ACCIDENT ANALYSIS FOR ATUCHA II NUCLEAR POWER PLANT

- Mayers “System description reactor, reactor coolant and moderator system” R10-85-e1002 Erlangen, 05.09.1985.
- Bordihn “Initial and boundary condition for accident analysis” KWU NA-T/1995/011 Erlangen, 24.02.1995.

List of abbreviation and terms:

RPV	Reactor Pressure Vessel
NPP	Nuclear Power Plant
UJB	Reactor building annulus
UFA	Fuel storage pool building
UKA	Reactor auxiliary building
UBA	Switchgear building
UMA	Turbine building
HP	High Pressure
RHR	Residual Heat Removal
KAG	Residual heat removal intermediate cooling system
ECC	Emergency Core Cooling system
SG	Steam Generator
RCP	Reactor Coolant Pump
PRZ	Pressurizer
SS	Secondary Side
KBA	Volume control system
JDJ	Boron injection system
HL	Hot Leg
MT	Moderator Tank
JND	Safety injection system
JNA	Residual heat removal system
KBA	Volume control system
LAB	Feedwater system
PE	Service cooling water system for assured plant

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ATUCHA II NPP SYSTEM DESCRIPTION

1.1- Preliminary consideration

The intent of this part is to describe the NPP Atucha II with an net electrical power of 692 MW.
The plant is equipped with a heavy water pressure vessel reactor of the same type as used in the Atucha I NPP with a net electrical output of 340 MW.

The NPP Atucha II has been designed by the KRAFTWERK UNION AG Erlangen, West Germany, with engineering participation of Empresa Nuclear Argentina de Centrales Electricas S.A., Buenos Aires., and it is located adjacent to the Atucha I approx. 110 Km north-west of Buenos Aires at the southern banks of the Rio Parana' de las Palmas.

