Survey of Regulations Applicable to the Finned Containment in Korean Nuclear Power Plant for Light Water Reactor

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1. Introduction

In severe accident, the molten corium would discharge into the reactor cavity and interact with water and concrete of cavity [1]. Molten corium includes non-oxidation metals such as Zr, Fe and Cr. These metal species reacted with water emit hydrogen gas. In addition to this, a mount of steam can be emitted to the containment such as steam line break accident. As a result, steam and hydrogen gas can pressurize containment over the design pressure and threaten its integrity. For this reasons, a concept equipped with finned on the containment building was proposed for coping with prolonged accident. Finned containment can enhance heat transfer to the ambient, and the building itself is working as a heat sink as shown in Figure 1. Multiple metal fins and metal rod are penetrated into containment wall as shown in Figure 2, and the rods are working as an additional path of heat removal. To be accepted in the nuclear power plants, this configuration should satisfy the requirement of heat removal and follow all regulations related with containment also. For applying to Korean nuclear power plants, the finned containment should follow all regulations specialized in Korea such as Nuclear regulatory criteria for light water reactor and Guidelines of nuclear safety examination for light water reactor. Therefore the purpose of this study is to survey and investigate important regulations related to the containment building to apply fins in the building.

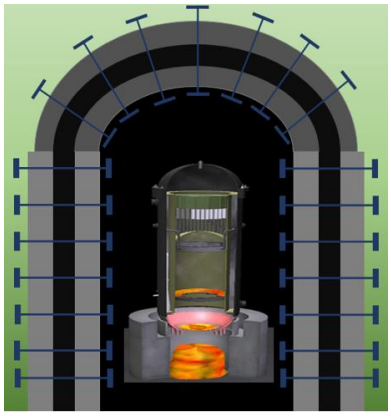

Fig. 1. Conceptual drawing of containment building that many fins are installed inside and outside of the building

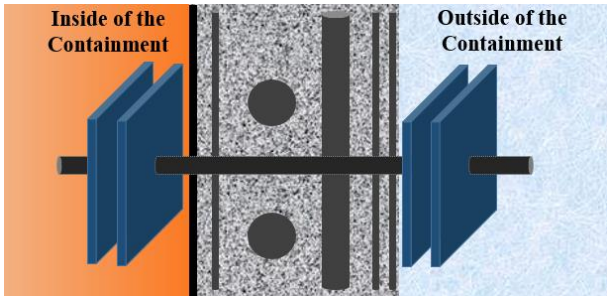

Fig. 2. Schematic diagram of steel fins penetrating into containment wall of OPR1000.

2. Nuclear regulatory criteria for light water reactor (Enforcement 2015.9.23)

2.1 Containment function design

Containment has to be designed by considering sufficient margin which does not exceed leak rate of design criteria and acceptance of predictable pressure and temperature conditions in case of Design Basis Accident (DBA). Design pressure and temperature of containment exceeds calculated peak pressure in case of DBA and has proper margin. Containment can endure external pressure condition according to negative pressure in inattention operation of heat removal systems inside of the containment.

2.2 Missile and aircraft protection of containment

For securing critical safety function of nuclear power plant, structure, system and equipment from generating on-site missile outside of the containment must be protected. In-depth examination has to be performed about aircraft impact. Design must protect safety related structure, required system and components about aircraft accident which can leak radiation above 10^{-7}/year probability. Potential effect of fire and explosion occurred by aircraft impact and dynamic effect and missile occurred by aircraft impact should be considered in the design.

2.3 Containment heat removal

Containment heat removal systems meet heat removal and depressurization capability below half of

peak pressure within 24 hours after DBA. Containment heat removal systems secure redundancy of facility and equipment conducting safety function in case of loss of on-site and off-site power along with single failure.

3. Guidelines of nuclear safety examination for light water reactor

3.1 Containment heat removal system

Containment heat removal system must decrease pressure and temperature of containment sharply and secure acceptable low standard. Appropriate plan for proper redundancy of equipment and facility must be suggested for ensuring system safety function in case of single failure of containment heat removal system.

3.2 Containment leakage test

Containment heat removal system must be verifiably designed for proceeding possible regular inspection of individual equipment and regular test for checking of system integrity and operability.

3.3 Rupture prevention of containment pressure boundary

Containment and related system must be installed for minimizing radiation leak to outside of containment and functionalizing of leakage sealing barrier in every accident condition. Materials used in containment pressure boundary must have characteristic maintaining maximum safety in case of pressurization of containment and tolerance for minimizing rapid progress of rupture.

