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Vibration Measurement Plan of RVI CVAP for Shin-kori Unit 4

Do-Young Ko, Jae-Gon Lee, Kyu-Hyung Kim,
Nuclear Engineering & Technology Institute, 25-1 Jang-dong, Yuseong-gu, Daejeon 305-343 Republic of KOREA
kodoyoung@khnp.co.kr, jglee@khnp.co.kr, khkim123@khnp.co.kr,

1. Introduction

U.S. NRC Regulatory Guide 1.20 [1] requires performance of the reactor vessel internal (RVI) comprehensive vibration assessment program (CVAP) in order to verify the structural integrity of the reactor internals for flow induced vibrations during pre-operation and initial start-up test. The reactor internals of RVI CVAP were classified according to arrangement, design, size, and operating conditions. We plan to verify the integrity of the design and manufacturing of RVI by performing the non-prototype category Ⅱ CVAP, for which limited measurement, analysis, and the inspection program as shown in Fig. 1. This paper explains the vibration measurement plan of RVI CVAP for Shin-kori unit 4.

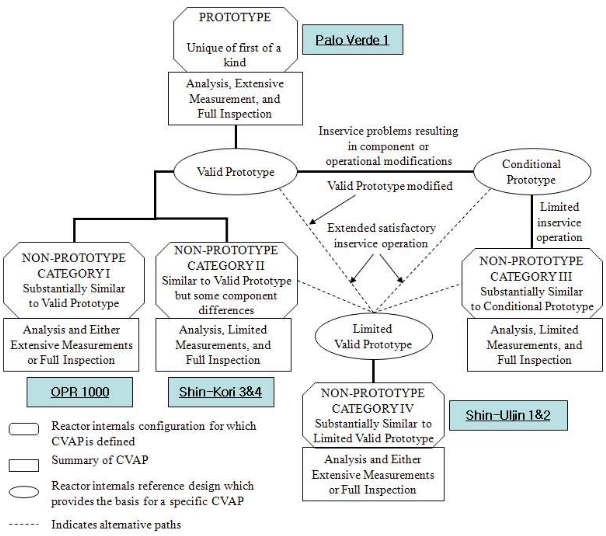

Fig. 1 Category of CVAP

2. Purpose and Main Procedures

Shin-kori unit 3 & 4 are the first commercial plants of APR1400 (advanced power reactor 1400 [MWe]) design. The prototype plant of Shin-kori unit 3 & 4 is Palo Verde unit 1 [2], but Shin-kori unit 3 & 4 have changed the type of the core element assembly (CEA) shroud, the thermal power and coolant flow rate, the thickness of the core support barrel (CSB) flange and fuel alignment plat, and the number of CEA guide tubes compared to Palo Verde unit 1. The nuclear power plant of the non-prototype category Ⅱ is similar to the valid prototype but some components have differences. Therefore, we plan to verify the integrity of RVI for Shin-kori unit 4 by performing the non-prototype category Ⅱ CVAP. The non-prototype category Ⅱ of RVI CVAP requires an analysis, limited measurement, and a full inspection program.

2.1 Purpose

The purposes of the vibration measurement of RVI CVAP are as follows. The first is to confirm results of the hydraulic and structural analysis. The second is to determine the margin of safety. The measurement program should be sufficiently flexible to permit definition of any significant vibratory modes. Fig. 2 shows a schematic diagram of the measurement program.

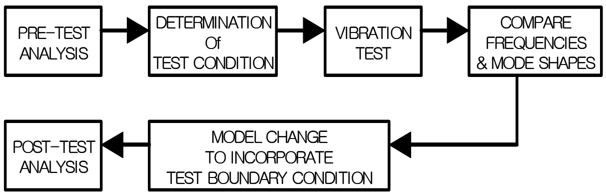

Fig. 2 Schematic diagram of measurement program

2.2 Main Procedures

The main procedures of the vibration measurement are as follows: (i) installation of CVAP instruments, accessories, and the data acquisition system (DAS) and obtaining data during hot functional testing (HFT); (ii) removal of CVAP instruments and accessories; and (iii) analysis and evaluation of obtained data.

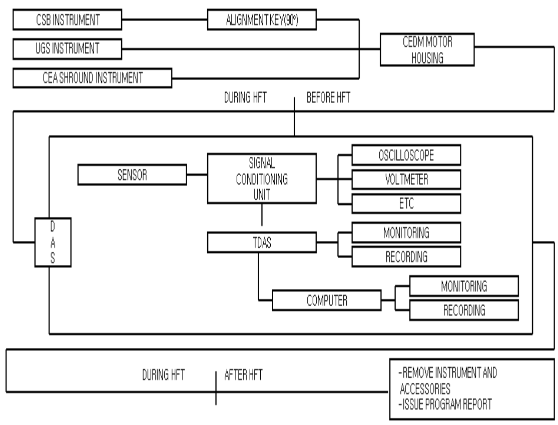

Fig. 3 Schematic diagram of general arrangement of RVI CVAP

Also, we will not remove measurement sensors in order to mitigate risk in relation to the construction progress of Shin-kori unit 4. Fig. 3 shows a schematic diagram of the general arrangement of RVI CVAP.

