THE EPR LAYOUT DESIGN

Uwe Mast[1], P.Y. Le Carrer[2]

[1] Siemens AG / Power Generation Group. Plant Layout and Civil Engineering
P. O. Box 3220. 91050 Erlangen, Germany
[2] Framatome. Plant and Piping Layout. Tour Framatome. 92084 Paris La Defense Cedex, France

ABSTRACT

General

The European Pressurised Water Reactor (EPR) is a French – German development for the next generation of Pressurised Water Reactor. The new reactor design is based on the experiences of operation and design of nuclear power plants in both countries. The EPR fulfils enhanced safety standards, higher availability and a longer service life.

Boundary conditions

Utilities aspects

For the Utilities one important requirement is the reduction of personnel exposure during maintenance and in-service inspection.

The other significant requirement is of economic nature. The main points influencing costs, which have also impact on the layout, are: outage times, accessibility of the reactor building and the available maintenance and set down areas.

The Utilities have also required to load the spent fuel assemblies into the shipping cask from the bottom of the fuel pool, because of the exclusion of the drop of the cask and in order to avoid contamination at the outer cask shell.

Layout and safety aspects

All safety relevant Nuclear Island (NI) buildings are designed against design earthquake as well as explosion pressure wave. The protection against Airplane Crash (APC) is realised by civil and layout dispositions. The Reactor Building, the Safeguard Buildings division 2 and 3 and the Fuel Building are protected by concrete structures. The other safety relevant nuclear buildings are protected by geographical separation.

Important safety requirements are the further reduction of the probability of severe accidents and the mitigation of such an accident on the plant area. For that, a spreading area for molten corium, a channel from the reactor pit to the spreading area and the In Containment Refuelling Water Storage Tank (IRWST) for flooding and initial cooling of the corium, were implemented in the design of the Reactor Building.

Layout results

The following buildings are arranged on a common raft to protect them against design earthquake: Reactor Building (RB), Safeguard Buildings (SAB) divisions 1 to 4 and Fuel Building (FB). The other Nuclear Buildings are built on separate rafts. The Safeguard Buildings are strictly separated into 4 divisions: the SAB division 1 on the west side, the SAB DIV 2 and 3 on the north and Safeguard Buildings division 4 on the east side of the Reactor Building. The Safeguard Buildings are separated into a radiological cold and hot mechanical area, an electrical and a ventilation part. The main control room is located in the middle of the Safeguard Building division 2 and 3. The Fuel Building is arranged southern of the Reactor Building. In this building the spent and the new fuel assemblies are stored. The equipment for the fuel assemblies and cask handling and a part of the set down area for the refuelling outage are also located here. The Nuclear Auxiliary Building (NAB) is arranged at the south side of Safeguard Building division 4 and at the east side of the Fuel Building. In the NAB the operational systems and also a part of the set down area are implemented. The Diesel Buildings (DB) are arranged close to the SAB DIV 1 and DIV 4. Each of the DB contains two-diesel generator and one station blackout diesel, which are separated according its redundancy requirements.

All NI buildings with their main routings were designed using a 3D model.

INTRODUCTION

The European Pressurised Water Rector is a new pressurised water reactor design developed between German and French partners on the basis of the cumulated engineering experience in Germany and France.

BOUNDARY CONDITION

Because of different national safety requirements and engineering practices the harmonisation of requirements was necessary during the development of the EPR.

The common rules were developed between the designers (Framatome and Siemens) and the Utilities (EDF and German Utilities) together with the Safety Authorities and Experts.

The requirements are split according the following parts:

- Codes and standards
- Engineering practice.

Codes and Standards

The basis for the harmonised codes were the existing national codes of both countries (German KTA and French RCC).

The harmonised codes are defined in the EPR Technical Codes (ETC's).

The different ETC's are listed below:

- ETC-C: Civil Engineering
- ETC-E: Electrical Equipment
- ETC-F: Fire protection
- ETC-I: Instrumentation and Control
- ETC-M: Mechanical Components
- ETC-S: Safety and Process.

Engineering Practice

Those requirements were developed between Designers and Utilities. The layout relevant items are listed in the "Layout requirements".

Examples for those requirements are provided in the following three points:

1. Security rules, which are not defined in the EPR Technical Codes e.g.:
   - Safety clearances for cranes (above, below and on each sides 0.60m)
   - Fire protection (accessible pipe or cable ducts between 20 and 100m length shall have at least two exits).

2. Utilities requirements
   - necessary set down and maintenance areas during refuelling and outage
     - Fuel Building: 278m²
     - Nuclear Auxiliary Building: 778m²
   - Fuel handling and storage (total storage capacity approximately 1000 FA's).
3. Common engineering requirements
   - Arrangements of valves and pipes
   - Minimum distance to pipes, air ducts and other equipment's.