4. SNB concrete containment in nuclear structures for finned containment

Regulations for structure change must be investigated for finned containment. Regulations intimately related with finned containment in concrete containment in nuclear structures are introduced in following contents.

4-1 General requirement

Prestressed and reinforced concrete containment must be satisfied such as rules for material, design, fabrication, construction, examination and testing. Containments having a design pressure greater than 5psi (0.35 kg/cm^2) which are classified as SNB containments shall be constructed.

4-2 Material for reinforcing systems and liners

The material to be used for reinforcing bars for containments shall conform to ASTM A 615 or A 706 and the special requirements described in SNB 2330. The material to be used for bar-to-bar splice sleeves in reinforcing bars shall conform to ASTM A 513, A519 or A 576. The material to be used for reinforcing bar splice sleeves attached to liner plates or structural steel shapes shall be carbon steel conforming to ASTM A 513, A 519, or A 576. Materials to be used for containment liners and attachments to liners are listed in Appendix Ⅰ, Table 1-2.2 [5].

4-3 Stud base requirements

A suitable deoxidizing and arc stabilizing flux for welding shall be furnished with each stud of 5/16 in (8mm) diameter or larger. Studs less than 5/16 in (8mm) diameter may be furnished with or without flux in Figure 3.

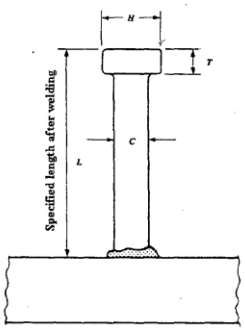

Fig. 3. Schematic diagram of stud welding in Nuclear Power Plant (SNB 2620-1)

4-4 Penetration assemblies and penetrations

Penetration assemblies, including nozzles, reinforcing plates, and penetration anchors, shall be designed to accommodate all design loads and deformations without loss of structural or leak-tight integrity. Effects such as temperature, concrete creep, and shrinkage shall be considered. Temporary or permanent brackets and attachments shall be designed to resist the design loads without loss of the liner integrity due to excessive deformation or load from bracket or attachment loads. The thermal stresses caused by process piping passing through the wall shall be considered.

4-5 Reinforcing steel splicing and development

Splices of reinforcement shall be made only as required or permitted on the design drawings or in the construction specification. Lap slices shall not be used for bars larger than D 35. Lap splices of bundled bars shall be based on the lap splice length required for individual bars of the same size and the bars spliced. The length of lap, as prescribed in SNB 3532.1 and SNB 3532.2, shall be increased 20% for a 3-bar bundle and 33% for a 4bar bundle. Bars spliced by noncontact lap splices in flexural members shall not be spaced transversely farther apart than one-fifth the required length of lap nor more than 6in (152 mm).

5. Regulations applicable to the finned containment

Welding of attachments and repair of weld metal defects must be considered for applying fins to containment.

5-1 Material for permanent structural attachments

Material for lugs, brackets and other permanent structural attachments which are permanently welded to liners shall meet the requirements of liner material (SNB 2500). If the welds are exempt from postweld heat treatment, the attachments shall meet the fracture toughness requirements of SNB 2520.

5-2 Welding of permanent structural attachments

The rules of SNB4532.1 governing welding qualifications shall apply to the welding of both internal and external permanent structural attachments to liner material. Welds shall meet the postweld heat treatment requirements of SNB 4552.

5-3 Repair of weld metal defects

Unacceptable defects in weld metal detected by methods required by SNB 5500 shall be eliminated and when necessary, repaired with the requirements of the following directions. In case of elimination of surface defects, weld metal surface defects may be removed by grinding or machining and not repaired by welding, provided the following requirements are met.

(1) The thickness of the section is not reduced more than 1/16 in.

(2) The depression, after defect elimination, is blended uniformly into the surrounding surface.

(3) The area is examined after blending by a magnetic particle or liquid penetrant method meeting the requirements of SNB 5500 to ensure that the defect has been removed or the indication reduced to an acceptable limit.

6. Conclusion

A concept of containment as a passive cooling system has been proposed. Furthermore, the new containment concept can be applied on the real containment which satisfies the various regulations. Finned containment would be expected positive effects on heat removal from the containment. If the fins are properly welded to the liner, finned containment could satisfy the leak tightness and prevention of external influences. Finned containment could be favorable to protect external impact like aircraft crash because of the additional structural integrity by the fins. However, the installation of fin must satisfy the SNB regulations regarding structure of reinforced concrete. This also will be examined with the penetration as well as the optimization of fin shape.

Acknowledgements

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