3. Vibration Measurement

3.1 Sensors for Vibration Measurement

The sensors for vibration measurement are an accelerometer, strain gage, and pressure transducer. The accelerometer is used to obtain natural frequencies for the vibratory character of the reactor internals by Fourier transform. Natural frequencies obtained by this method are analyzed and compared with natural frequencies calculated by the analysis program. The strain gage converts the strain measured from the sensor into stress. The pressure transducer obtains the forcing function, indicating flow of coolant and pump pulsation with excitation of reactor internals. Palo Verde unit 1 used a total of 38 instruments. (i.e., 13 pressure transducers, 8 accelerometers, 14 strain gages, and 3 displacement devices) while Yonggwang unit 4 used a total of 30 instruments. (i.e., 8 pressure transducers, 6 accelerometers, and 16 strain gages) All sensors must be correctly operated in the high pressure (2250 psia) and high temperatures (650 deg F) water environment conditions inside the reactor. A comparison of sensor locations and quantities between Palo Verde unit 1 and Yonggwang unit 4 is shown in table 1. The sensor locations and quantities of Shin-kori unit 4 will be selected so as to be similar to Yonggwang unit 4, considering the risk of damage to the reactor internals during site installation of the sensors, their leads, and the hardware to protect against flow induced vibration.

Table 1 Comparison of sensor locations and quantities of Palo Verde unit 1and Yonggwang unit 4

Nuclear Power Plant	Palo Verde unit 1			Yonggwang unit 4		
Sensor location	CSB	UGS	LSS	CSB	UGS	LSS
Pressure transducer	9	3	1	-	8	-
Accelerometer	1	6	1	2	4	-
Strain gage	8	4	2	4	12	-
Displacement device	3	-	-	-	-	-

3.2 Data Acquisition

A schematic diagram of the data acquisition system (DAS) is shown in Fig. 3. The DAS consists of a sensor, signal conditioning unit (SCU), data acquisition equipment, data monitoring equipment, and a computer.

The sensors transform pressure, acceleration, and strain into voltage signals. The SCU plays the role of signal amplification and filtering for digital signal processing. Data acquisition equipment is based on a digital computer that employs the signal processing program. Data monitoring equipment is used to monitor and analyze signals from the SCU using an oscilloscope, voltmeter, etc. The computer has a program for assessment of CVAP data.

Data acquisition will be performed for 21 vibration test conditions during HFT at reactor internals. Table 2 shows the CVAP test conditions. These test conditions are selected to measure various operating conditions including steady state and transient.

Table 2 CVAP test conditions

Test conditions		Temp.	RCP operation				Test type
No.	Pump	(℃)	1A	1B	2A	2B	
0*	Noise	65.6	NO	NO	NO	NO	Steady state
1	Pump start	65.6	NO	NO	S	NO	Transient
2	Pump start	93.3	S	NO	O	NO	Transient
3	Pump start	93.3	O	NO	O	S	Transient
4	Pump stop	126.7	O	NO	O	O	Transient
5	Steady state	126.7	O	NO	O	NO	Steady state
6	Steady state	126.7	O	NO	O	O	Steady state
7	Steady state	126.7	NO	NO	NO	O	Steady state
8	Steady state	182.2	O	NO	O	O	Steady state
00*	Noise	182.2	NO	NO	NO	NO	Steady state
9	Steady state	260	O	NO	O	NO	Steady state
10	Steady state	260	O	NO	O	O	Steady state
11	Pump start	260	O	S	O	O	Transient
12	Steady state	260	O	O	O	O	Steady state
13	Steady state	295.5	O	NO	O	O	Steady state
14	Pump stop	295.5	O	NO	O	SP	Transient
15	Steady state	295.5	NO	NO	O	NO	Steady state
000*	Noise	295.5	NO	NO	NO	NO	Steady state
16	Pump start	295.5	O	NO	O	S	Transient
17	Steady state	295.5	NO	NO	O	O	Steady state
18	Steady state	295.5	O	O	O	O	Steady state

4. Conclusions

The vibration measurement plan of RVI CVAP for Shin-kori unit 4 can obtain sufficient data to confirm predictions at operating conditions of steady state and transient. Before real vibration measurement of RVI CVAP for Shin-kori unit 4, which employs the first model of the APR1400, we plan to perform a vibration experiment for RVI CVAP using a 1/5 downsized mock-up. This work is now ongoing related to a R&D project of APR+ (advanced power reactor plus) safety system optimization at KAERI (Korea Atomic Energy Research Institute).

REFERENCES

[1] U.S. Nuclear Regulatory Commission Regulatory Guide 1.20, Comprehensive Vibration Assessment Program for Reactor Internals during Preoperational and Initial Startup Testing, Revision 3. March 2007.

[2] KEPRI, TM.99NJ13.P2000.243, Report on the Observation and Synthesis about CVAP in KNGR RVI, June 2000.