Development of the APR+ Reactor Containment Building General Arrangement (GA)

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1. Introduction

The general arrangement (GA) drawing of a nuclear power plant is the most basic drawing, containing all of the plant equipment, systems, and rooms. Therefore, it should be issued at an early design stage to provide the contours of the overall plant structure. This type of drawing is typically used widely throughout the design stages.

The development project of the APR+ (Advanced Power Reactor+), as a model to succeed the APR1400 (Advanced Power Reactor 1400) design, has its own GA that encompasses all of its power buildings. This drawing was developed starting in October of 2009. Among several of the buildings in this design, the Reactor Containment Building (RCB), Auxiliary Building (AB), and EDG (Emergency Diesel Generator) Building are some the most important buildings to produce electricity, and to protect against undesirable radiation emissions.

This paper focuses on the design characteristics of the general arrangement of the RCB.

2. Design requirements for the GA

The design requirements for the RCB GA are described in several documents as specific items. The requirements listed below are related to the building structure. A diverse range of other requirements is also described in this paper.

- Code of Federal Regulation
  - 10CFR100 Appendix A
  - 10CFR50 Appendix A and B
- NRC Regulatory Guide
  - ASME Section III. Div.2 CC-2000: Material
  - ASME Section III. Div.1 Appendix I: Design stress intensity values, Allowable stresses, Material properties, and Design Fatigue Curve.
  - ASTM A416

3. The GA of the Reactor Containment Building

The Reactor Containment Building (RCB) is located at the center of the Nuclear Island. It is placed on a common basemat with the Auxiliary Building (AB). This configuration prevents the propagation of system damage by internal and external events such as flood, fire, security incidents and sabotage.

Other internal structures are also arranged to improve maintainability, accessibility, and convenience of equipment replacement.

3.1 The design features of RCB

As a kind of Engineered Safety Facility, the RCB should be designed as a seismic category I structure and should contain the reactor, the reactor coolant system, the IRWST (In-Refueling Water Storage Tank), the steam generator, the reactor coolant pump, and the pressurizer. The main functions of the RCB are as follows:

- Leak-tightness to endure the load of the normal operation and the LOCA (Loss of Coolant Accident).
- Protective wall to preserve internal structure from an earthquake, a tornado or an external missile collision.
- Support to maintain the polar crane and internal slab structure.

The structural design features of the RCB, compared between the APR1400 and the APR+, are summarized in Table 1.

Table 1. Comparison of design features of the RCB between APR1400 and APR+

Item	APR1400	APR+
Design pressure	60 psig	60 psig
Building height (above basemat)	278 ft	280.5 ft
Spring line height (above basemat)	186 ft	186.7 ft
Inside wall diameter	150 ft	153 ft
Wall thickness	4 ft	4.5 ft
Dome thickness	3.5 ft	4 ft
Floor space	19,607 ft^2	20,612 ft^2
Total volume	4,243,738 ft^3	4,466,428 ft^3

3.2 The Structure of RCB

The RCB of the APR+ has referenced that of the APR1400, which was proven technology. The structure of the building is composed of the reinforced concrete basemat, the primary and secondary internal shield wall, the 1/4" steel wall liner plate, and pre-stressed concrete cylindrical wall.

The operation floor is divided into Levels 1~5 in order to allow for the operator's easy access to the major equipment. A two (2) inch seismic gap has been applied between each operation floor and the inside wall to absorb any earthquake impact.

The tower crane rail, used to lift the major equipment, is arranged in the top of the cylindrical containment building.

The Reactor Containment Building is designed as a Steel Concrete (SC) structure with seismic category 1. It shares a common basement with the Auxiliary Building (AB).

3.3 Design change between APR1400 and APR+

In addition to changing the structural design, certain aspects of the system and component design was changed.

As the Reactor Drain Tank (RDT), which is allocated in EL. 100', is somewhat larger than that of the APR1400, its room also larger in proportion. And the Letdown Heat Exchanger of the CVCS (Chemical Volume Control System) at the same elevation is relocated from EL. 100' to EL. 136' in order to cooperate with the regenerative heat exchanger in same elevation.

To ease the manipulation of the pressurizer and to increase radiation protection, the compartment design of the pressurizer area was reinforced.

The major piping design related to the RCS has been changed. The shutdown cooling piping is doubled from each RCS hot leg to conform with the new four (4) trains design concept. And the charging piping has also been doubled to allow the pressurizer to reinforce the integration against piping thermal shock.

3.4 Preparing for a Severe Accident

The RCB has incooperated several design features to cope with the beyond design basis accident and the severe accident.

As measures to mitigate the consequences of severe accidents, the reactor vessel cavity was designed so that the heat transfer area of corium is not less than 0.02 m^2 /MW, such that it is cooled and solidified on the cavity floor. This cavity floor area is designed to sufficiently contain the core catcher facility in the future and is one of the optional design features to cool the molten core. Also, the convoluted vent path of the reactor vessel cavity prevents any molten core debris from being released into the containment atmosphere.

3.5 Reinforcing wall thickness

According to the recently issued aircraft crash requirements 10CFR52 RIN 3150-AI19 'Consideration of Aircraft Impacts for NPPs', the APR+ has a reinforced wall thickness for not only the AB but also for the RCB, as shown in Fig.2. Recently, to meet the new requirements, WEC (Westinghouse Company) evaluated the potential impact of aircraft crash accidents of a large commercial aircraft and a military aircraft.

An APR+ structural analysis for RCB was also conducted to evaluate the aircraft crash effect of the aforementioned large commercial airplane and military plane.

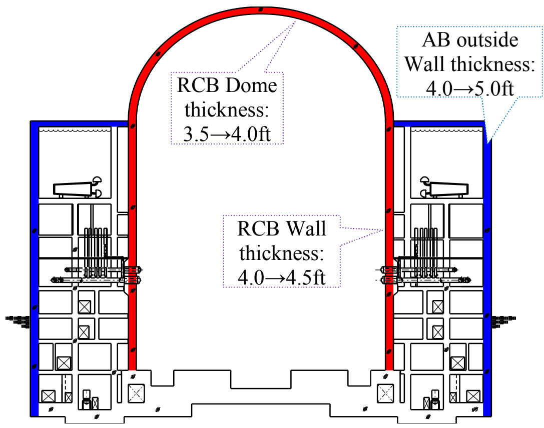

Fig.2 Reinforced APR+ RCB wall thickness compared to APR1400 RCB wall

3.6 Building Structure Modularization

Modularization is an alternative construction method that can reduce the construction period. The steel plate concrete (SC) module, a composite component with steel outer shells and a concrete core, and component modules will be applied to the internal or external structures of the RCB such as:

- IRWST
- Primary shield wall
- Secondary shield wall
- Pressurizer room
- Containment liner plate
- RCB dome

4. Conclusions

The APR+ RCB was developed on the basis of the APR1400 adding the APR+ advanced design features. It was developed to meet several international structural design requirements. It accommodates major safety related nuclear steam supply systems (NSSS) equipment and a severe accident coping facility.

To increase the constructability, some internal or external structures of the RCB are modularized. Its outer wall is thickened and therefore reinforced for protection against an air-craft crash.

The overall structure volume of the RCB is increased somewhat owing to several major pieces of equipment that have been enlarged.

REFERENCES

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