LAYOUT RESULTS

Reactor Building

The reactor building is located at the centre of the nuclear Island. Its main function is to enclose the reactor coolant system (primary system).

The containment is a double-wall structure founded on a basemat. It constitutes the third barrier between fuel and environment after the fuel cladding and the reactor coolant system boundary. The inner containment shell is prestressed. It can resist internal hazards including those resulting from severe accident (design pressure: 6,5 absolute bar). The outer containment shell is a reinforced concrete structure. It can withstand an air plane crash.

The first function of the reactor coolant system is to transfer heat from the reactor core to the secondary system, to produce steam for turbine operation.

The main parts of the reactor coolant system are:

- The reactor pressure vessel (RPV) with the fuel inside,
- Four loops, each one consisting of one reactor coolant pump (RCP), one steam generator (SG) and piping,
- The pressurizer (PZR), connected to one of the four loops, which function is to maintain the pressure inside the reactor coolant system.

Internal structures

Internal structures are made of reinforced concrete and principally consist of:

- The primary shield, also called reactor pit,
- The secondary shield,
- The reactor pool,
- The in-containment refuelling water storage tank (IRWST) and corium spreading area.

The primary shield supports the reactor pressure vessel and acts as a biological shield. Its bottom is connected to the corium spreading area.

The secondary shield consists of walls and floors which form, with the primary shield, compartments enclosing all major equipment of the reactor coolant system. It protects the containment from missiles and provides additional radiological protection during reactor operation, allowing access of personnel on the operating floor and into the annular space between the inner containment wall and the cylindrical external wall (secondary shield wall).

The reactor pool is used in case of reloading fuel for fuel handling and reactor pressure vessel internals storage. It allows the reloading fuel operations to be performed under water with good personnel protection. It is connected to the fuel building via the fuel transfer tube. Removable concrete blocks cover the reactor pool in operation.

The in-containment refuelling water storage tank (IRWST) and corium spreading area is located at the bottom of the containment, inside secondary shield wall and surrounding reactor pit. In the event of a severe accident, corium is cooled by flooding of water coming from IRWST.

Other structures and equipment

- Main steam and feedwater lines run inside reactor building and cross the containment respectively just above and just below the operating floor (level 19,50 m).
- Easy access ways are provided into the reactor building containment in particular with:
  - one personnel airlock located on the heavy floor (level 1,50 m),
  - a second personnel airlock located on the operating floor, which provides access from and to the fuel building.
- Heavy components (RPV, SGs, RCP's, etc.) can enter the reactor building through the equipment hatch located at operating floor level. This hatch (diameter 8,30 m) is sized by the introduction of RPV during erection stage. The operating floor is served by the polar crane, which is designed to handle all heavy components. A replacement in one piece of a SG and PZR has been considered for the design of civil structures and layout. The reactor building is also provided with the reloading fuel machine which rail track is on the operating floor.

Operation and maintenance aspects

Requirements for operation, maintenance and in-service inspection of systems and equipment in addition to specific customer requirements for plant operation have major consequences on layout design.

– Reactor Building accessibility

In order to shorten plant shutdown duration, Utilities require accessibility of containment (operating floor and annular space) before and after reactor outages. This requirement is the leading factor for secondary shield wall thickness design and imposes implementation of extra protections such as concrete slabs above reactor vessel and primary pumps, shielded doors or labyrinths between primary and annular space compartments.

– Reactor shutdown constrains for fuel loading

At regular intervals, fuel assemblies need to be removed. A specific area at operating floor, large enough, is foreseen in order to be able to receive equipment to be dismounted and all tools used for these operations.

Handling equipment and required tools (examples):

- multistud tensioning machine (used to open the reactor vessel),
- lifting unit for RPV closure head.

Equipment to be removed (examples):

- RPV closure head,
- reactor cavity slabs.

Safeguard Building

The safety relevant systems and the control stations are implemented in the Safeguard Buildings.

The Buildings are strictly separated into 4 divisions. The SAB division 1 is located on the West Side, the division 2 and 3 at the north and the division 4 on the East Side. Between the SAB division 1 and 2 and SAB division 3 and 4 are arranged towers with implemented staircases. The SAB division 2 and 3 are protected against APC by civil construction and the division 1 and 4 by geographical separation. All SAB's are also protected against design earthquake as well as Explosion Pressure Wave. The Safeguard Buildings are located on a common raft.

The buildings are separated into mechanical, electrical, I&C and ventilation areas. The mechanical parts of the buildings are subdivided into the radiological controlled (hot) and non-controlled (cold) areas.

On the lowest levels from –9.60m to ±0.00m are arranged in the radiological controlled areas the Low Head (LHSI) and Medium Head Safety Injection Systems (MHSI). The Component Cooling Water (CCWS) and the Emergency Feedwater Systems (EFWS) are located in the radiological non-controlled areas. In the SAB division 1 and 4 the Containment Heat Removal Systems (CHRS) are implemented.

