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Flamanville 3 EPR

Safety assessment and on-site inspections

Flamanville 3 EPR – Safety assessment and on-site inspections

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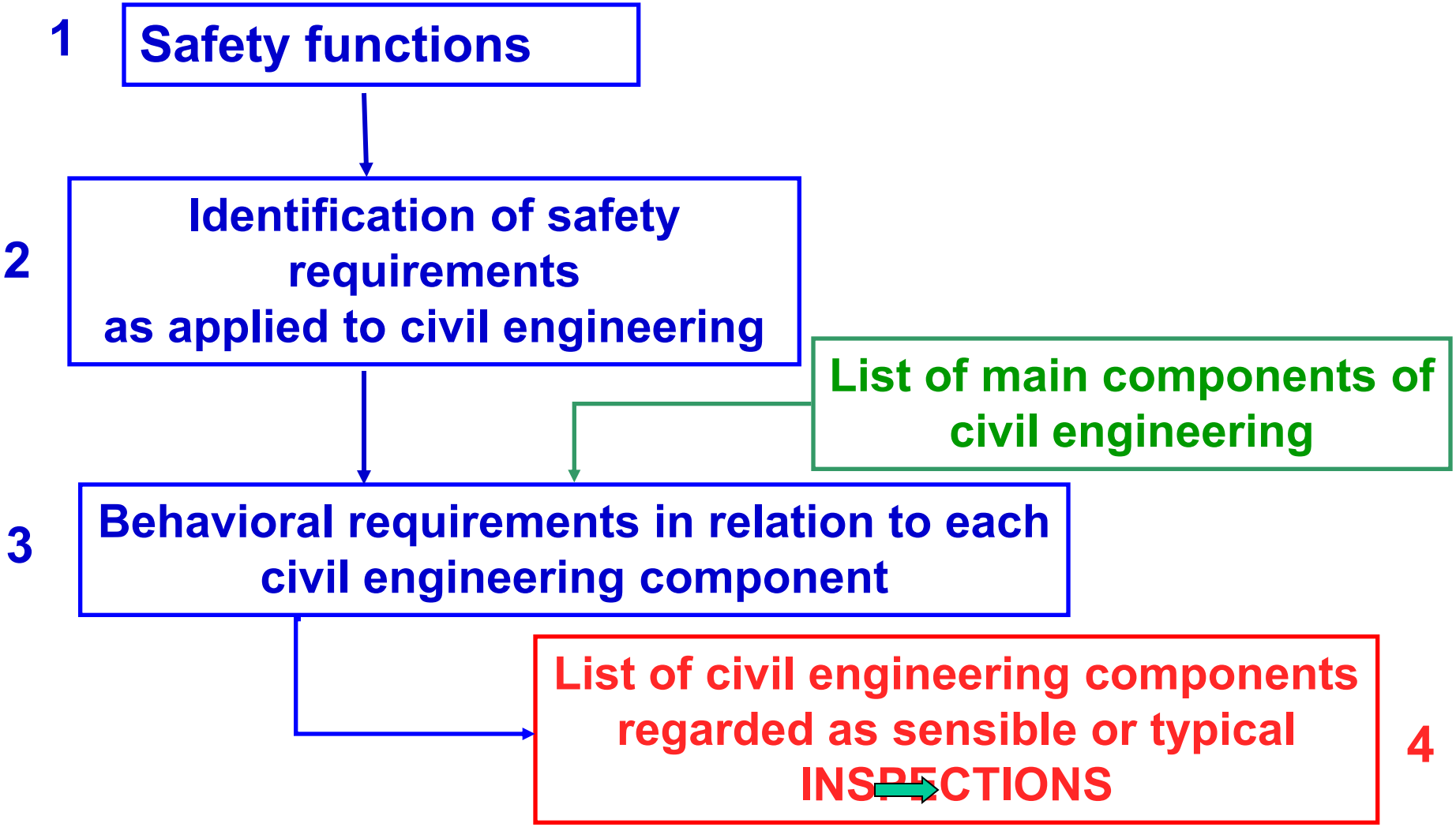
Introduction

- IRSN : Technical Support Organisation of the French Safety Authority (ASN)
  - carries out the safety assessment of EPR project design;
  - participates in the ASN inspections performed at the construction site and in suppliers factories.
- Design assumptions and features are confirmed only if they are correctly implemented and maintained in the plant

