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Pressure distribution in the containment of VVER-1000 during the first seconds of large break LOCA

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ABSTRACT

A specific type of the Large Break Loss of Coolant Accident (LB-LOCA), in its worst condition, named Double-Ended Cold Leg (DECL) pipe guillotine break accident. When a LOCA occurs the coolant is lost and the fluid leaks to the containment, fourth barrier against the releases of fission products. VVER-1000 containment is studied during 200 s of the DECL break accident. The average pressure of the containment computes by CONTAIN 2.0, and MELCOR codes. The results are compared with the existing final safety analysis report (FSAR) data which resulted by the ANGAR code.

1. Introduction

The LOCA accidents in the containment divide to Small Break LOCA (SB-LOCA) and LB-LOCA (Tabadar et al., 2012), (FSAR, 2005a), (FSAR, 2005b). SB-LOCAs result from break of pipelines with equivalent diameter 100 mm and less, whereas LB-LOCAs result from break of pipelines with equivalent diameter more than 100 mm. The mass and energy of the coolant are released from the reactor coolant system to the containment through the break, in the event of an LB-LOCA. If the accident is not mitigated by action of safety systems, core meltdowns and release of radioactive material to the containment through the break is followed by reactor vessel failure and debris will eject eventually (Kljenak et al., 1998). In this study, a DECL break accident which followed by a 850 mm break diameter accident in the Cold leg pipe in loop 4 of Bushehr Nuclear Power Plant (BNPP), a VVER-1000, has been simulated using thermal hydraulics codes. The increase in average pressure distribution of the containment during the accident compared with FSAR.

2. VVER-1000 containment

Bushehr VVER-1000 containment is in the category of low sub atmospheric containments. Based on safety requirements in the design, it was adopted a double containment, an outer cast-in situ reinforced concrete one and inner steel spherical one (FSAR, 2005b). It is used as biological protection against ionizing radiation. The outer containment with the foundation plate, together with the inner steel containment forms an annulus. Negative pressure is maintained in the annulus in order to minimize activity release into the environment in case of an accident. Diameter of spherical steel part is about 56 m that some of the auxiliary instruments and core main systems have been included in this part. Containment thickness on the upper side is about 1750 mm and on the lower side is about 2000 mm. Containment has been composed from the grade Bn 250 concrete with the density of 2.35 g/cm^3. The containment system is designed to withstand the effects of a maximum possible earthquake, including a loss of coolant accident concurrent with the single active failure in a safety system. Fig. 1 shows the containment structures and rooms.

Some of the containment specifications have been given in Table 1. The rooms of BNPP containment have been introduced in Table 2.

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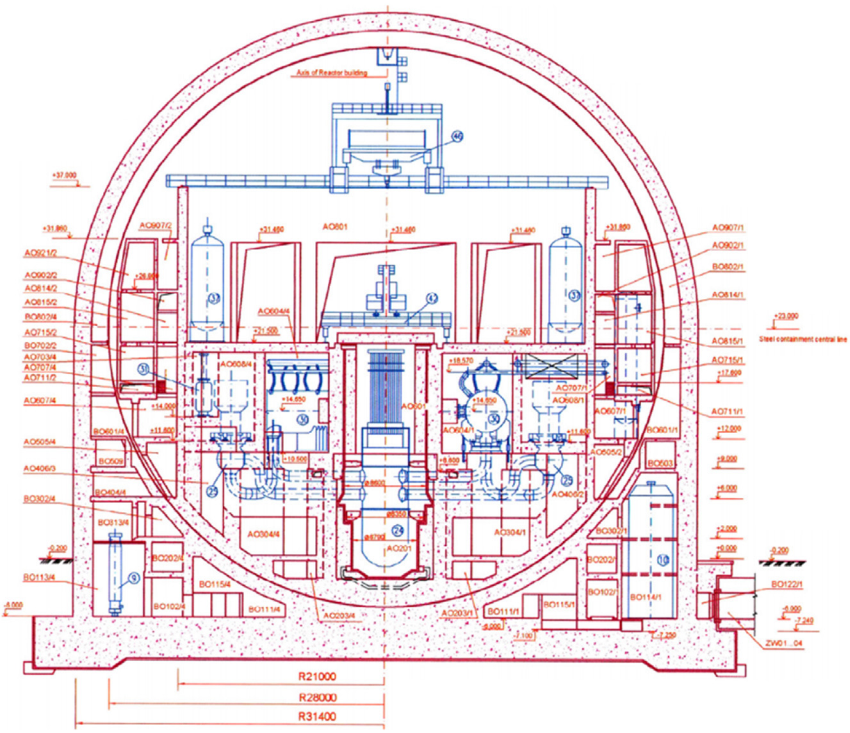

Fig. 1. VVER-1000 containment structure and rooms (Noori-Kalkhoran et al., 2014a).

Table 1
Some of the BNPP containment specifications (FSAR, 2005b).

Parameter	Value
Structural parameters	
Steel containment inner diameter (mm)	28,000
Steel thickness (mm)	30
Gap thickness (mm)	1650
Concrete thickness (mm)	1750
Containment free volume (m^3)	71,040
Design parameters	
Maximum internal pressure at 150 °C (MPa)	0.46
Maximum pneumatic test pressure at a temperature of up to 60 °C (MPa)	0.51
Peak temperature (in separate compartment) (°C)	Up to 206 °C during up to 5 min
Maximum (averaged over the volume) temperature (°C)	150
The main heat sinks inside the containment	
The total area of all the concrete walls (m^2)	18,860
The surface area of the steel containment, the effective area of the metal structures and the equipment without heat insulation (m^2)	17,712

3. DECL break scenario

Primary pipeline break accidents in the reactor are divided into two main categories, SB-LOCA accident and LB-LOCA accident. The specific type of large break LOCA is DECL break, which means a total guillotine type of break in cold leg pipe. Since in DECL accident maximum amount of primary coolant releases in containment atmosphere and there is a risk of reactor core melting, it is one of the most dangerous accidents in the reactor containment.

DECL break can be identified proceeding from the following indications:

- Reactor coolant pressure decreases
- Pressurizer level decrease
- Containment pressure increase

Schematic of the loops has been shown in Fig. 2.

DECL scenario can be hypothetically divided into three stages:

- The first stage, stage with fast reduction of pressure in the primary system.
- The second stage, stage of re-flooding of the reactor core.
- The third stage, the stage of long-term core cooling.

Any of the stages enumerated is characterized by the features of mass and energy release from the primary system. The first stage starts at the moment of Reactor coolant pipe line (RCPL) rupture, is characterized by release of substantial quantities of water from the primary system in the form of sub-cooled liquid at the first moment of the accident and in the form of steam and water mixture at subsequent moments. The level ends in the leveling of pressure in the primary system relative to the pressure under containment and practically complete loss of the reactor coolant system. In the event of complete loss of reactor coolant system, the reactor core would heat up due to residual heat from the core. A steam–zirconium reaction, accompanied by hydrogen release and generation of additional heat inside the fuel element cladding, begins on the