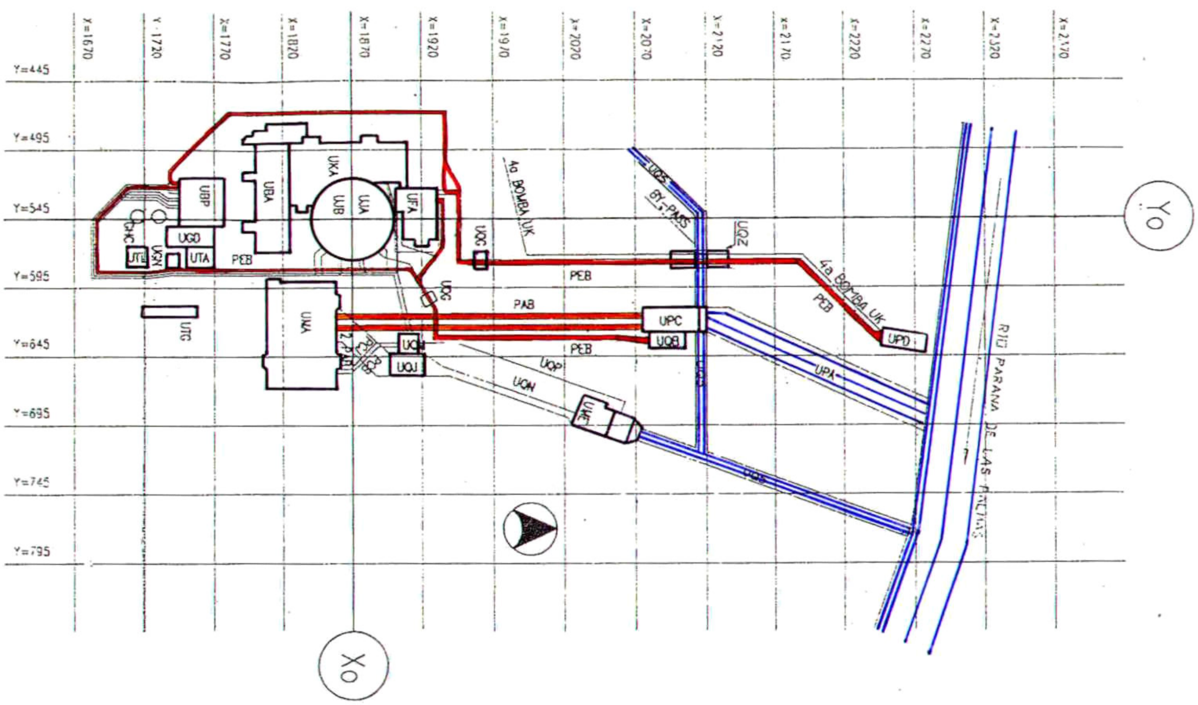

Fig.1-Plant layout

Since the fuel is natural uranium, heavy water (D_2O) is used in the reactor as the coolant and moderator.
For reactivity and burnup reason it is necessary that the moderator temperature has to be less.
Consequently the moderator and the coolant are separated from one another in the RPV.
The coolant flows separately from the moderator through enclosed coolant channel and absorbs the heat released by the fuel assemblies.

The heat absorbed by the moderator is transferred to the feedwater through the moderator cooler, which replace the otherwise usual HP feedheaters.
The average moderator temperature at full load is normally 170°C and, at the most, 220°C.
To supplement its function of heat transfer in normal operation, the moderator system serves also as a high pressure RHR system.
For this purpose, heat is transported via the moderator coolers to the RHR intermediate cooling system (KAG).
Like the moderator system when in the RHR configuration , this system comprises four redundancies in accordance with the requirements for ECC and RHR conditions.

Owing to the various functions which the primary is required to perform, it is divided up into reactor, reactor coolant and moderator system.

The ***reactor system*** consists in essence of the RPV, its internals and the control shutdown equipment. Its functions is to generate thermal power.
The core contained in the RPV is the centre of nuclear heat generation.
A thermal power of approx. 2161 MW is generated in the core .
At normal moderator temperature, the coolant absorbs approx. 90% and the moderator approx. 10% of the generated power.
The power absorbed by moderator is composed of the power generated directly as a result of the slowing down and absorption of neutrons (approx. 5%) and the power imparted by heat transfer from the coolant channel and the moderator tank and by coolant flow through the gaps between the coolant channel and moderator tank (approx. 5% at normal moderator temperature).

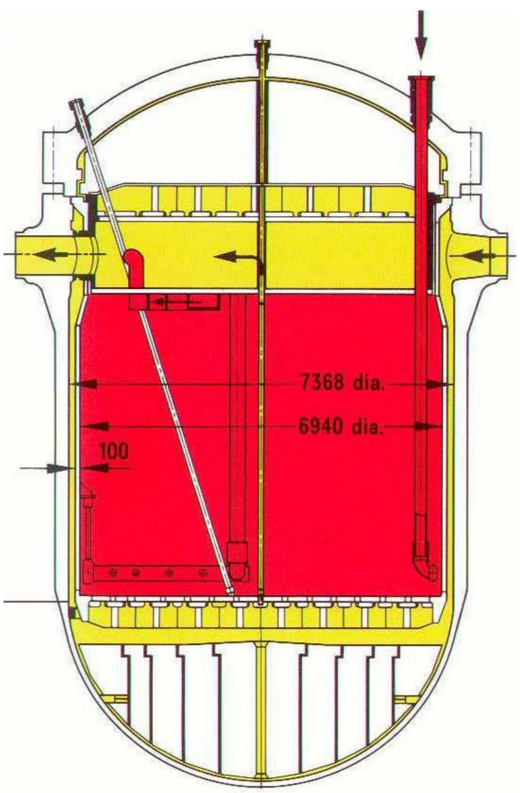

Fig.2-RPV

The ***reactor coolant system*** consists of two identical loops each comprising one SG, one RCP and the interconnecting reactor coolant piping together the pressurizing and PRZ relief system.
The two identical, parallel reactor coolant loops have the task of transferring the power generated in the RPV (1958 MW) and by RCP's (approx. 14.5 MW), in total 1952.5 MW at the normal operation and 2015.5 MW at maximum moderator temperature, to the steam plant via the SG's.
The remainder of the power generated in the reactor of 203 MW at normal and 160 MW at maximum moderator temperature is transferred by the moderator to the SS via the moderator coolers.
The total power transferred to the steam plant is 2175.5 MW.

