

Comprehensive Vibration Assessment Program Measurement Test Plan for Advanced Power Reactor 1400

신형경수로 1400 종합진동평가프로그램 측정시험 계획

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ABSTRACT

A reactor vessel internals comprehensive vibration assessment program(RVI CVAP) of an advanced power reactor 1400(APR1400) is being verified on the integrity of RVI for the design life of the plant by performing the non-prototype category-2 type on the US Nuclear Regulatory Commission Guide(NRC RG) 1.20, for which consists of a vibration and stress analysis program, a limited vibration measurement program, an inspection program, and the correlation of these programs. The aim of this paper is to describe the plan for the vibration measurement, test and acceptance criteria portion, and documentation and results of the APR1400 RVI CVAP. We will conduct the limited vibration measurement program of the APR1400 RVI CVAP according to the measurement plan and the vibration measurement testing in this paper.

요 약

미국 원자력규제위원회 규제지침(US NRC RG) 1.20의 비원형범주(non-prototype category)-2를 기준으로 신형경수로 1400(APR1400) 원자로내부구조물(RVI)의 설계수명기간 동안 건전성이 확보될 수 있는지를 확인하기 위해 종합진동평가프로그램(CVAP)을 수행하고 있다. US NRC RG 1.20의 비원형범주-2는 진동 및 응력 해석프로그램, 제한적 진동 측정프로그램, 검사프로그램 그리고 이런 프로그램들의 비교, 평가로 구성된다. 이 논문은 APR1400 RVI CVAP 측정프로그램의 측정계획, 시험, 허용기준과 결과 및 문서화에 대한 내용을 기술하였다. 우리는 이 논문의 진동측정 계획 및 시험에 따라서 APR1400 RVI CVAP 제한적 진동 측정프로그램을 수행할 것이다.

1. Introduction

The first Advanced Power Reactor

1400(APR1400) reactor vessel internals(RVI) are classified by the APR1400 Standard Design Approval(SDA)⁽¹⁾ as a non-prototype category-1 as defined in US Nuclear Regulatory Commission Guide(NRC RG) 1.20⁽²⁾. Although, we classified the APR1400 RVI CVAP as a non-prototype category-2 reactor as part of an independent validation of its design⁽³⁻¹⁰⁾. The assessment of the non-prototype category-2 reactor includes a vibration and stress

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analysis program, a limited vibration measurement program, a full inspection program, and the correlation of these programs.

The guidance for RVI comprehensive vibration assessment program(CVAP) during pre-operational and initial startup testing of light-water-cooled power reactors is laid out in US NRC RG 1.20. CVAP is intended to demonstrate that the RVI is adequately designed to withstand flow-induced vibration(FIV) forces at normal and transient plant operating conditions for the design life of the plant.

The vibration and stress analysis program involves predictive stress analysis of RVI with respect to flow-induced vibration⁽³⁻⁷⁾. The vibration measurement program consists of selected RVI and reactor vessel components with transducers, and collecting data at selected plant conditions during Pre-Core hot functional testing(HFT). These data are used for comparative analysis to determine whether the measured stress levels are acceptable for long-term plant operation.

This paper outlines the vibration measurement plan, the vibration measurement testing, acceptance criteria, and documents and results of the APR1400 RVI CVAP⁽⁸⁻¹⁰⁾.

2. Measurement Plan

This chapter provides an overview of the vibration measurement test plan. The transducer types⁽¹⁰⁾, installation locations^(4,5,9), and the rationale behind each measurement are listed. Also, included in this chapter are the signal conditioning and data acquisition system (DAS) requirements and planned analysis of the data to be collected.

2.1 Transducer Specifications

Specifications are applicable to all of the transducers that are placed on the RVI inside the pressure boundary. Some of the requirements are driven by the measurement locations, and the design and size of the APR1400 plant, which the

transducers to consider conditions slightly different

Table 1 Requirements of the sensors

Generic requirements	<ul style="list-style-type: none"> Static pressure: 158.2 kgf/cm² (2250 psi) Operating temperature: 291.3 °C (556.3 °F) Surrounding medium: water with HFT
Dynamic strain gage	<ul style="list-style-type: none"> Gage factor: 1.9 or greater (25 °C, 2 m) Strain limit: 8000 microstrain (25 °C) Frequency response: 1 to 500 Hz
Accelerometer	<ul style="list-style-type: none"> Sensitivity: 50 pC/g or greater (25 °C) Dynamic measuring range: 200 g Frequency response: 2 to 2500 Hz
Dynamic pressure transducer	<ul style="list-style-type: none"> Sensitivity: 16 pC/psi (232 pC/bar) or greater Dynamic measuring range: 250 bar Frequency response: 2 to 10000 Hz

from historic CVAP programs performed on other plant designs⁽¹¹⁻¹²⁾. Table 1 shows the requirements of the sensors for the APR1400 RVI CVAP⁽¹⁰⁾.

Additional requirements of the transducers for the APR1400 RVI CVAP except for the Table 1 are as follows:

- Transducer and cable shall be hermetically sealed.
- Transducer outer casing and mineral-insulated (MI) cable sheath shall be made of stainless steel or Inconel metal suitable for reactor internals application.
- The cable shall have mineral insulation approved for the reactor environment.
- The minimum insulation resistance of sensors is 10⁹ (one billion) ohms at 25 °C and 10⁷ (ten million) ohms at 291.3 °C.
- The outer diameter of the cable shall be 2 mm.

2.2 Transducer Types and Locations

These transducers types are planned for design and manufacturing of measurement system previously identified: first, uniaxial, weldable, encapsulated strain gages for dynamic strain, second, uniaxial, piezoelectric accelerometers, lastly, piezoelectric dynamic pressure sensors.

Selection criteria for the transducers are based on desired response, prior application in reactor environment, performance, and reliability.

The major RVI components to be instrumented include IBA(inner barrel assembly) top plate,