Civil design safety assessment



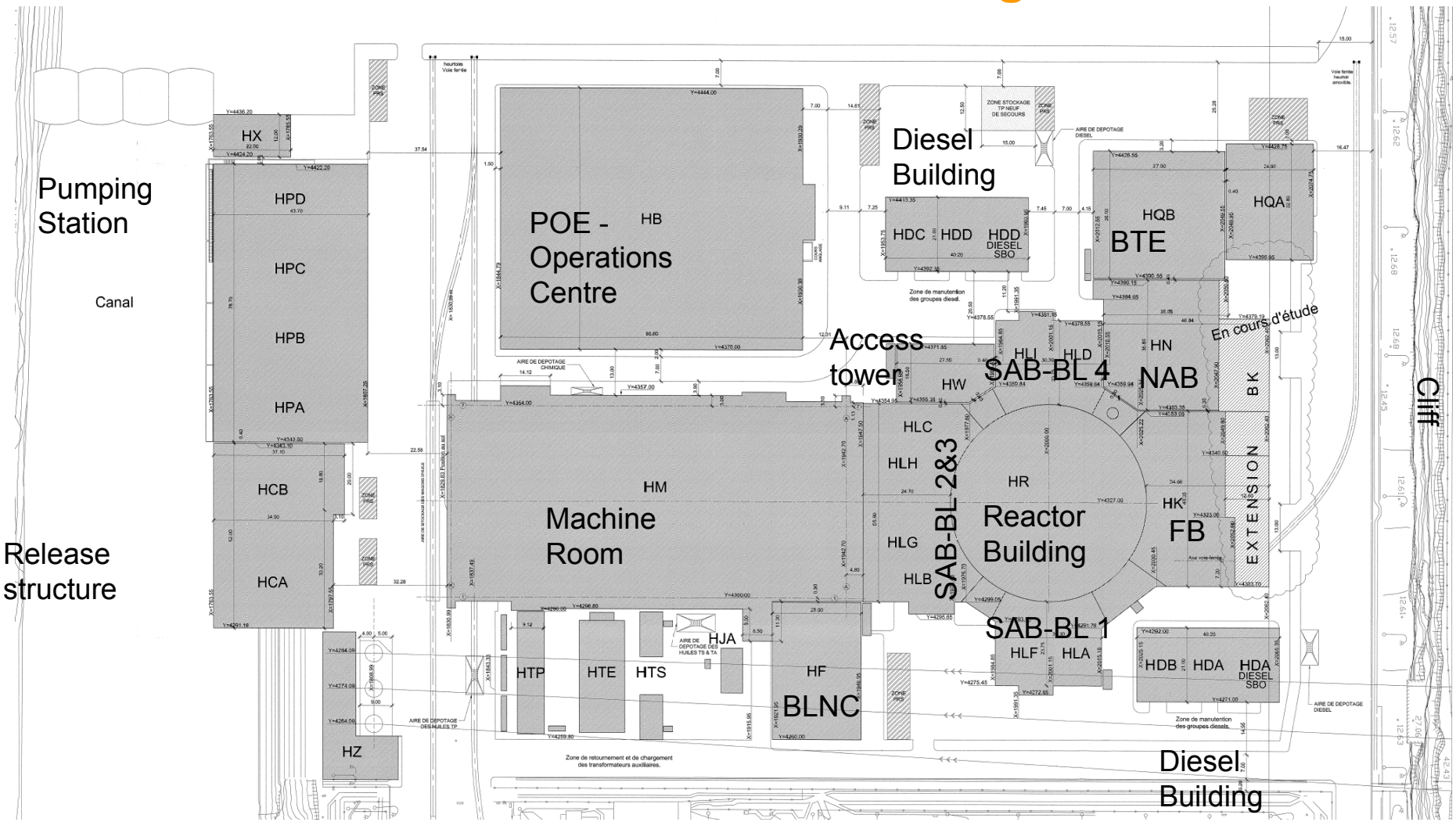
Civil design safety assessment

- Civil engineering safety functions:
  - ensure containment (in particular a 3rd barrier), in all circumstances, including for serious accidents;
  - withstand internal hazards (operational accidents, flooding, fire, explosion...);
  - withstand external hazards (floods, earthquakes, plane crash, explosion, extreme weather conditions...).