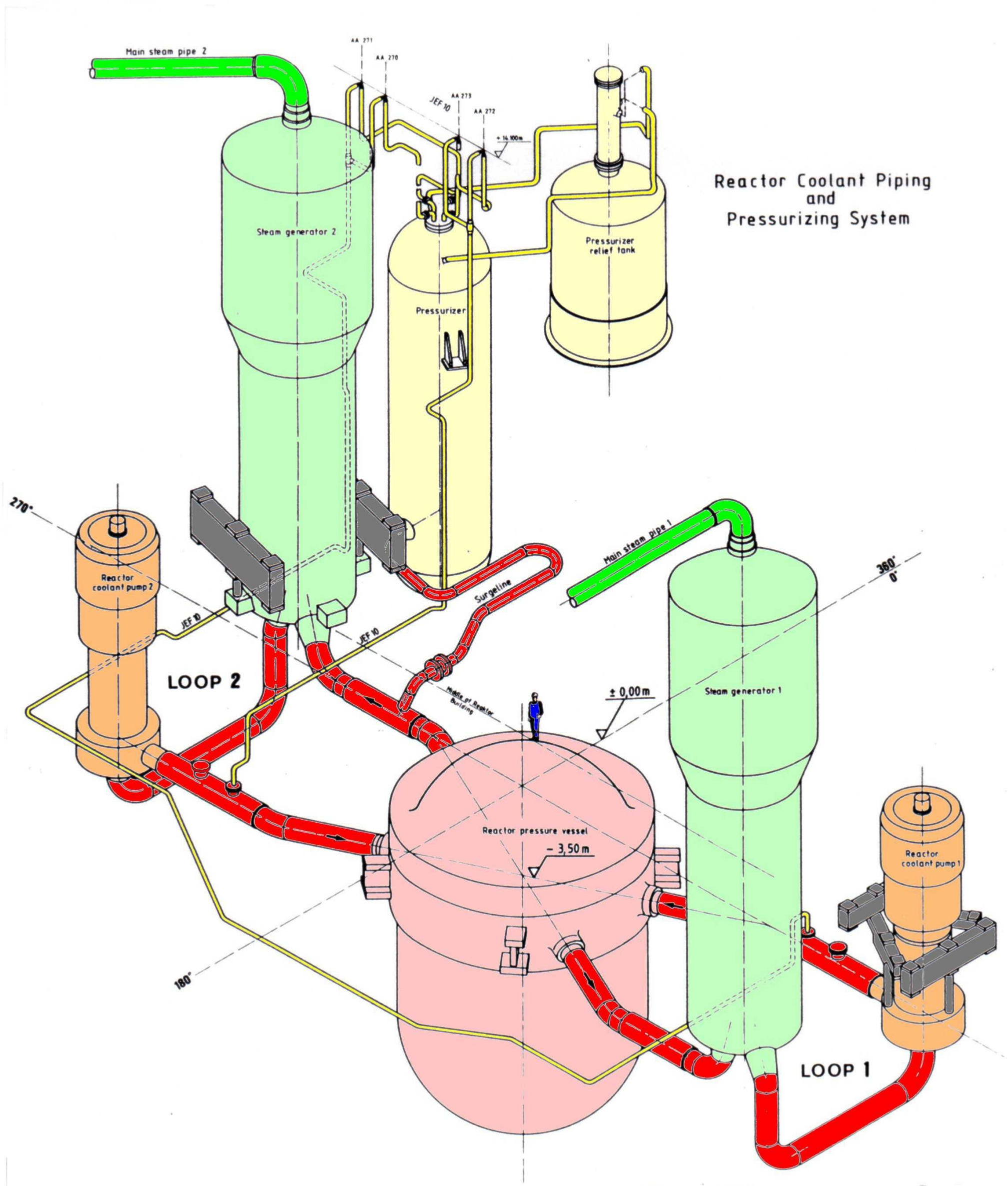

Fig.3-Reactor coolant system

The ***moderator system*** consists of four identical loops each comprising one moderator cooler, one moderator pump, the interconnecting piping and the valves necessary for isolation and changeover. In addition to maintaining the average moderator temperature during power operation, irrespective of the coolant temperature, the moderator has the following task:

> Removal of RHR from the shutdown reactor and of the heat stored in the primary system during cooldown and when the plant is in the cold condition.