The Electrical and I&C components are installed on the higher floors. At the level +4.70m are located the cable floors and at the levels above the switchgears, electrical panels and I&C cabinets. The Main Control Room is arranged in the SAB division 2 and 3 with its associated rooms and at the level below the Remote Shutdown Station.

Above the electrical floors the Ventilation and Air Conditioning Systems are arranged. Each SAB has own ventilation systems.

The Main Steam and Feedwater Valve Stations are installed on the roof of the SAB division 1 and 4. The 2 by 2 arrangement has the advantage that two MS and FW Valve Stations remain functionable in case of APC on SAB 1 or 4. The pipes and valves of those systems are protected against internal hazards by civil walls.

Fuel Building

The main function of the Fuel Building is the storage of the spent fuel assemblies.

The FB is arranged in the south of the Reactor Building. The access to the FB is either possible through the SAB division 1 or through the SAB division 4. On both sides of the FB are arranged towers in which the main staircases are implemented.

The Fuel Building is located on the common raft as the SAB's and the RB. The protection of the FB against APC is achieved by civil construction. The complete FB is designed as a radiological controlled area.

It is divided from the level –9.60m to ±0.00m in two separate divisions due to the division assignment of following systems:

- Extra Boration System (EBS)
- Fuel Pool Cooling System (FPCS)

In this area are also located the Fuel Pool Purification System (FPPS) and the Chemical and Volume Control System (CVCS). But these systems are not safety relevant.

The Volume Control Tank of the CVCS and the leakage control system of the pools are located at the level ±0.00m.

Between the level ±0.00m and the operating floor (+19.50m) are implemented:

- In the east side of the Fuel Building
    - The safety relevant Ventilation Systems
    - – Annulus ventilation system (at the level +7.40m)
    - – Controlled Safeguard Building Ventilation system (at the level +11.10m)
    - – Containment sweep ventilation system (at the level +14.80m)
    - Operational boric acid system and
- In the west side:
    - The Spent Fuel Storage Pool (SFSP)
    - The fuel transfer station
    - The cask loading pit
    - The new fuel storage compartment
    - The new fuel examination facility

The operating floor level +19.50m is divided into two parts. At the west side is located the spent fuel pool area and at the east side in front of the hatch the set down handling area.

For the lifting of the equipment a gantry is foreseen.

For shipping of the FA's to outside storage units or to fuel processing plants the cask is docked at the bottom of the loading pit (connected with the SFSP). The benefits of the loading from the bottom are:

- Exclusion of the cask dropping accident
- No contamination of the outer shell of the cask
- No heavy crane above the spent pool area (only 20t Crane).

Nuclear Auxiliary Building

In the NAB are located the nuclear operational systems, the maintenance areas and laboratories.

In comparison to the above mentioned NI Buildings the Nuclear Auxiliary Building is situated on its own raft.

The main parts of the NAB are designed as radiological controlled areas and a small part as a non-controlled area.

The access to the controlled areas of the building is foreseen from the SAB division 4 (hot area) and the non-controlled area either from SAB division 4 (cold area) or from the outside.

In this radiological non-controlled area is the Operational Chilled Water system installed.

In the controlled area following main systems are located:

- Boron storage and treatment System (from +3.70m to +15.20m)
- Coolant Storage and Treatment System (from –9.60 to +15.20m)
- Coolant Purification System (from –6.50m to +7.40m)
- Gaseous Waste Processing System (from –9.60m to +15.20m)
- Air Supply System for RB, FB and NAB (at level +10.50m)
- Air Exhaust System for Controlled Areas (at level +15.20m)

At the level +19.50m are located the hot workshop and storage areas. The working and storage areas are connected via a large door with the set down and transport area of the FB.

On the highest level of the NAB two rooms for the monitoring of the exhaust air are foreseen.

Diesel Building

The Diesel Buildings have the function to supply the plant with electrical power in case of emergency power operation. The DB's are also located on separate rafts.

Two divisions of the DB are arranged into one building but the two redundancies are separated by civil walls. The DB division 1 and 2 are arranged close to the SAB division 1 and the DB division 3 and 4 close to the SAB division 4 and the NAB.

In each building at the level ±0.00m is implemented the Diesel Generator. Below ground level the Diesel Storage Tanks are arranged. Above the Diesel Generators the ventilation systems are located.

ENGINEERING METHOD

The EPR layout was developed by means of a 3D model. All NI buildings with civil structures, pipes (bigger a 100mm), HVAC ducts (bigger a 300x300mm) and the big cable trays were implemented in the 3D model.

From time to time the results of the layout and of the routing were discussed between the designers and the Utilities directly on the 3D model with the help of Virtual Reality (VR). The participants had in addition also the possibility to check the results via Internet.

