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CONCRETE CONTAINMENT AGING STUDY

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ABSTRACT

During normal plant operation, a concrete containment building provides shelter to safety-related components inside the building against external hazards. In the event of a postulated design basis accident, the containment serves as a pressure boundary and as a fission product barrier to minimize radioactive releases to the atmosphere. These mitigative functions are periodically tested using leak-rate test at rated pressure to ensure leakages are within acceptable limits, and for a containment with a non-grouted prestressed tendon system, by a tendon surveillance program. Recognizing the importance of having an effective program to manage aging of plant structures and systems on safety margin and on the control of future operation and maintenance (O&M) cost, the International Atomic Energy Agency (IAEA) initiated in 1989 a pilot study on the management of aging of nuclear power plant components. Phase I of this effort was completed in October 1992. In addition to the concrete containment building, the IAEA studies also addressed the primary nozzle of the reactor pressure vessel, the motor-operated isolation valve, and instrumentation and control cables inside the containment. The objectives of the pilot studies were to identify important aging mechanisms and to develop a strategy to better control degradation of systems, structures, and components by these aging mechanisms. The Phase II studies, which involve more extensive aging research, were implemented through IAEA's Coordinated Research Program (CRP) in late 1992.

The objectives of this CRP are to produce a summary of current aging management practices and experience for concrete containment structures; to compile a state-of-the-art report on concrete repair techniques and materials specifically applicable to nuclear concrete containment structures; to develop crack mapping techniques and acceptance/repair guidelines applicable to nuclear concrete containment structures; and to develop a set of condition indicators for the monitoring of concrete containment aging. With the availability of this database, plant owners will have the opportunity to review and enhance their existing programs if necessary. The implementation of an effective program on the concrete containment and other plant structures will be useful in assisting the control of ever rising O&M cost for a nuclear power plant. This information will be compiled through a survey which includes a general description of the plant and a request of historical data pertaining to structural aging and inspection/repair. IAEA will analyze data provided by participating plants and the report is scheduled to be released by late 1994.

BACKGROUND

Aging of nuclear power plants (NPP) must be effectively managed to ensure that the required plant safety and reliability are maintained throughout plant service life, including any extended life. To facilitate the exchange of information and collaboration among international organizations, including utilities, architect/engineers, and vendors, the IAEA initiated pilot studies[1] in 1989 to develop a methodology to perform aging studies on the primary nozzle of the reactor pressure vessel, the motor-operated isolation valve, the concrete containment building, and instrumentation and control cables inside the containment. The study also identified the following technical issues:

1. What is the current understanding of relevant aging phenomena and how are the research results and operating experience being applied to operational plants.
2. The potential safety impacts of aging if aging mechanisms are not properly mitigated.

3. The effectiveness of existing techniques used to monitor and to mitigate aging degradation.
4. The effectiveness of current procedures to predict future component performance.
5. The need to develop methods and criteria to predict remaining service life of nuclear systems, structures, and components.

Pilot studies were performed for each component with the objectives of identifying dominant aging mechanisms and developing a strategy to manage the effects of aging. These pilot studies are being implemented in two phases. Phase I activities, which have been completed,[2] included a review of current understanding of, and methods and mitigation of aging; identification of relevant knowledge and technology gaps; and a formulation of recommendations for follow-up work.

PHASE I STUDY OF CONCRETE CONTAINMENT

The Phase I study of the concrete containment in identifying aging mechanisms and the mitigation of the effects of these aging mechanisms utilized results from other research efforts by IAEA,[3] EPRI and NUMARC,[4] and Oak Ridge National Laboratory.[5] Results of the Phase I study in Reference 2 summarize the design functions of a concrete containment and the service conditions of the structure during normal and abnormal operations. These include external events such as tornadoes and seismic activities, and internal events such as design basis accidents. The study also compiled operating experience of containments and concluded that the performance of the containment has been excellent during normal operations and periodic pressure tests although none of these structures have experienced a design basis type of dynamic load. Typical deteriorations identified have been minor cases of concrete cracking, corrosion in reinforcing steel, and excessive prestress losses in wires of a prestressed tendon system in a concrete containment. Most, if not all these deteriorations have been anticipated in the design and were mitigated by using a conservative design margin. Nonetheless, the report summarized all aging mechanisms that could degrade the structural components (concrete and steel) of a containment which ultimately impact the performance of the concrete containment. These aging mechanisms are:

- concrete shrinkage cracking
- freeze-thaw effects
- reactions with concrete aggregates
- concrete leaching by water
- aggressive chemical attacks on concrete
- carbonation of cement paste
- prolonged exposure to elevated temperature
- excessive irradiation by gamma and neutron radiation
- corrosion of reforcing steel
- corrosion of containment steel liner
- corrosion of prestressed tendons
- prestressing losses of tendons
- fatigue
- settlement

PHASE I RESULT OF CONCRETE CONTAINMENT

Based on the understanding of the identified aging mechanisms and their deteriorating effects observed, the study compiled a list of techniques to monitor the conditions of various components. These techniques, used by plants in different countries, are summarized as follows:

