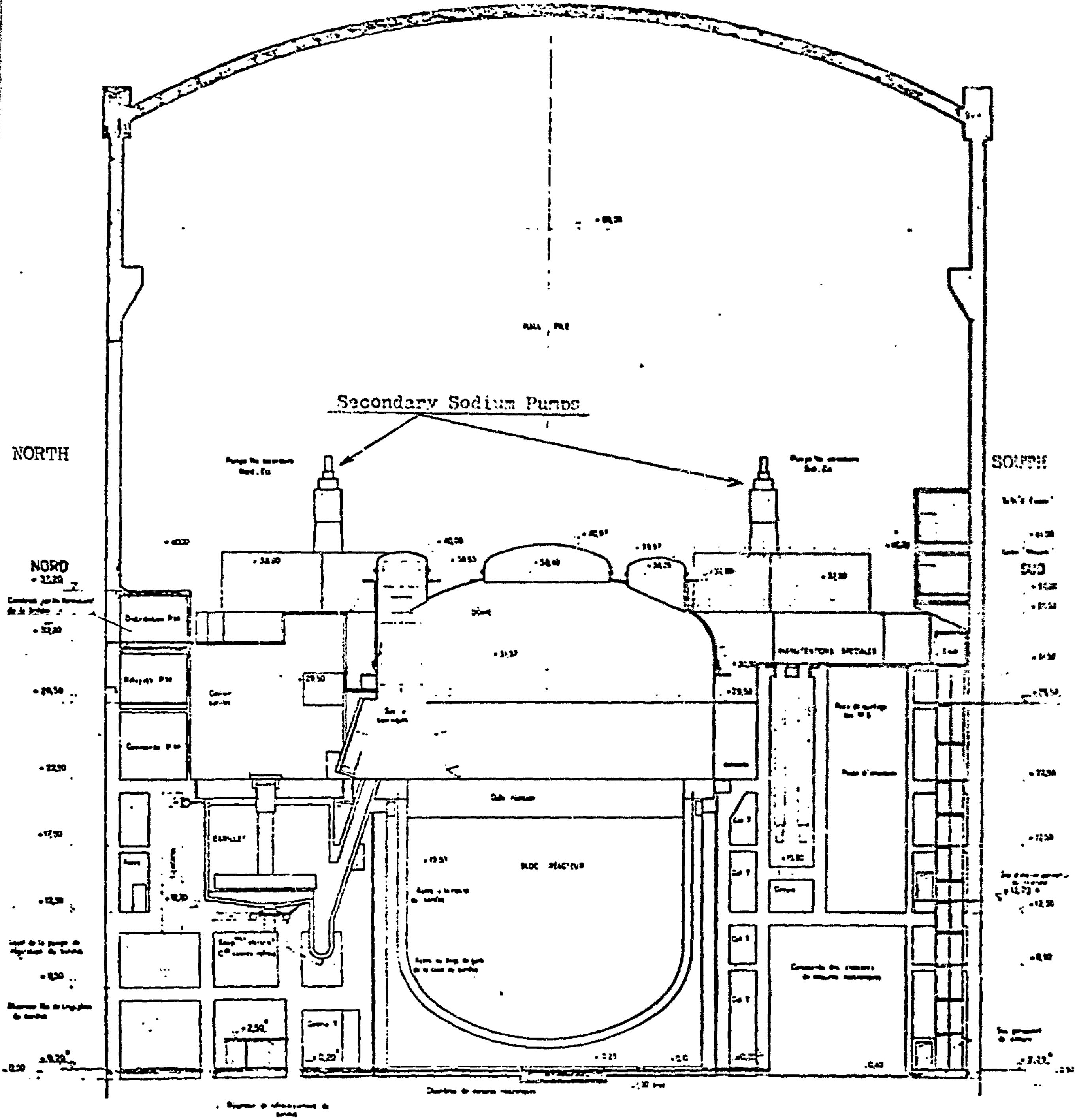


REACTOR BUILDING - PLAN VIEW

SUPER PHENIX