For a better understanding and the optimisation of the transport of the heavy components (Steam Generator / Reactor Pressurise Vessel) and of the available space during refuelling and outage 3D animations were established.

CONCLUSION

In co-operation with all partners it was possible to develop a new pressurised water reactor, which fulfils the current European utility requirements. The new design is a cost competitive product to fossil power plants.

The project has shown that with modern tools the design works on different places is possible. The layout and the routing of the RB was developed in France and the other NI buildings in Germany in co-operation with EDF CNEN also in France.

ABBREVIATION

APC	Airplane Crash
CVCS	Chemical and Volume Control System
ETC	EPR Technical Codes
FB	Fuel Building
I&C	Instrumentation and Control
IRWST	In Containment Refuelling Water Storage Tank
KTA	Kern Technischer Ausschuss
RB	Reactor Building
RCC	Règles de Conception et de Construction
RCP	Reactor Coolant Pump
RPV	Reactor Pressure Vessel
SAB	Safeguard Building
SFSP	Spent Fuel Storage Pool
SG	Steam Generator
VR	Virtual Reality

Figures:

REFERENCES

[1] Olivier Mallet – Reinhold Klaus. Main Features of the EPR Layout and Civil Structures 8th International Conference on Nuclear Engineering . April 2000, Baltimore, USA.