Use the moderator loop for the ECC and RHR by cooling and injection of moderator into the coolant, and cooling of the water injected by the safety injection pump from the containment sump.

The tasks involved in ECC and RHR are performed by changing over the moderator system to the RHR configuration.
In this configuration the moderator system is of four-train redundancy, as required.
Two out of the four loops are capable of removing the power generated.
Quite apart from the above mentioned tasks, the moderator serves as a reflector and as a solvent for boric acid, which is either injected for long term reactivity control by the volume control system (KBA) or for fast shutdown of the reactor by the boron injection system (JDJ) in the event that adequate shutdown reactivity is not ensured by the control rods.

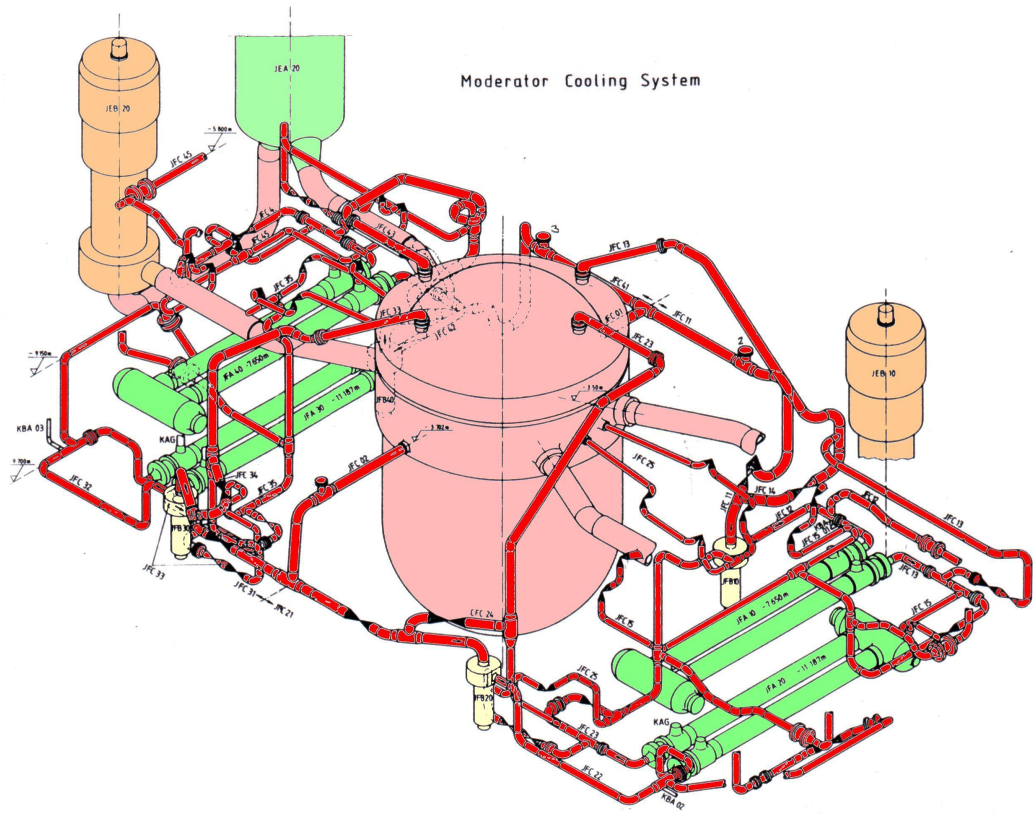

Fig.4-Moderator system

The ***pressurizing system***, which in essence consists of the PRZ, the safety valves, the pressurizer spraying and heating equipment serves to ensure that the pressure necessary for normal operation is maintained and to balance out and limit volume fluctuations due to moderator and coolant temperature changes without significant pressure changes.
The pressurizing system is connected by surgeline to the reactor coolant piping and the latter to the moderator system by pressure equalizing ports in the moderator tank closure head.