Bâtiment réacteur, vue en plan

Figure 2

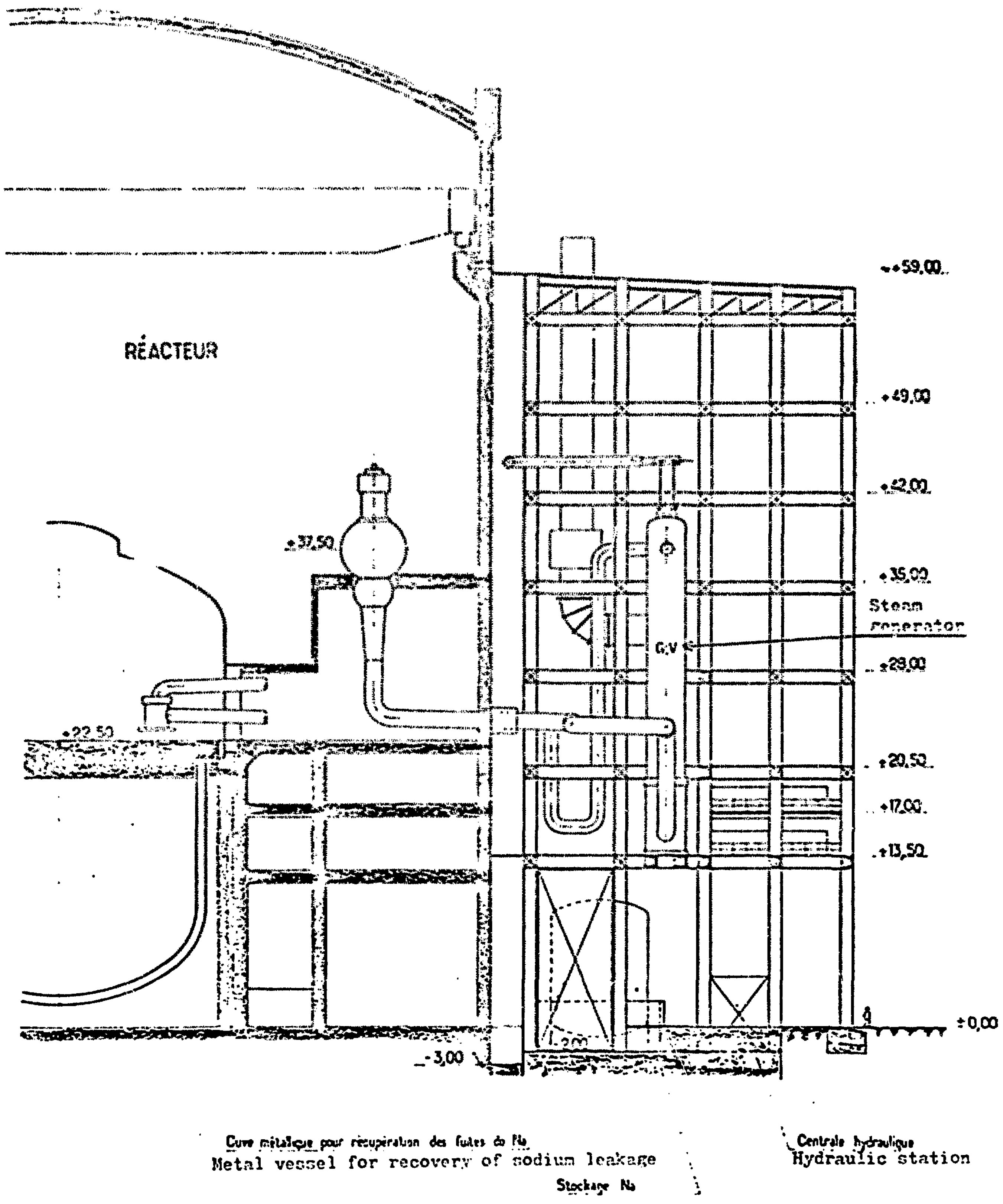


REACTOR BUILDING – ELEVATION