Civil design safety assessment

- Civil engineering safety requirements:
  - leak-tightness and retention;
  - resistance, stability, supporting capacity for safety equipments and systems;
  - choice of materials and determination of their biologic thickness;
  - controllability and durability of the construction during the time designated for operation of the unit.

Overview of EPR buildings



Civil design safety assessment

- Behaviour requirements are defined for each structure or part of structure.

- IRSN assessment consists in evaluating:
  - ETC-C: Technical Code for Civil works in which are defined design criteria and construction rules;
  - global models, calculations and results in term of consistency with assumptions and existence of margins, according to ETC-C;
  - robustness of design and demonstrations by carrying out a more detailed assessment.

Civil design safety assessment

- <u>Results of IRSN civil design safety assessment:</u>
  - Design studies were globally satisfactory;
  - Demands to EDF to provide additional justifications, sometimes involving significant modifications;
  - Definition of items whose construction should be inspected:
    - ✓Importance for safety,
    - ✓Execution difficulties.

On-site inspections

- Objectives and general overview:

The inspection program aims to check that:

- the technical specifications of the designers have actually been implemented in the operating procedures during structural construction;
- the master documents supplied by the designers have been satisfactorily accounted for by the civil contractors;
- good building practice has been followed during construction;
- management and survey of its site by EDF is sufficient.

On-site inspections

- IRSN has defined a methodology and an inspection program intended to ASN based on:
  - safety functions associated with civil works;
  - experience gained from the construction and operation of the existing plants;
  - experience of Olkiluoto 3 site (EPR construction in progress).
- IRSN takes part systematically in those inspections.
  - Non-conformities and bad practices can be identified;
  - Warning letters can be sent to ASN;
  - Corrective actions can be asked to EDF in order to ensure a higher construction quality level.

On-site inspections

- Examples of technical problems highlighted during inspections:
  - Water excess in structural concrete;
  - Lack of reinforcement in the nuclear island basemat;
  - Cracks in the concrete of the reactor basemat;
  - Welding process of the containment steel liner;
  - Unsatisfactory treatment of concreting joints;
  - Difficulties in anchor plates placing
  - Unsatisfactory location of prestressing ducts

Water excess in structural concrete

The water/cement ratio (0,50) of the structural concrete seemed to be too high to meet the objectives of durability of the project in marine atmosphere:

- Higher porosity of concrete;
- Additional cracking;
- Poor protection of steel reinforcement.

The formulation of concrete was changed to reach a better ratio (0,45).

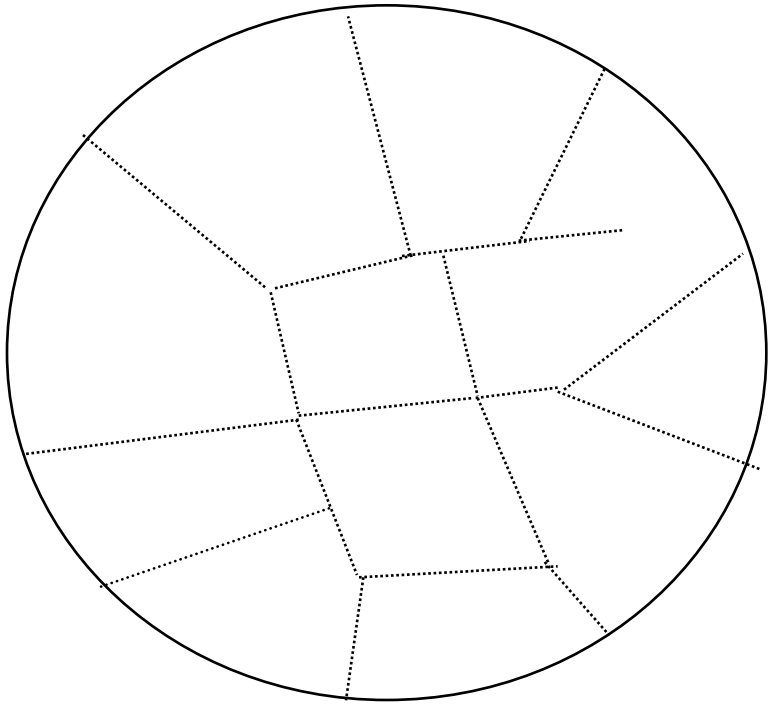
Lack of reinforcement in the nuclear island basemat

Noticed during the inspection of block number 2 of the fuel building while the concreting was in progress.