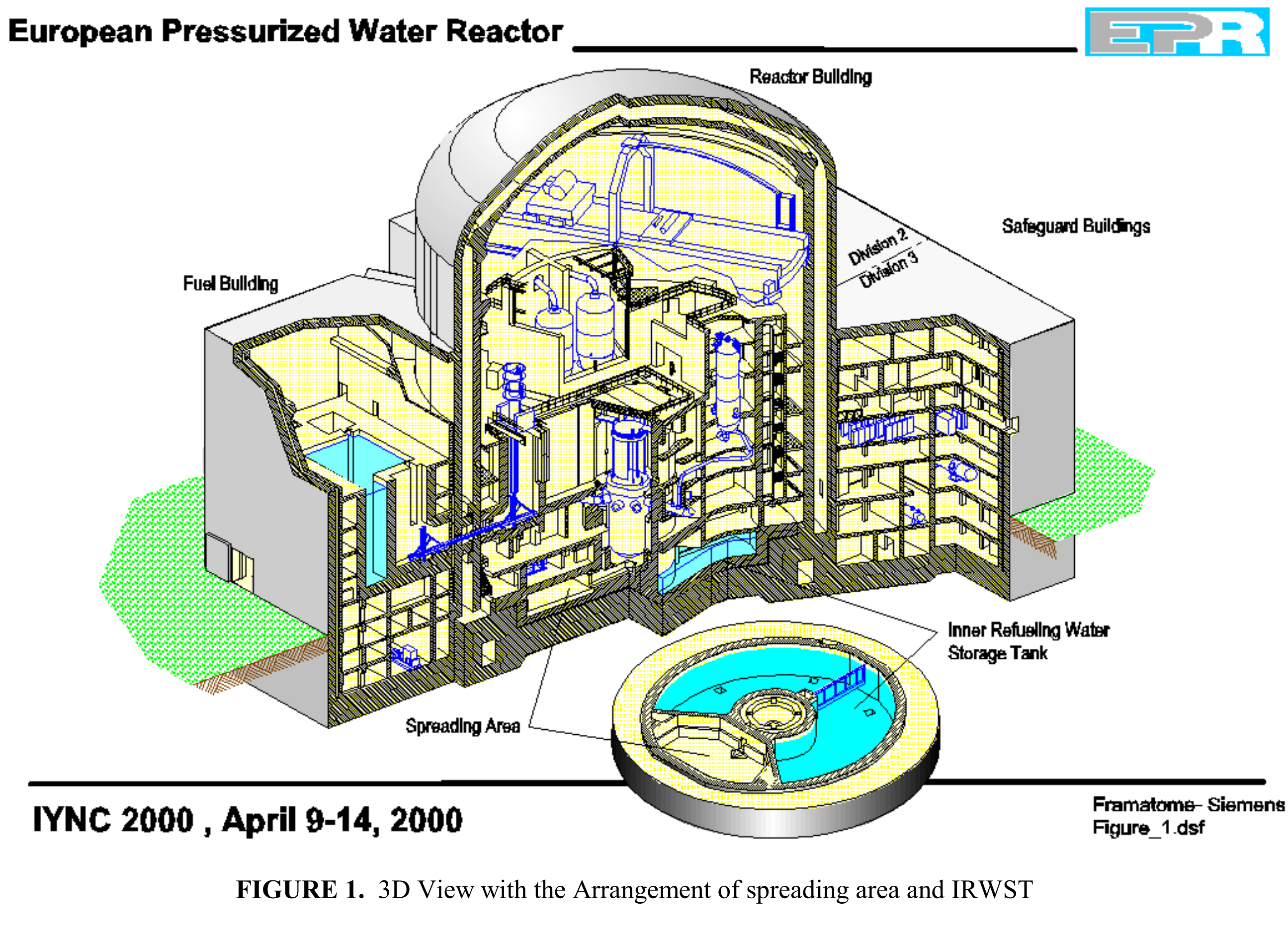

FIGURE 1. 3D View with the Arrangement of spreading area and IRWST

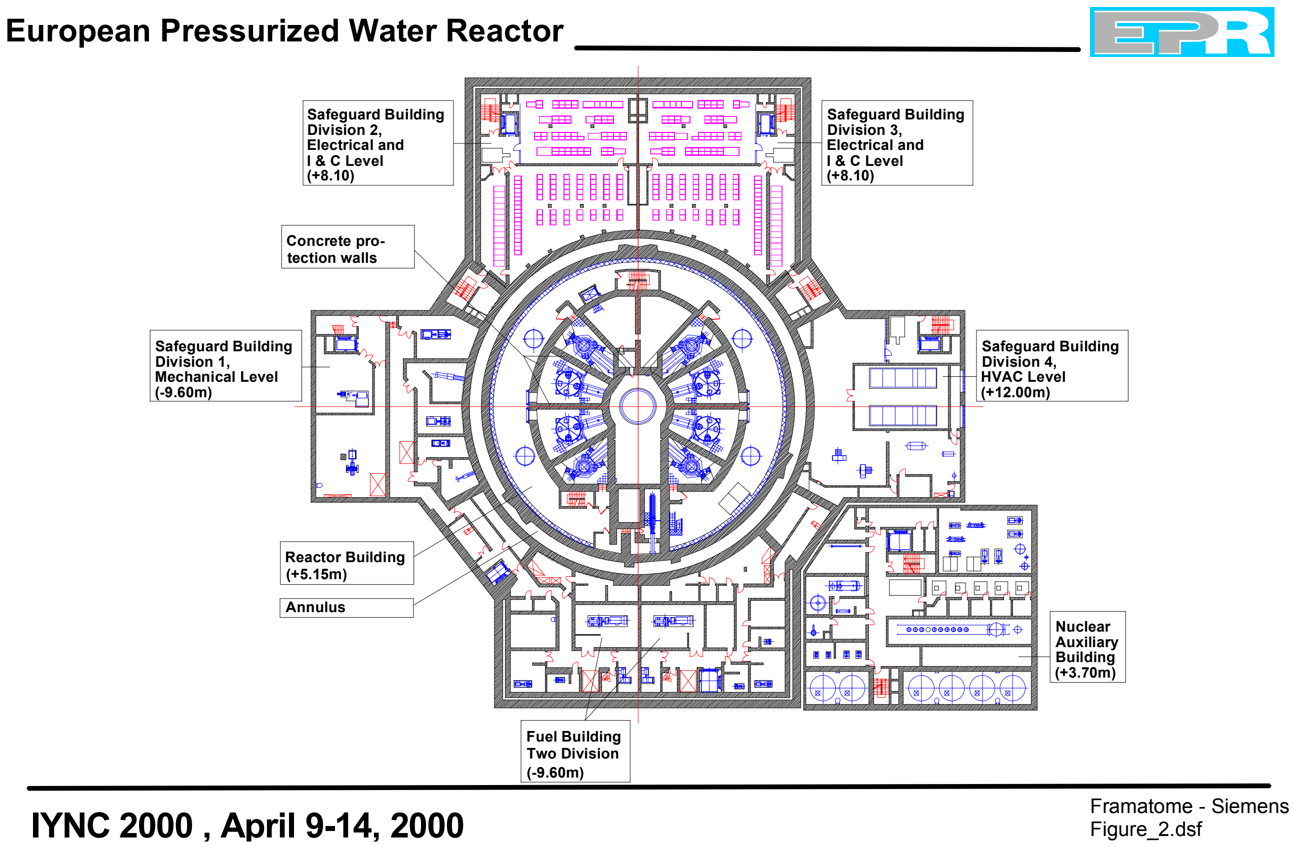