SUPER PHENIX

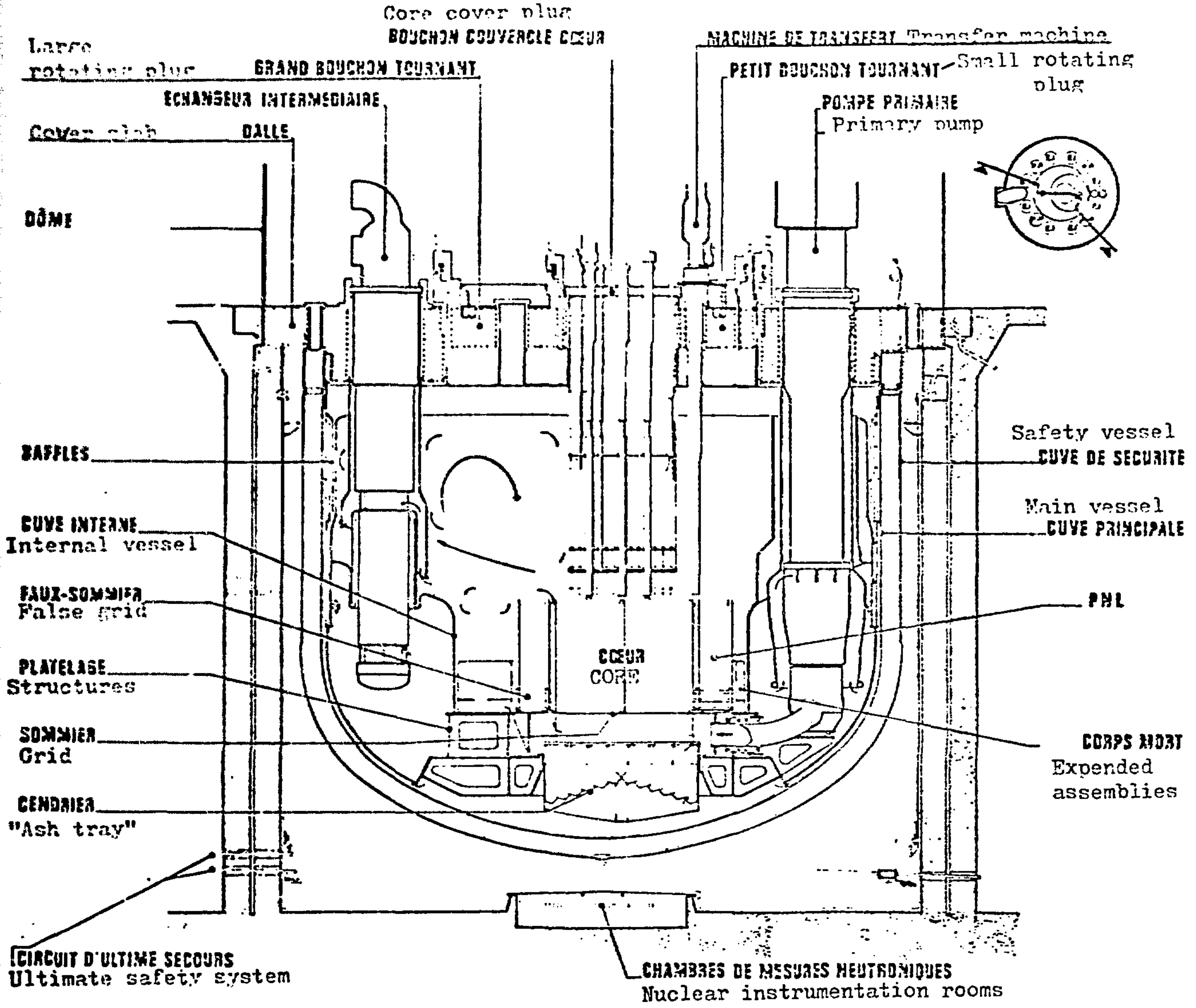
Bâtiment Réacteur - Elévation

