SUMMARY RESULTS FROM PHEBUS FPT-1 TEST AND LESSON LEARNT WITH MELCOR ANALYSIS

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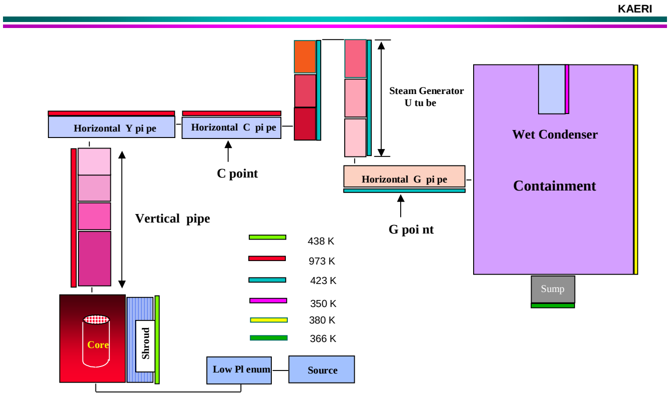
INTRODUCTION

The objectives of this paper are to summarize the new findings and the confirmed results from the Phebus FP experimental data and to notify the helpful information for the better use of MELCOR.

The aim of the Phebus FP experimental program is to study the core degradation phenomena and the behavior of the fission products both in the reactor coolant system and in the containment building. The credible results and information from this program can contribute to improve our knowledge and validate the severe accident codes such as MELCOR.

The Phebus FP experimental facility consists of the five important components [Fig 1]; the reactor vessel and core, the vertical and horizontal pipes with C-point for simulating the hot leg in the real plant, the cold horizontal pipe with G-point connected at the exit of the SG U-tube (the cold horizontal pipe stand for the cold leg in the real plant), the containment building of cylindrical shape including sump. The three condensers in the containment building are to simulate the condensing phenomena being occurred on the several cold surfaces that may exist in the steam filled containment under the severe accident.

Figure 1. Phebus FP experimental Facility



Phebus FP program has been performed by IRSN in France under the frame of international cooperative research program. Initially six tests from FPT-0 to FPT-5 were planed but the last test was canceled and other five experiments were already performed. Table.1 shows the experimental conditions and features of the Phebus FP tests.

Table.1 Phebus FP test conditions and the date of experiment

	Fuel Condition	Control rod type	Objective	Date of complete
FPT-0	Fresh rod	Ag-In-Cd	Core Damage & Max FP release Under steam rich condition	1993. Dec
FPT-1	23 GWD/MTU Burn-up rod	Ag-In-Cd	Core Damage & Max FP release Under steam rich condition	1996.July
FPT-2	32 GWD/MTU Burn-up rod	Ag-In-Cd	Core Damage & Max FP release Under steam rich condition	2000.Oct
FPT-3	24 GWD/MTU Burn-up rod	B_4C	Core Damage & Max FP release Under steam rich condition	2004
FPT-4	23 GWD/MTU Rubble Debris	NA	Low volatile FP release from rubble debris	1996. July

KAERI has been participated in this program since 1991. The data from the Phebus FP experiment have been applied to validate the predicted results from the MIDAS computer code, which is being developing by KAERI. This paper describes the summary of the experimental results and lesson learnt from only the Phebus FPT-1 test.

II. LESSON LEARNT AND RESULTS

II.1 CORE DAMAGE & MELT PROGRESSION

The special features found in Phebus FPT-1 were the early liquefaction of fuel and its relocation [1]. In the FPT-1 test, fuel relocation was initiated at about 2100K~2200 K. In the model of MELCOR, it is expected that the fuel relocation can start just after the oxide layer failure at about 2500~2600 K [2]. This early liquefaction and relocation may be explained with the eutectic reaction and the effect of burn-up, which cause a crack, a swelling and a melt penetration into the fuel cracks.