The ***pressurizer relief system*** consists in essence of the pressurizer relief tank.

The latter is connected to the pressurizing system by the safety valves flanged on the relief tank dome.
The pressurizer relief system serves to condense and remove the steam blow down via the pressurizer safety valves.
Cooling and level control is performed by components of the volume control system (KBA).

1.2- Description of configuration

Reactor and reactor coolant system.
The coolant circulated through the two parallel reactor coolant loops by the MCP's enters the RPV via two inlet nozzles and flows through the annular downcomer between the pressure vessel and moderator tank walls.
After deflection on the RPV bottom, the coolant flows upward to the coolant channels and passes, reunited with the closure head bypass and gap flows, via two reactor outlet nozzles in to the hot reactor coolant lines.
Given a total coolant mass flow of 10344 kg/s, the coolant is heated by the power absorbed from 277.8°C to 313.8°C.
The working pressure at the reactor outlet is 115 bar.
The coolant flows from the RPV through the reactor coolant piping to the two SG's, where the power imparted by the reactor and coolant pumps is removed from the coolant.
This and the power transferred to the feedwater via the moderator cooler serve to generate saturated steam at a rate of 957.2 kg/s at a pressure of 54.9 bar equivalent to a temperature of 271°C.
In receiving this power, the feedwater temperature rises in the moderator cooler from 121°C to 170.6°C at normal moderator temperature (up to 233.1°C at maximum mod. temperature).
Located between each SG and the RPV is a RCP which recirculates the coolant to the RPV with a mass flow of 5172 kg/s (the pressure rise under these conditions is 11.2 bar).
The require coolant pressure of the reactor, reactor coolant and moderator system is maintained by the pressurizing system.
The pressurizing system is connected to the reactor coolant system by the surgeline, which ties into the HL of reactor coolant line, and by two spray lines which are connected to the cold reactor coolant line.
Each spray lines branches in two pipes ahead of the spray valves with the result that there are four connections to the PRZ in all.
The connection to the moderator system takes the form of pressure equalizing ports in the MT top head.

Moderator system.
The various functions of the moderator system require the configuration of the system to be variable.
In normal operation (see 1.2.1) the hot moderator is drawn out of the top of the MT and injected into the bottom of the tank.
This configuration, suction pipes are located at roughly the height reactor coolant nozzles and injection pipes, lead through the RPV closure head and downcomers into the lower ring header in the MT.

Heat removal from shutdown reactor in ECC and RHR operation, necessitates reconfiguration of the moderator loops (see 1.2.2).
In this mode moderator is removed via the four normal injection pipes from the lower ring header of the MT and injected after cooling into the coolant.
This mode of injection ensures the require degree of the heat removal from the coolant.
From the point of view of pressure the moderator system is connected to the upper plenum of the RPV, and hence to the reactor coolant system, by four pressure equalization ports in the MT top head.
The configuration employed for emergency core cooling and residual heat removal is referred to as the RHR configuration.

1.2.1- Configuration of moderator system in normal operation

The moderator system is arranged in the normal configuration in power operation (see fig.5).
In this configuration 222.9 kg/s at normal and 208.9 kg/s at maximum moderator temperature are circulated by the moderator through each of four circuits.
After absorbing heat the moderator is drawn out of the top of MT via ring header to which the two RPV outlet pipes are connected.
After branching, equal parts flows pass the suction side check valves to the suction side of the moderator pumps.
These discharge the moderator through check valves to the moderator coolers, from there through the open throttling gate valves and trough the downcomer pipes attached to the RPV closure head into the lower ring header in the MT.
The moderator cooler inlet temperature in full load operation is 194.2 °C at normal and 238.7 °C at maximum moderator temperature.
After cooling in the moderator cooler, the outlet temperature are 140 °C and 194.9 °C respectively.
Even adjustment of the mass flows through the individual moderator circuits is performed by the orifices provided in the normal injection line.
The check valves provided in the suction lines have the function of preventing loss of the moderator in the event of a crack in the suction line.
The check valves on the pressure side of the moderator pumps maintain availability of the injection direction in the event of a crack.
The connections of the safety injection pumps (JND system) tie into the system between these check valves and the moderator coolers.