FIGURE 2. Plan View Different Levels

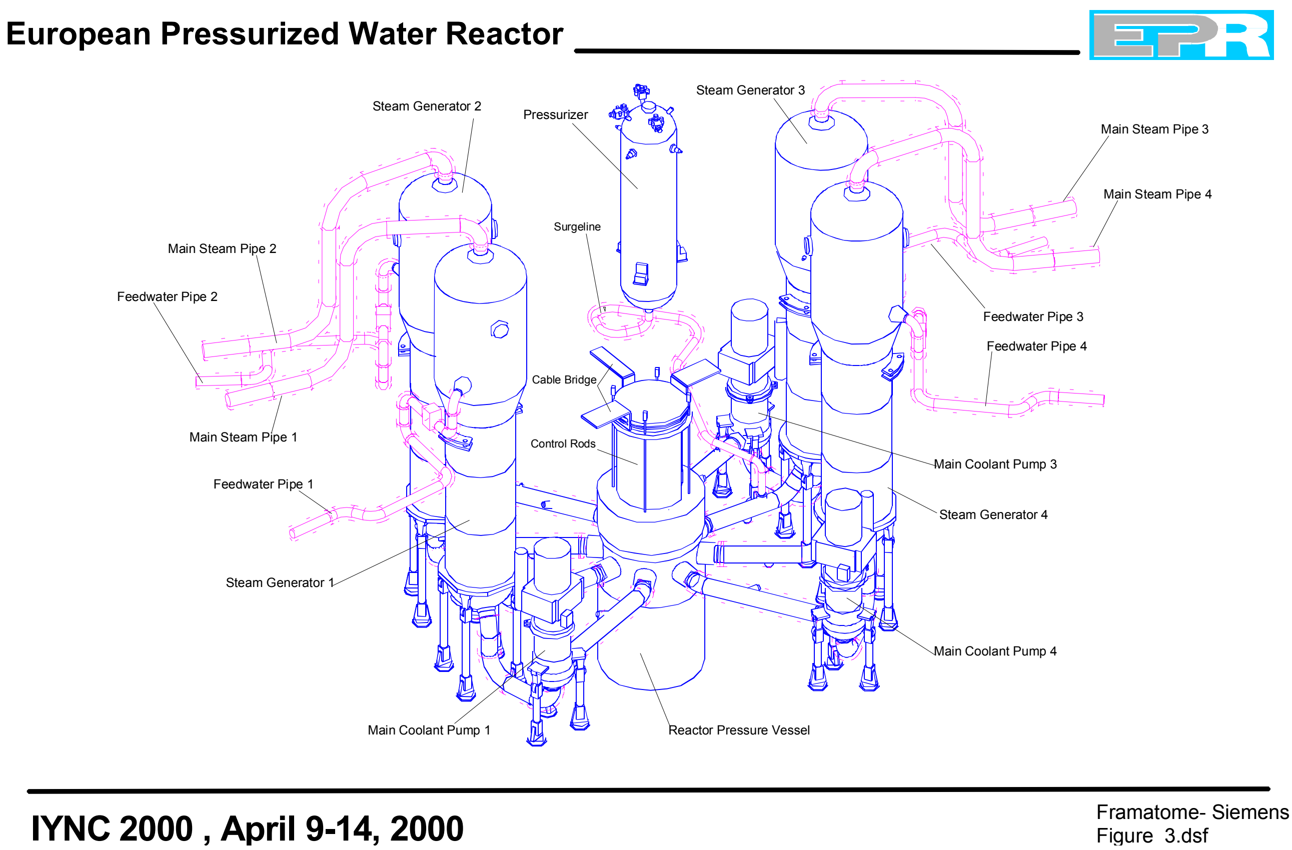

FIGURE 3. Primary circuit installation (3D)

