

Effects of Severe Accident Conditions on Integrity of RPV Pedestal of Fukushima Daiichi Nuclear Power Plant

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Received 27 March 2022, accepted 15 June 2022

doi:10.3151/jact.20.444

Abstract

The Fukushima Daiichi Nuclear Power Plant lost its core cooling function due to the massive tsunami generated by the 2011 off the Pacific coast of Tohoku Earthquake, which caused core meltdown, resulting in high temperature inside the containment vessel and exposing the RPV pedestal, a reinforced concrete structure, to an unusually high temperature environment. After the earthquake, water was poured into the containment vessel to cool the molten core, and the concrete structure was gradually cooled in the process. Since it will take at least 40 years to remove the fuel from the core, the integrity of the RPV pedestal is a major concern for the decommissioning of the Fukushima Daiichi Nuclear Power Plant. In order to assess the long-term integrity of the RPV pedestal, a horizontal loading test was conducted using a 1/6 scaled model of the RPV pedestal of Unit 1 considering the effect of the high temperature heating and subsequent wet conditions. And then, the static stress analysis of the RPV pedestal was performed considering the degradation phenomena revealed by the experiments. As a result, it was confirmed that the RPV pedestal of Unit 1 would be structurally sound for 40 years against the current design basis earthquake even if the material degradation due to severe accident and aging was considered.

1. Introduction

The Fukushima Daiichi Nuclear Power Plant (FD-NPP) was hit by a large earthquake ground motion caused by the 2011 off the Pacific coast of Tohoku Earthquake. FD-NPP has six power units, and Units 1 through 3 were in normal operation according to TEPCO (2011a). All the control rods of the operated units were auto-

matically inserted following detection of the large seismic ground motion, and the reactor was safely shut down. However, a huge tsunami generated by the earthquake then hit the plant, causing the loss of power supply and, more importantly, the loss of the core cooling function, leading to core meltdown.

As a result, the inside of the primary containment vessel (PCV) reached high temperature and high pressure, the containment vessel function was impaired, and the pedestal of the reactor pressure vessel (RPV pedestal), which is a reinforced concrete structure, was exposed to an unusually high temperature environment. As an emergency measure to cool the molten core, seawater was initially injected, but this was later switched to fresh water and then to water treated in the stagnant water purification system. In these processes, the temperature and the chloride ion concentration were greatly reduced. Since it will take at least 40 years from the time of the earthquake to remove the fuel from the core, however, the effects of high temperature and aging on the integrity of the RPV pedestal are a major concern for the decommissioning of FD-NPP. The RPV, PCV, and the RPV pedestal are illustrated in Fig. 1 according to Tanaka *et al.* (2021).

Currently, it is almost impossible to repair the RPV pedestal because access to the containment vessel is very difficult due to the radiation conditions. It is necessary to evaluate the integrity of the RPV pedestal in its current and long-term states considering the influence of severe accidents, subsequent environmental conditions, and aging. Therefore, the International Research Institute for Nuclear Decommissioning (IRID) has conducted various experimental studies to evaluate

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Kathleen Armour



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Severe Accidents and Other Topics in the RPV Design, 2000 Surender Bhandari, Kenneth K. Yoon, Dominique Moinereau, 2000 Index of Conference Proceedings British Library. Document Supply Centre, 2001 **Severe Accidents and Topics in the NESC Project** Surender Bhandari, 1998 Thirty six papers from the July 1998 Conference treat two independent subjects namely severe accidents and topics in the NESC Project both related to the safety issues of nuclear power plants Topics include steam explosion hydrogen deflagration and fast reactor core problems modelling creep behaviour reactor pressure vessel and piping behaviour under severe accident conditions integrity of containment structures under severe accident conditions introduction to NESC pre test structural assessment and the spinning cylinder test Contains an author index but no subject index Annotation copyrighted by Book News Inc Portland OR *Advances in Light Water Reactor Technologies* Takehiko Saito, Junichi Yamashita, Yuki Ishiwatari, Yoshiaki Oka, 2010-12-21 *Advances in Light Water Reactor Technologies* focuses on the design and analysis of advanced nuclear power reactors This volume provides readers with thorough descriptions of the general characteristics of various advanced light water reactors currently being developed worldwide Safety design development and maintenance of these reactors is the main focus with key technologies like full MOX core design next generation digital I C systems and seismic design and evaluation described at length This book is ideal for researchers and engineers working in nuclear power that are interested in learning the fundamentals of advanced light water plants **RPV Integrity and Fracture Mechanics** Dominique Moinereau, 2004 **Nuclear Power or a Promise Lost** Edward T. Burns, 2020-05-01 This book captures the status of current electrical energy markets including the principal forces affecting decisions on selecting an energy source It represents a seminal work that lays out the electrical energy decision tree for selecting an energy source in a world that is on the verge of catastrophic global warming because of the choices that have been made in the name of cheap energy The impetus for this book includes the dire need to mitigate continued anthropogenic causes of global warming by turning to carbon free energy sources Nuclear energy represents such a carbon free energy source and could be a partial solution to the existential threat facing future society the threat of a warming planet and its consequential catastrophic effects on future generations The world is at a crossroads in human interaction with their environment The effects of radiation and the relationship of nuclear power to nuclear weapons are both discussed in an understandable and compelling manner Nuclear energy is contrasted with other energy sources including fossil fuels and renewable energy sources regarding the risks and benefits imposed by each Important personalities and world events that shaped nuclear power s development are recounted The historical origins of nuclear power are outlined and the continued impetus to include nuclear power as part of the electric grid energy mix is assessed exposing the obstacles and road blocks to the continued use of nuclear power Specific attention is paid to revealing the causes and lessons learned from the three severe accidents in commercial nuclear plants TMI 2 Chernobyl and Fukushima An extensive discussion of