The concreting work was rapidly stopped and resumed only after the reinforcement was completed.

Cracks in the concrete of the reactor building basemat

- December 2007: concreting for first time of common basemat on nuclear island under the reactor building
  (4225 m3, thickness 1.8 m)
- Several days later: open cracks of 1 mm to 3 mm
- After cooling: open cracks of 0.4 mm to 1 mm
- Repair: injection of cracks



Configuration of cracks in the circular basemat

Cracks in the concrete of the reactor building basemat

- Cause of this non-conformity:
  - thermical effect due to the heat of hydratation of the cement during concrete setting (expansion and contraction due to exothermic reaction)

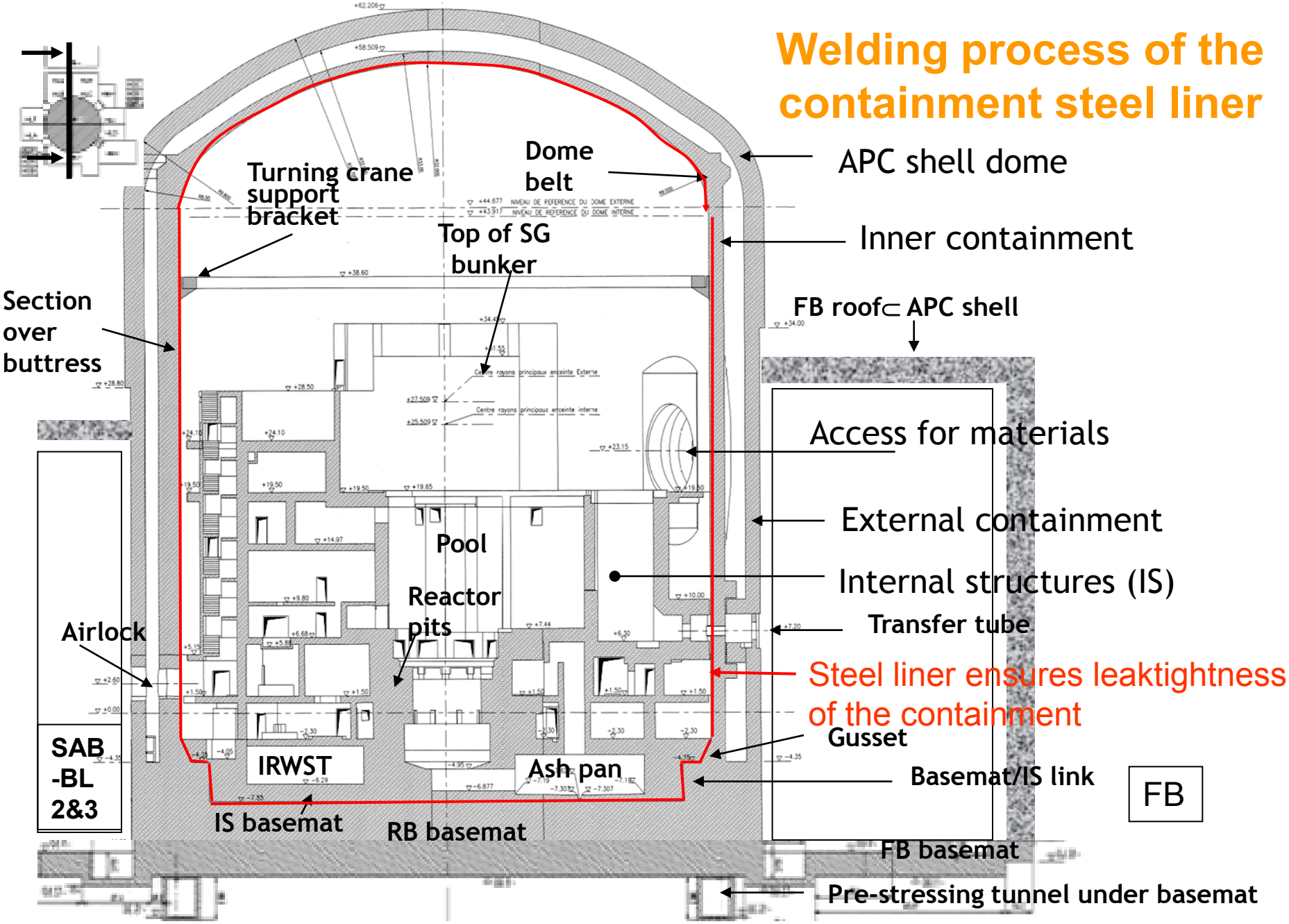
- Aggravating circumstance:
  - lack of reinforcement mesh in the upper part of the lift

- Risk:
  - reduced durability of the structure;
  - possible corrosion of the bottom reinforcement even if cracks are grouted;
  - presence of water below the basemat should be detected during the lifetime of the plant.