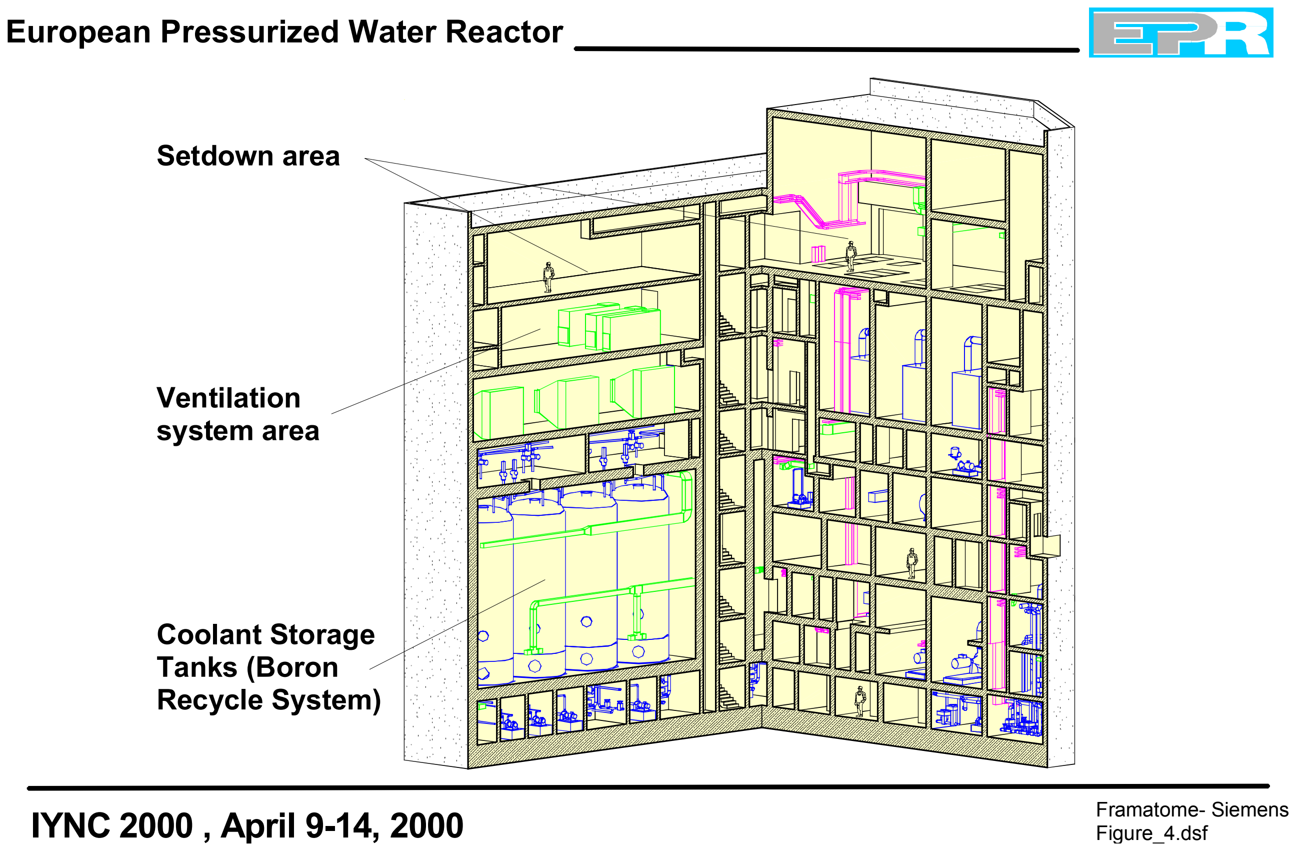

FIGURE 4. Section of the NAB

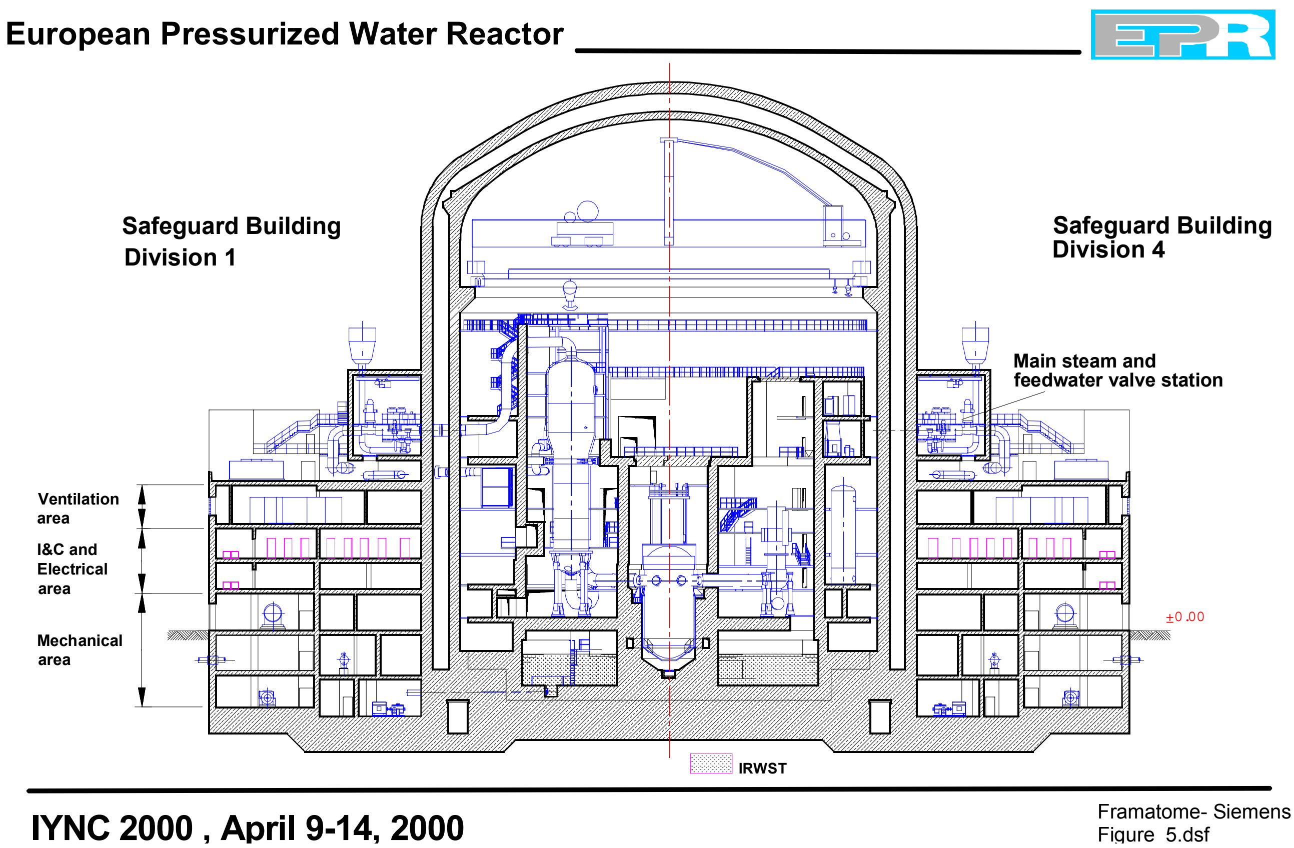