Figure 3



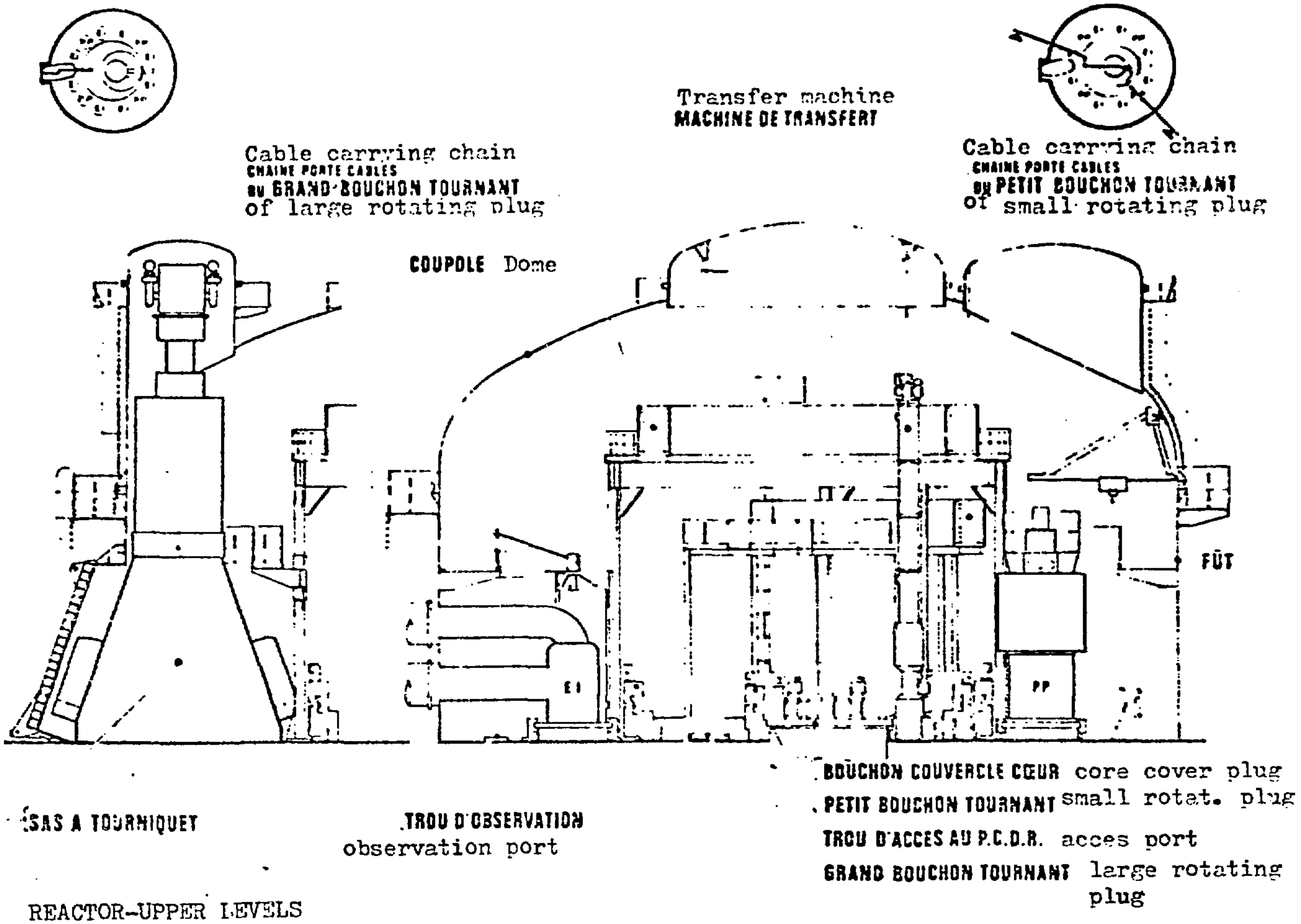
SUPER PHENIX

Bâtiment des générateurs de vapeur