In FPT-1 with the burn-up fuel, fuel swelling and foaming occurred at the central part of the core. This foaming phenomenon seems to start from 2300 K and it leads to the decrease of the radial heat transfer to the shroud. This decrease of heat transfer increases the fuel temperature in the inner region rapidly and the resulting foaming from the fuel melt can produce a flow blockage.

Also these swelling and foaming phenomena cause the bundle to expand to the shroud. These phenomena could induce the vessel attack or the complete flow blockage having a flow chimney. These new features from the high burn-up fuel found in this program require an alternative-challenging model through the next severe accident research program.

II.2 FISSION PRODUCT BEHAVIOUR

The overall fission product release pattern from the fuel, control rod materials and structure materials in the Phebus FPT-1 test showed a similar trend with the three peaks at the separate phases such as Zr oxidation, fuel liquefaction and relocation of molten corium. The only exceptions were Zr and Re. These two species showed a delay of release due to the reduction of the contact area between the flowing gas and molten pool.

The release of cesium revealed a strange behavior because the mass flow rate of Cs at G-point (after SG) was lager than that at C-point (before SG). This unphysical phenomena could be explained by the fact that the flow rate of Cs was influenced not only by the release rate from the core but also by the difference between the deposition in SG u-tube and the re-suspension from the surface of the horizontal circuit at C-point. Therefore, it is necessary that the re-suspension phenomena should be counted for modeling the Cs release.

From the experimental data, large amount of Ru, which belongs to the less volatile species, was released from the fuel. Though most of the released Ru was deposited on the inside surface of vessel including the bundle, the deposited Ru can be changed into the oxidic form of Ru such as RuO_4 with a high volatility under the condition of air ingress.

Regarding the circuit deposition, a negligible amount of fission product was condensed in the horizontal pipe, which was kept at 973 K by the heater. But the exceptions were Cs and In. These two species were deposited on the horizontal pipe near the inlet where the SG U-tube remained at 423 K. It means that the Cs and In vapor become to condense near or less than the 973 K. Currently, MELCOR assumes that Cs becomes to condense less than 600 K and In less than 1000 K.

Another astonishing result was the less release of low volatile species such as Ru, Ba and La after the formation of molten pool. The reason for the less release during the formation of molten pool may be explained both by the decreased surface to volume ratio to escape the fission product gas and the formation of stable material with the low volatile species within the molten pool.

The knowledge on the aerosol size is the most important information for modeling the aerosol behavior in the containment. The size of aerosol was measured at three locations such as C-point, G-point and containment using an impactor and a sampling bulb. The measured data at C-point (hot-leg) showed that the AMMD (aerodynamic mass mean diameter) and standard deviation were 1.5~2.0 μm and 2.0 respectively. The results at G-point (cold-leg) were 3.0 μm and 2.0 and they showed the lognormal distribution. The results in the containment showed also the lognormal type with the AMMD of 3.5~4.0 μm and standard deviation of 2.0.

The experimental results showed that the gravitational settling was the dominant mechanism for the removal of aerosol in the containment under severe accident. The second one was a condensation on the condenser by the diffusio-phoresis.

The existence of gaseous iodine in the containment is important in terms of source terms because of its large contribution to the public hazard. After the isolation, the concentration of gaseous iodine in the containment was dependent on the balance among the three processes such as the generation of organic iodine from the painted condenser, the overall depletion processes and the release of gaseous iodine from the pool of sump to the atmosphere by the radiolysis. But the concentration of gaseous iodine before the isolation between circuit and containment depends on the amount of gaseous iodine entering the containment in addition to the above-mentioned three processes

The important finding on the iodine chemistry was the identification of the trapping effect of iodine by silver within the pool of sump.

III. CONCLUSION

The new features such as the effect of high burn-up fuel, the strange release behavior of Cs, the gaseous form of iodine in the RCS and the organic iodine generation found in Phebus FPT-1 raise the alternative challenging phenomena. They need to be modeled through the next severe accident research program.

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