FIGURE 5. Section of the RB and the SAB (division 1 and 4)

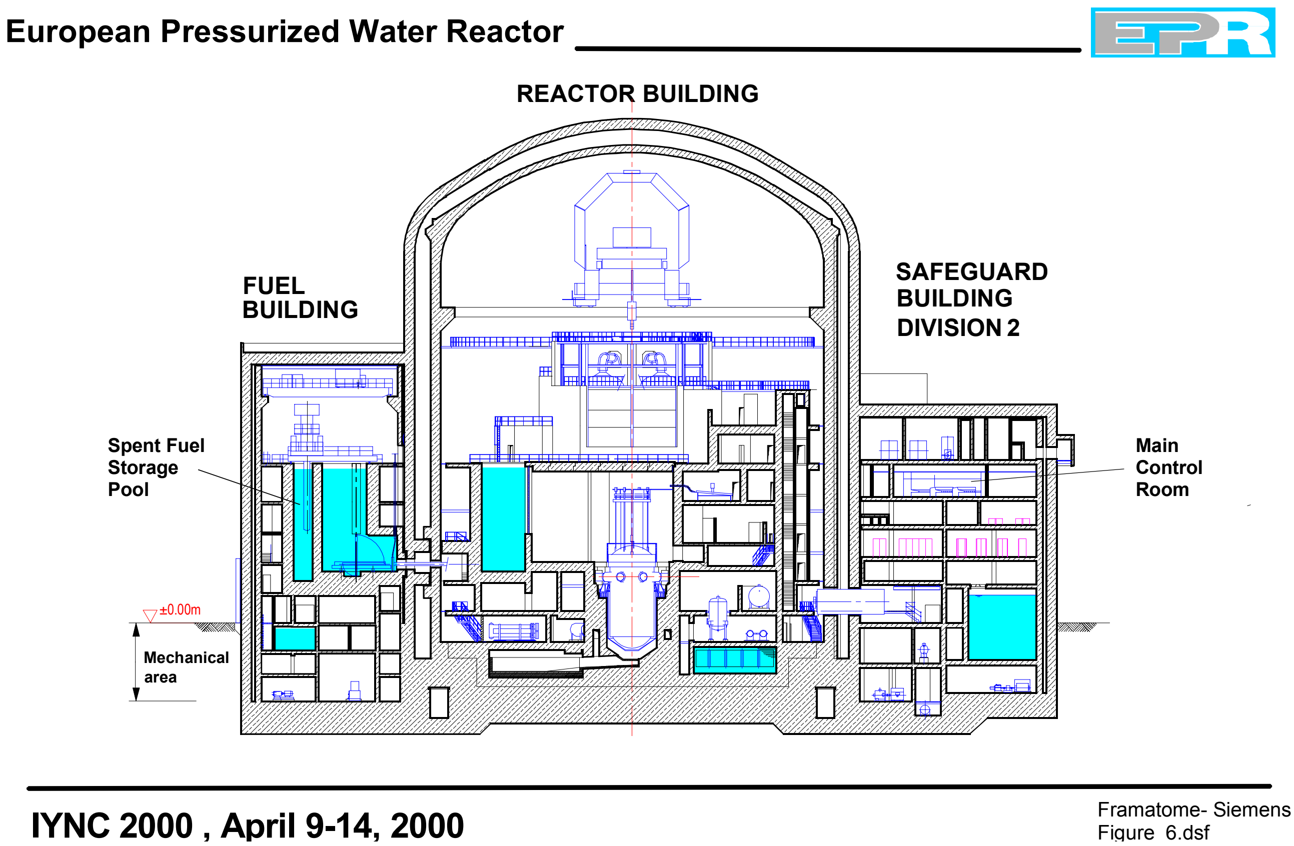

FIGURE 6. Section of the RB, FB and SAB (division 1)