A Survey of Core Inlet Blockage Test Due to Debris after Large Break LOCA

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1. Introduction

There has been concern that following a LOCA, the chemical precipitate, fibrous and particulate debris within the sump after a LOCA could collect on the sump screen and block the flow of cooling water into the core. There is also concern about the effects of the debris that passes through the sump screen. This debris could be ingested into the ECCS and flow into the RCS. The debris mass that bypasses the sump screen and enters the RCS could result in sufficiently large head losses that may impede core inlet flow and challenge long-term cooling of the core. During operation of the ECCS to recirculate coolant from the containment sump, debris that has passed through the sump screen and into the recirculating fluid may collect throughout the fuel assemblies (FAs). Since the FAs are designed with flow passages that provide coolant flow from the reactor vessel (RV) lower plenum into the region of the fuel rods, flow resistance through this path may occur. This concern raised with respect to the collection of debris and post accident chemical products within the core itself is called "downstream effect of GSI-191"[1]. Generic Letter (GL) 2004-02 [2] identified actions that utilities must take to address the sump blockage issue.

In this study, status of evaluation/test for downstream effect of GSI-191 is surveyed for US-APWR, U.S. EPR which are pursuing US NRC Design Certification(DC) and AP1000 which has obtained US NRC DC recently. Moreover, it is presented the current status and study plan of evaluation/test of downstream effect for APR1400 in order to pursue US NRC DC.

2. Research History of Each DC Applicant

The new pressurized water reactors which are currently pursuing US NRC DC are US-APWR by Mitsubishi Heavy Industries(MHI) and U.S. EPR by AREVA. AP1000 designed by Westinghouse(WEC) has obtained NRC DC on Dec. 30, 2011. Specifications of these new reactors and schedules for NRC DC are presented in Table 1. It is necessary to survey evaluation/test status of these reactors for APR1400 reactor which will be pursuing US NRC DC.

[MHI]

MHI performed debris generation with zone of influence(ZOI), debris transport, chemistry modeling and test, ECCS strainer performance evaluation with NPSH assessment and performance tests, strainer mechanical integrity and upstream effect[6,7]. Recently, they are performing core inlet blockage tests and they will submit the test report to NRC in the latter half of this year[8].

Table 1 Specifications of New reactors which are pursuing US NRC DC

	APR 1400	*US-APWR*	*U.S. EPR*	*AP 1000*
Thermal Power(MWt)	3983	4451	4590	3400
Electric Power(MWe)	1400	1700	1600	1000
Hot Leg Temp(°F)	615	617	625	610
No. of FA	241	257	241	157
No. of hot/cold leg	2/4	4/4	4/4	2/4
Start of DC Review	‘13	‘08.2	‘08.2	‘08.2
End of DC Review	-	‘14.5	‘12.10	‘10.12
DC Rulemaking	-	‘14.10	‘13.6	‘11.12

[AREVA]

AREVA performed debris generation with ZOI, debris transport, chemistry modeling and test, ECCS strainer performance evaluation with NPSH assessment and performance tests, upstream effect[5]. They performed also core inlet blockage tests. NRC found that there were meaningful differences between the results from AREVA and those from PWROG after reviewing AREVA's CIB test report. Therefore, NRC asked to perform cross test, that is, PWROG needs to perform CIB tests with AREVA fuel by using PWROG test facility. Recently, PWROG concludes that the differences are within the measurement uncertainties.

[PWROG]

The Pressurized Water Reactor Owners Group (PWROG) sponsored a program to provide analyses and information on the effects of debris and chemical products on core cooling for PWRs when the ECCS is realigned to recirculate coolant from the containment sump. The intent was to demonstrate

adequate heat removal capability for all plant scenarios. This program is documented in Ref.[3]. The PWROG initiated prototypical FA testing to establish limits on the debris mass that could bypass the reactor containment building sump screen. Initial head loss tests were performed in 2008~2009 by WEC and AREVA to define a bounding debris load for PWRs. The WEC results were documented in this document and the results of both the WEC and AREVA tests were integrated into the later version of Ref.[3]. The results of the additional testing conducted by both WEC and AREVA will be integrated into Revision 2 of Ref.[3]. Final conclusion by WEC up to now is that the long term core cooling capability after large break LOCA can maintain in case that less than 15 grams of fiber per FA enter the reactor core.
Table 2 shows auxiliary information regarding the tests which are necessary for GSI-191 issue.