nuclear waste disposal is provided as part of the decision tree for energy selection The context for the future of nuclear power as a viable energy source is illuminated by the current battle between economic growth and the harm created by burning fossil fuels The status of the world's climate and projections for the disruptive effects of global warming on future populations migration economics and world strife are debated against the backdrop of an increasing world population and the drive by developing nations to achieve economic parity with the industrialized nations Within the context of increased world strife the quest by nations to obtain nuclear weapons is also discussed The steps taken by the world to limit nuclear weapons proliferation are examined with emphasis on potential links between nuclear power generation and access to nuclear weapons The final chapter discusses the moral responsibility of current generations with respect to future generations specifically the applicability of intergenerational equity in political and social decision making regarding the actions that add to global warming and those risk averse actions that can be taken to minimize global warming

Nuclear Thermal Hydraulic and Two-Phase Flow Jun Wang, Kaiyi Shi, Zhaoming Meng, Shripad T. Revankar, 2018-10-11 Nuclear energy is one of the most important clean energy and contributes more than 10% electric power to human society in the past decades of years The nuclear thermal hydraulic and two phase flow is one of the basic branches of nuclear technology and provides structure design and safety analysis to the nuclear power reactors In the new century the basic theoretical research of thermal hydraulic and two phase flow and innovative design for the next generation nuclear power plants especially for the small modular reactor and molten salt reactor along with other nuclear branches constantly support the development of nuclear technology

Proceedings of the Topical Meeting on Safety of Operating Reactors, 1995 *Energy Research Abstracts*, 1993 **JSME International Journal**, 2004 *Proceedings of The 20th Pacific Basin Nuclear Conference* Hong Jiang, 2017-01-10 This is the first in a series of three proceedings of the 20th Pacific Basin Nuclear Conference PBNC This volume covers the topics of Safety and Security Public Acceptance and Nuclear Education as well as Economics and Reducing Cost As one in the most important and influential conference series of nuclear science and technology the 20th PBNC was held in Beijing and the theme of this meeting was Nuclear Powering the Development of the Pacific Basin and the World It brought together outstanding nuclear scientist and technical experts senior industry executives senior government officials and international energy organization leaders from all across the world The book is not only a good summary of the new developments in the field but also a useful guideline for the researchers engineers and graduate students

Proceedings, 1995 [Transactions of the American Nuclear Society](#) American Nuclear Society, 1993 **Proceedings of the International Topical Meeting on Advanced Reactors Safety**, 1997 [Proceedings of the ... International Conference on Nuclear Engineering](#), 2006 [Title List of Documents Made Publicly Available](#) U.S. Nuclear Regulatory Commission, 1990 [Proceedings of the Topical Meeting on Advances in Human Factors Research on Man/Computer Interactions](#), 1990 This meeting was intended as an opportunity to catch a snapshot of the state of research

into the problems and questions of human interaction with computers **Research Facilities For The Future Of Nuclear Energy - Proceedings Of An Ens Class 1 Topical Meeting** Hamid Ait Abderrahim,1996-05-15 The ENS Class 1 Topical Meeting on Research Facilities for the Future of Nuclear Energy provided an international scientific and technical forum for a broad review at world level of the large research facilities dedicated for tests for nuclear energy production which are existing under construction or planned for the future The research facilities covered during the conference are those supporting R D programmes related to the operation of nuclear reactor power plants and the development of new concepts in the areas of material testing nuclear data measurements code validation fuel cycle reprocessing and waste disposal The conference was relevant to a wide range of people such as the operators and managers of research facilities research organizations that depend on the facilities for results young professionals who will shape future requirements nuclear utilities vendors fuel components service and engineering companies designers plant operators waste management agencies licensing authorities and the decision makers **Proceedings of the International Topical Meeting on Probabilistic Safety Assessment** ,1996 Energy and Water Development Appropriations for 1997 United States. Congress. House. Committee on Appropriations. Subcommittee on Energy and Water Development,1996

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