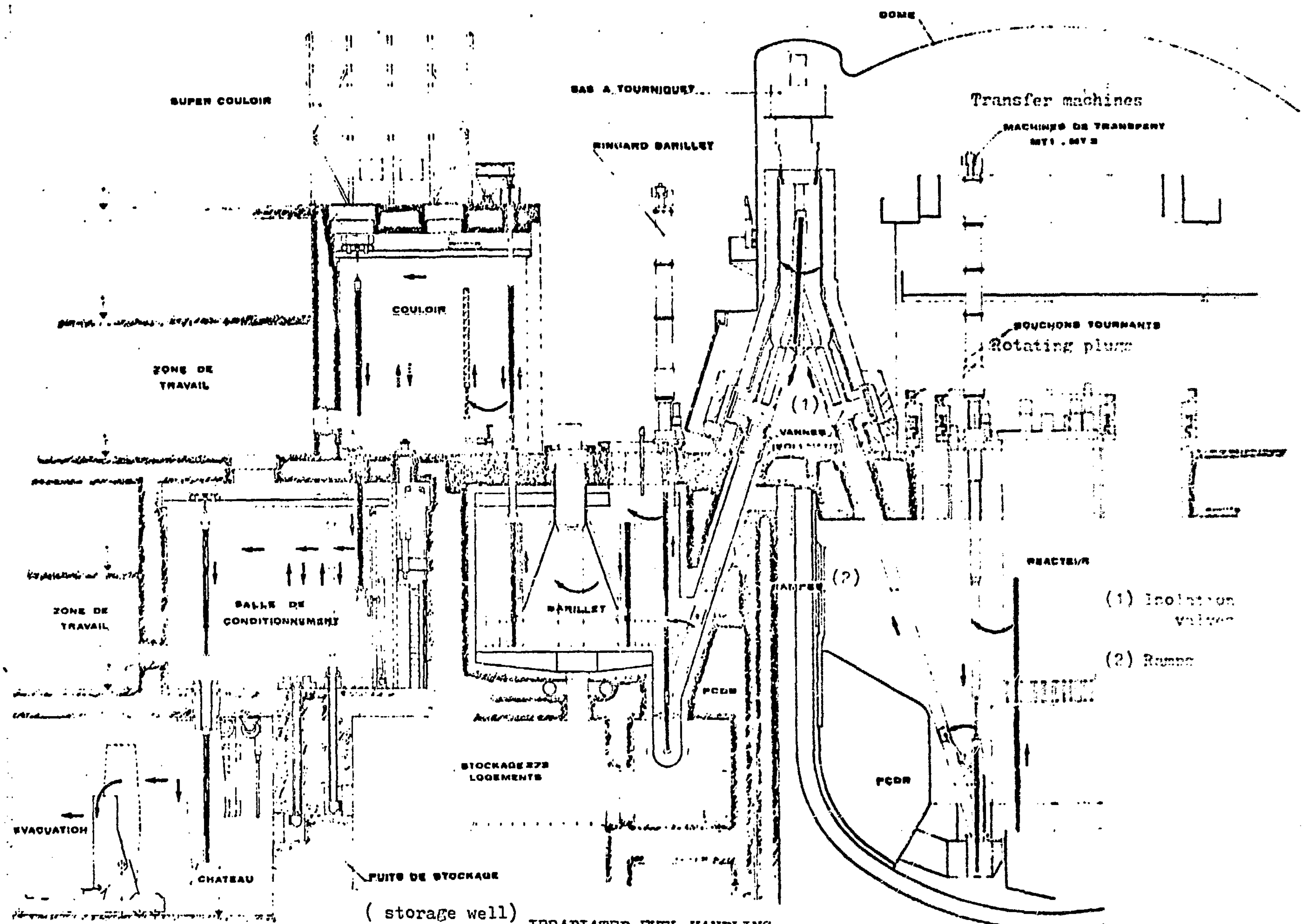
Reactor Cross-section
Through Pump and Heat Exchanger