- visual inspection of concrete for cracks, spalling, leaching and alkaline-aggregate gel reaction products (CARR)
- instrument aided inspection for concrete such as strain meters and the use of ultrasonic techniques
- test methods to determine the presence of AAR if leaching and gel products are visible
- pressure test including measurements of pressure, temperature, humidity both inside and outside the containment
- visual inspection for corrosion, cracks, or chemical attacks on containment liner; use of dye penetration testing if pressure test indicates excessive leakages
- laboratory examination of cut-out samples from steel liner
- visual and acoustic inspection and check for cracks in the liner system

- visual inspection, including checking anchors for damage, checking concrete under anchor for bearing failure, checking cables/tendons for corrosion, checking grease in tendon ducts
- measurement of tendon tensions, checking of tendons for relaxation against design values
- visual inspection for gross building settlement
- monitor building settlement by instrumentation
- checking of building expansion and deformation during pressure tests against allowable design values
- visual inspection for leaks, cracks, the physical conditions and freedom of operation of bellows, and insulation and seals of containment penetrations
- testing of containment penetrations by bubble tests, pressure hold tests, and helium or Freon leak tests

Since the effects of aging on a concrete containment are generally considered predictable, the techniques applied by nuclear plants to mitigate these effects are standard industry practices. These techniques include:

- Resin injection or epoxy injection to fill cracks and voids in concrete to protect reinforcing steel from being exposed to corrosive environment.
- Protective coating, qualified for the environmental conditions, to protect steel liner and concrete.
- Repair or replacement of equipment hatches and hatch seals to maintain a leaktight pressure boundary.
- Retensioning of prestressed tendons in accordance with predetermined design values to ensure containment pressure retention capability.

As a result of the Phase I finding, the IAEA determined that the following areas would require additional research:

- current experience and aging management practices including inservice inspection, testing, and repairs of all containment structural components
- state-of-the-art repair techniques on concrete and other containment structural components
- crack mapping and acceptance criteria for repair including a correlation of crack category to repair methods
- condition indicators and guidelines for monitoring the aging of concrete containment

PHASE II STUDY

The Phase II study of the concrete containment has been implemented by the Coordinated Research Programme (CRP) sponsored by the IAEA. Organizations participating in this effort include utilities, regulators, research laboratories, and architect engineers from the United States, Canada, the United Kingdom, India, France, the Czech Republic, Switzerland, and Austria.

The objectives of this CRP are:

(1) To produce a summary of current aging management practices and experiences for concrete containment structures
(2) To compile a report containing state-of-the-art repair techniques and materials
(3) To develop crack mapping and acceptance criteria to repair concrete containment structures
(4) To develop a set of practical condition indicators and associated guidelines to monitor concrete containment structures

To accomplish these objectives, the CRP is preparing a questionnaire to conduct a survey of nuclear power plant owners/operators. The survey questionnaire will be evaluated by IAEA CRP participants. In addition to general plant information, the survey requests information in in-service inspection programs, age-related degradation experiences, and mitigation and repair practices. The CRP intends to make available the results of the survey to all participating plant owners/operators to assist their aging management programs. The results will not identify individual plants and utilities who participate to protect the confidentiality of the source of information.

The survey questionnaire consists of three major sections. The first section asks for general

information such as reactor type, location, external and internal environmental conditions, type of containment and design features, and applicable design codes and standards. Although Phase I identified a list of age-related degradation mechanisms related to a concrete containment, it is expected that the impact of these mechanisms could vary due to geographic locations and operating environments. The purpose of collecting this information is to correlate these parameters with identified issues and corrective actions.

The second section of the survey is designed to gather information on practices to inspect various materials associated with the concrete containment structure. Information requested includes inspection and investigation programs for materials and components commonly used in a containment. These include concrete, anchorage elements, reinforcing steel, prestressing steel, and metallic or non-metallic containment liner, and penetration assemblies. This section also requests information on the preventative maintenance programs implemented at the plant to repair or to refurbish containment components and the effectiveness of these programs.

The purpose of the third section is to solicit experiences related to repair of the degradation of the containment structure due to normal operation or any abnormal events. Information requested include the identification of age-related degradation mechanisms which have resulted in degradation; identification of the remedial actions chosen to mitigate any effects of the degradation; and the assessment of the root cause of degradation, including a determination of design or construction related defects. To assist participants to respond to the questions, a list of deterioration manifestations commonly observed in a structure requiring repairs is provided. The age-related degradation mechanisms (ARDMs) that are the potential cause of these deteriorations have been identified in the Phase I effort.

PHASE II SCHEDULE

The preparation of the survey questionnaire has been completed and approved by IAEA and sent to utilities in February, 1994. The schedule for the coordination with international utilities and receiving responses from all participants is April, 1994. The effort to evaluate survey data, perform literature search to accomplish the Phase II objectives is expected to require a minimum of three months. The CRP members have agreed on a division of responsibilities to coordinate with utilities, conduct research, and the preparation of the final report. The committee will reconvene to discuss the finding and progress of this effort in October, 1994. The final report is tentatively schedule to be released mid-1995.

REFERENCES

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