Cracks in the concrete of the reactor building basemat

- Comments:
  - risk associated with the execution of large concrete blocks had been pointed out by IRSN in its technical assessment a few months before;
  - proven techniques (cutting in pads, 1st lifting with a moderate height…) should have been better;
  - the formulation of the concrete could have been better in order to limit temperature inside the block;
  - there are specific constraints related to a continuous concreting during three days.

Welding process of the containment steel liner



Welding process of the containment steel liner

- Inspection in September 2008

Detailed attention to the first welding activity carried out on site on an element endorsing a safety function: the liner manufacturing

- IRSN Technical assessment

- Deviations to technical requirements detected on the welding procedure ➡ perform complementary examination tests and a 100% non destructive vacuum tests over all those welds;
- Perfectible conditions of welding (climatic conditions protection…);
- Non-conformity in documentations;
- Abnormally high rates of repairs for easily weldable steel
  ➡ welding activity not completely controlled
  ➡ 100% volumetric non-destructive tests until return to a normal situation.

Welding process of the containment steel liner

- <u>Manufacturer actions :</u>

- action plan to significantly improve the quality of works:
  - ✓Optimization of welding procedures;
  - ✓Improvement of their conditions of implementation;
  - ✓Complementary training sessions and selections of welders.

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After a few weeks , clear improvement and a return to a normal situation

Unsatisfactory treatment of concreting joints

- According to ETC-C all horizontal construction joints must be treated.
  - When the concrete is setting, the surface must be completely cleaned of any grout using a compressed air and water hose in order to remove all crumbling and oily parts, taking care not to remove any aggregates.
  - However, before any concreting, it is necessary to check if the surface of hardened concrete is clean, otherwise cleaning is performed using a pressurized water jet (pressure > 10 Mpa).
  - The use of other construction joint treatment techniques must be justified and approved by EDF.
- The site procedure contains a deviation to ETC-C, which authorized a normal use of deactivator and chipping or bush hammering

Unsatisfactory treatment of concreting joints

- Site practice seen during 4 inspections
  - Gusset -6.25 m : no treatment
  - Rake
  - Deactivator

Examples of concreting joints

Unsatisfactory treatment of concreting joints

- <u>IRSN Technical assessment >> ASN letter sent to EDF</u>
- An unsatisfactory treatment of construction joints can lead to lower quality joints which jeopardize construction quality:
  - Robustness of structures;
  - Durability (faster than expected steel reinforcement corrosion).
- Structures are not conform to design hypothesis: design margins and expected lifetime can be lower than previewed.
- IRSN asks dedicated structural verifications, taking into account awkward joints treatments.

Unsatisfactory treatment of concreting joints

- <u>EDF actions :</u>

  - stopped using one of the « deactivators »;
  - undertaken a dedicated test program;
  - strengthened its survey in that field.

Difficulties in anchor plates placing

Problem at the interface between civil works and mechanical components due to insufficient strictness of civil contractor:

- No topographical survey after concreting
- Plates shifted from their theoretical position

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Location deviations higher than stated tolerances

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- Released tolerances
- Corrective actions to improve anchor plates placing
- A topographical survey just after concreting to identify important deviations which could modify arrangement and installation drawings

Unsatisfactory location of prestressing ducts

- Significant deviations from their specified locations for several horizontal prestressing ducts, in the first concrete layer
- Final control partially carried out

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Location deviations higher than stated tolerances

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- Reduce the inner containment resistance
- Reduce its capacity to ensure the safety function required

Unsatisfactory location of prestressing ducts

<u>EDF actions :</u>

- demonstration of acceptability of those deviations
- corrective actions for next concrete layers, to obtain deviations lower than stated tolerances

Conclusion

- The analysis of all the problems encountered during the inspections have revealed:
  - flaws in the organisation of the contractors teams together;
  - unsatisfactory control by EDF of the contactor's activities.
- However, three years after the beginning of the construction, the organization and strictness of the main civil contractor and of EDF construction team have improved.