SUPER PHENIX
Bloc réacteur "coupe par pompe et échangeur"
Figure 5



REACTOR-UPPER LEVELS

SUPER PHENIX
Bloc réacteur "grenier"
Figure 6

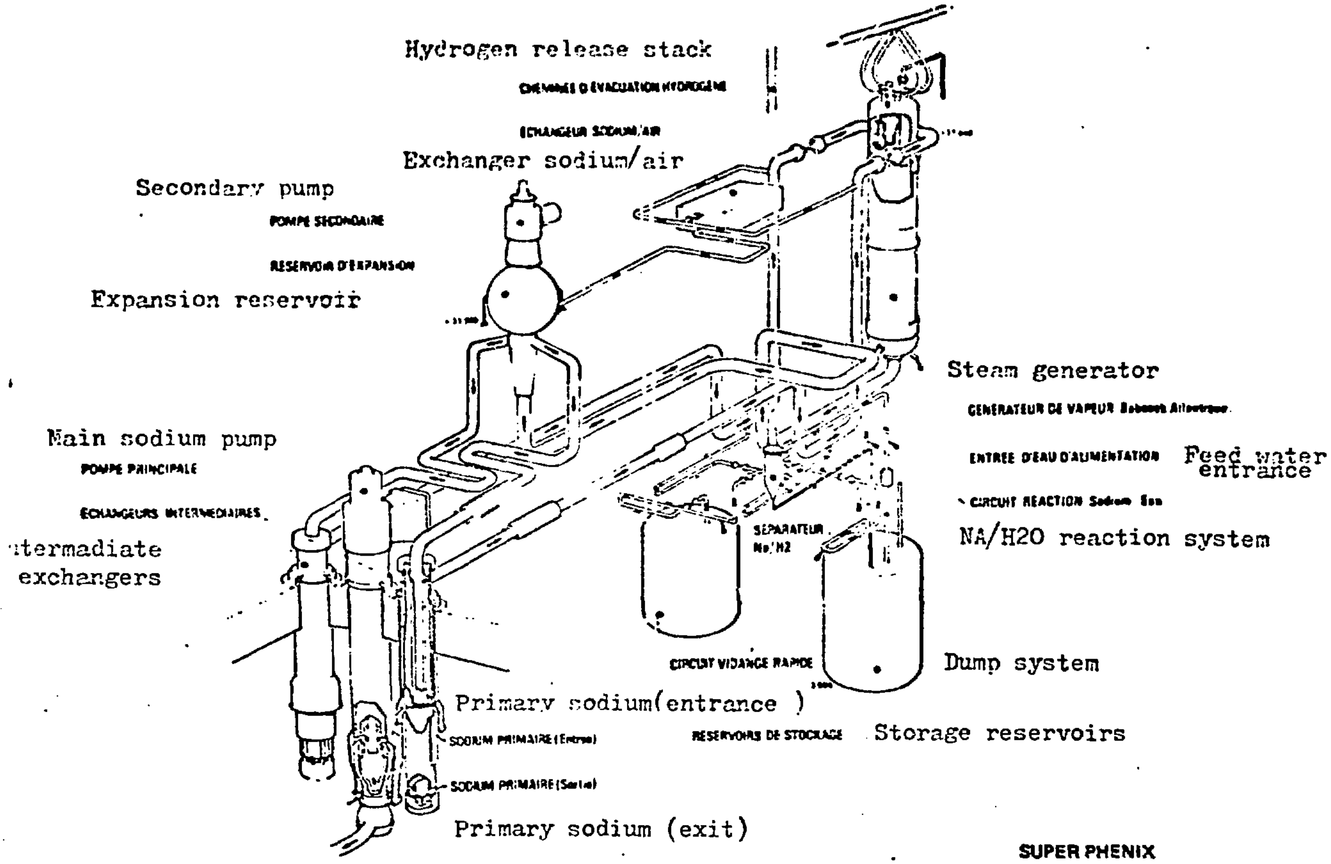


IRRADIATED FUEL HANDLING

SUPER PHENIX

