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Prevent Corium Stratification In-Vessel Retention

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1. Introduction

The meltdown, which may threaten the integrity of the hemisphere under the core, is often regarded as a severe accident. When the reactor core is melted down, it is stratified into the metal layer and the ceramic layer. Stratification is determined by the amount of carbon(C) in corium. As the heat conductivity of metal layer is higher than that of the ceramic layer, heat concentration occurs in the upper part of the bottom hemisphere which comes into contact with the metal layer. As a result, the thermal margin decreases, and the nuclear reactor vessel may be destroyed. To control carbons, which is the major cause of stratification, platinum may be applied.
When certain amount of platinum is inserted inside the lower reactor head, it's capable of absorbing carbon at a high temperature under a melting condition.

2. Methods and Results

To find investigate a principle to prevent the stratification of the corium, the behavior of the reactor corium was started, and the factors affecting to stratification are as follows:

2.1 Reactor corium

The key conclusions of the RASPLAV experiment using the original material similar to the reactor corium ($UO_2/ZrO_2/Zr$ 200kg) are as follows:

1) In all experiments conducted to study the behavior of the oxidic-ceramic melt pool, composed of U-Zr-O, slightly oxidized and having a carbon content of 0.3~0.4 wt.%, two unmixed layers were formed and stratification occurred.
   ① Liquid like light metal with plenty of Zr and carbon
   ② Heavy liquid composed of $(UZr)O_2 - x$
2) In the behavior experiments for oxidic-ceramic melt pool with a carbon content of 0.01 wt.% or less, no stratification occurred.

2.2 Stratification in corium

In the case of PWR such as APR1400, since the B_4C control rod is used, the amount of carbon in the corium is sufficient to cause the stratification. Accordingly, if carbons are dispersed into the corium pool by adding a metal that may reacts with carbon, the stratification will be prevented. If stratification does not occur, heat concentration will not take place, and Departure from Nucleate Boiling (DNB) does not occur in the upper part of the hemisphere under the pressure vessel, and thus the threat to the integrity of the nuclear reactor will disappear.

2.3 Lower support structure

If a severe accident takes place, and the temperature of the reactor core rises, heat will be delivered to the cladding and nuclear fuel will dissipate very quickly due to the exothermic reaction of zircaloy. At this time, the nuclear reactor structure, control rod, cladding and nuclear fuel will begin to melt. The geometrical shape of the nuclear reactor structure will be lost considerably, and the reactor corium pool will be formed inside the reactor core. The core plate will melt and will be destroyed due to the reactor corium, and the reactor corium will be relocated in the hemisphere under the nuclear reactor. If a metal reacting with carbon is put inside the ICI nozzle in the lower support, and carbon is controlled, the carbon content affecting the stratification of the reactor corium will decrease, and thus prevent stratification. As the existing carbon content is maintained at about 0.3wt.%, it is possible to prevent stratification simply by adding such a material inside the ICI nozzle.

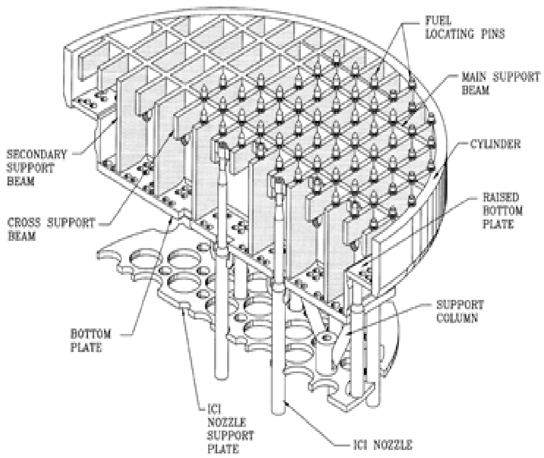

Fig Ⅰ. Lower support structure

2.4 Combination between the metal and the carbon

The metal reacting with carbon is put inside the lower support structure during normal operation, and the conditions for controlling carbon when a severe accident occurs are as follows.

- It must be suitable for the ionic bond chemical formula.
- No radioisotope should be included.
- It must be possible to explain the principle of combination with carbon.
- The reaction product should not result in stratification.
- Metals that meet these conditions are osmium, rhenium, tungsten and platinum.

Table Ⅰ.Properties of the elements and certain molecules

	Tungsten	Rhenium	Osmium	Platinum
Symbol	W	Re	Os	Pt
Atomic Number	74	75	76	78
Atomic or Molecular Number	183.85 g/mol	186.207 g/mol	190.23 g/mol	195.084 g/mol
Melting Point	3400℃	3186℃	3030℃	1768℃
Density	19.32 g/㎤	21.02 g/㎤	22.59 g/㎤	21.45 g/㎤
Cross-Section	18.5b	99.3b	3.76b	21.2b
Price	0.015$/g	3.600$/g	12$/g	52.6$/g

Among them, the most suitable metal is platinum. As platinum melts at 1768℃, it exercises influence only in an accident. Also, it absorbs carbon at a high temperature. The weight of platinum is compared with the carbon content in the reactor corium, and an appropriate amount will be filled.

3. Conclusions

When the severe accident takes place, platinum reacts first with carbon, a component of the reactor corium, and prevents stratification. So the threat to the integrity of the nuclear reactor due to Departure Nucleate Boiling disappears.

4. Further Research Works

1. For the specific determination of the amount and location of carbon controller, further research work should be continued.

2. For the effectiveness of the carbon controller, the density of the material is recommended around 10. That can be applied by the alloy of low density material.

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