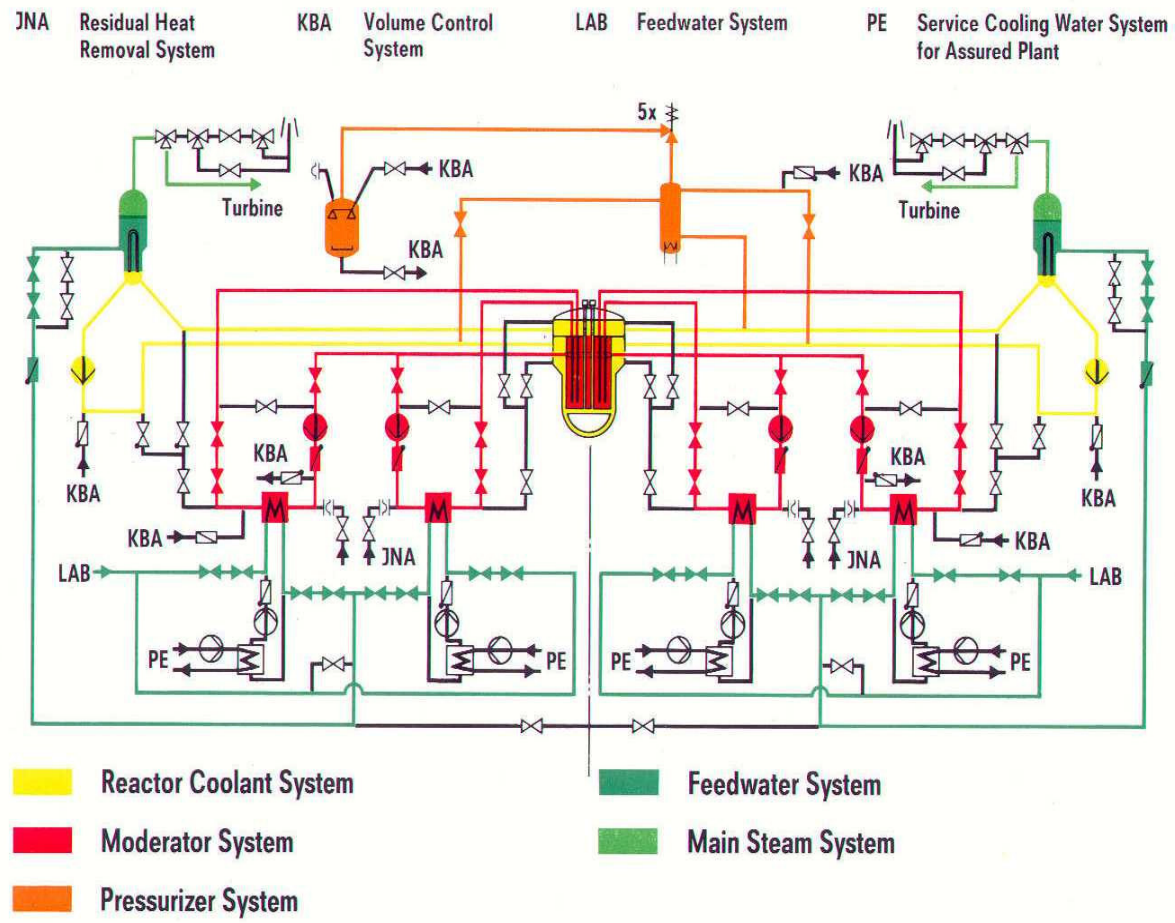

Fig.5-Primary system – Normal operation

1.2.2- Configuration of moderator system in residual heat removal (RHR) operation

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