Table 2 Test categories and Testers for each DC applicant

	SKR 3/4	*US-APWR*	*U.S.EPR*	*AP1000*
Vendor of strainer	AECL	PCI	Prototype	CCI
Strainer perf. test	AECL	ARL	ARL	FAI
Chemical effect test	AECL	MHI	AREVA	WEC
CIB test	-	MHI	CDI	WEC

3. KHNP Research on CIB Test

The design control documents(DCD) of APR1400 DC are produced based on FSAR of Shinkori Units 3/4. Debris generation with ZOI, debris transport, ECCS strainer NPSH assessment are performed and described in the DCD of APR1400 DC. During DCD review phase, the performance test for ECCS strainer, chemical effect test will be performed if US NRC asks to perform them. These test results are already available for Shinkori Units 3/4. We can use them for APR1400 DC with the condition of AECL's acknowledgement. One of research items for downstream effect is core inlet blockage test and it is necessary for APR1400 DC because APR1400 DC will use PLUS7 fuel for which CIB test has not been performed before. KHNP is now performing this test using PLUS7 fuel assembly with the condition of APR1400 DC as a sub-item of "Development of Verification Technology for the Change of International Regulatory Requirements" which is supported by Ministry of Knowledge Economy. Fig.1 shows the schematic diagram of CIB test facility which will be used for PLUS7 CIB test.

4. Conclusions

There have been many studies on a safety issue regarding confirmation of long term core cooling capability due to debris clogging after large break LOCA. There are many established methodologies for various areas to resolve this issue but there is one issue that is necessary to establish a methodology to resolve GSI-191, that is, "downstream effect" which is an issue of blocking core inlet flow due to the bypassed debris from ECCS strainer. In order to resolve this issue, each DC applicant has performed CIB tests. PWROG proposed less than 15 grams of fiber per fuel assembly entering the reactor core can satisfy downstream effect concern. According to preliminary assessment of debris generation for APR1400 DC, we cannot meet this 15 grams of fiber per fuel assembly. This is why we are trying to test CIB using PLUS7 fuel assembly with the condition of APR1400 DC.

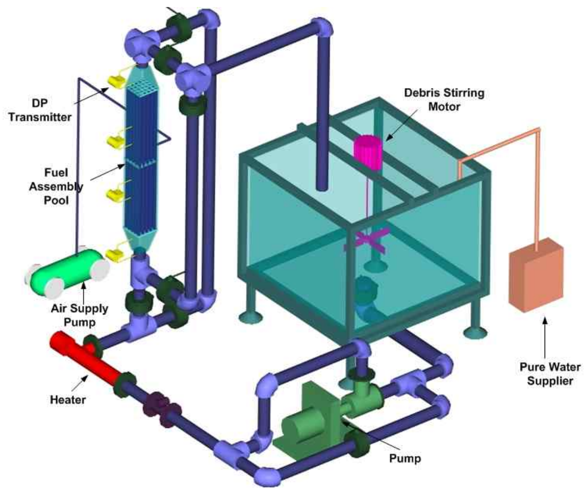

Fig.1 Schematic Diagram for APR1400 CIB Test Facility

REFERENCES

[1] Generic Safety Issue, GSI-191, "Potential of PWR Sump Blockage Post-LOCA," 1998
[2] Nuclear Regulatory Commission Generic Letter GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized Water Reactors," Sep. 2004
[3] WCAP-16793, R2, Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid, Sep. 2011
[4] WCAP-17028,R5,Evaluation of Debris-Loading Head Loss Tests for AP1000 Fuel Assemblies During LOCAs, Mar. 2010
[5] ANP-10293NP, R3, U.S. EPR Design Features to Address GSI-191, Mar. 2011
[6] MUAP-08001, Sump Strainer Performance, Aug. 2011
[7] MUAP-08013, Downstream Effects, Aug. 2011
[8] MUAP-10021, Core Inlet Blockage Test, Nov. 2010