Cheminement d'un assemblage irradié

Figure 7

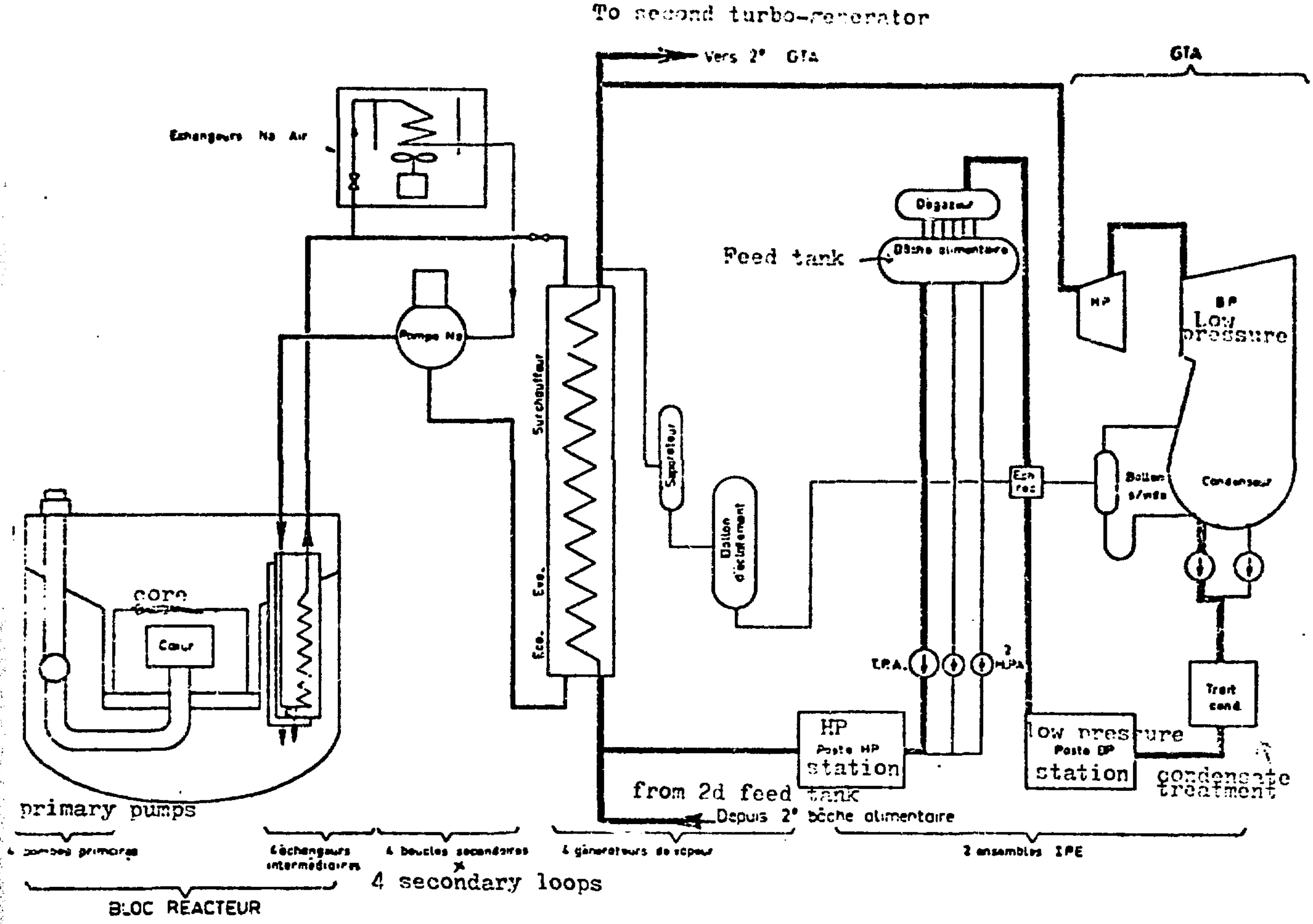


SUPER PHENIX

Circuits principaux de sodium secondaire

Figure 8

Main secondary sodium systems



SUPER PHENIX
Schéma de fonctionnement
Figure 9

Operating schematic