Instructor Training Course JFY2025

Course Prospectus

Reactor Engineering

Nuclear Human Resource Development Center
JAPAN ATOMIC ENERGY AGENCY

1 COURSE INTRODUCTION

1.1 OBJECTIVE

The objective of this course is to educate future instructors in the field of reactor engineering. Through a five-week program, participants are expected to acquire basic knowledge to be able to contribute as instructors in their countries. The course involves lectures on basic topics such as nuclear reactor physics and radiation shielding. After going back to their home countries, **all participants are required to give a lecture in the future Follow-up Training Course (FTC).**

1.2 PARTICIPANTS

The course is open to those who work for nuclear-related organizations or academic institutions and are willing to contribute to human resource development in the field of reactor engineering in their own countries. Please refer to the Application Guidance for further information.

1.3 NOTE

・This course will be conducted in person.

2 COURSE SYLLABUS (Tentative)

2.1 Lecture

(1) Nuclear Reactor Physics
- Fundamentals of reactor physics
- Diffusion of neutrons
- Two group diffusion equation and six factor formula

(2) Radiation Shielding
- Gamma-ray shielding
- Neutron shielding
- Items of shielding calculation
- Shielding calculation method (Methods of Point Kernel, Sn and Monte Carlo)

(3) Thermal Engineering
- Thermodynamics (equation of state, ideal gas, the first and second law of thermodynamics, efficiency of heat engine)

(4) Nuclear Reactor Kinetics
- Derivation of kinetics equation
- Solution to reactor kinetics equation

(5) Pressurized Water Reactor (PWR)
- Mechanism of PWR power plant
- Types of PWR
- Design of PWR
- Design of safety systems

(6) Outline of Fukushima Daiichi Nuclear Power Station Accident and Exposure Situation
- Outline of Fukushima Daiichi NPS accident
- The reason why Fukushima Daini and Onagawa NPS survived even attacked by mega tsunami
- Strengthening of safety measures after Fukushima Daiichi NPS accident based on new safety regulation standard
- Present ambient dose rate at Fukushima Daiichi NPS and Fukushima area
- Radiation exposure situation of radiation workers and residents in the accident
- Decommissioning of Fukushima Daiichi NPS

(7) Boiling Water Reactor (BWR)
- Principles of BWR
- Features of Advanced BWR

- Key issues for technology selection

(8) Nuclear Reactor Control and Small Module Reactor (SMR)
- Basis of control system and mathematical approach
- Laplace transformation and transfer function
- Frequency response and stability
- Transfer functions and stability of reactor system
- Control system of reactor
- Feature of SMR
- Type of SMR

(9) Probabilistic Risk Assessment (PRA) and New Regulatory Requirements
- Overview and history of PRA
- Concept of level 1 PRA and exercises
- Concept of levels 2 and 3 PRA

(10) Nuclear Reactor Thermal Hydraulics
- Basic heat transfer modes including heat conduction, heat convection, radiation, boiling, and condensation
- Basics of two-phase flow including flow patterns, important two-phase flow variables, governing equations, pressure drop/heat transfer and flow instability
- Reactor thermal system including nuclear heat generation, heat balance, thermodynamic circles, efficiency of NPPs, evaluation of burnout condition
- Basic concepts for the reactor thermal design

(11) Fuel Behavior under Reactivity Initiated Accident (RIA)
- Fundamentals of nuclear safety
- Reactivity initiated accident (RIA)
- Fuel behavior under RIA conditions

(12) Loss of Coolant Accident (LOCA)
- PWR accident and transient (LOCA, SGTR, Station blackout transient)
- Thermal hydraulic phenomena during LOCAs
- Licensing of water-cooled-reactors
- Computer codes for safety analysis and verification

(13) Severe Accident and Accident Management
- Past severe accidents
- Research activities and accident management implementation in Japan
- Understanding severe accident (severe accident research, important phenomena during severe accident, fuel degradation, fission product release

and transport, severe accident analysis codes)

(14) Structural Mechanics

- Basic concept of material response subject to loading (equilibrium of forces and moments, stress and strain, deflection of beam, 3-D stress field, thin and thick cylinder)
- Fracture Mechanics (overview of fracture, stress intensity factor and fracture toughness, crack growth analysis)

(15) Nuclear Fuel Engineering

- Fundamental characteristics of fuel materials (structure and design of fuel)
- Fuel behavior under normal operations (high-burnup fuel, fuel failure)
- Irradiation test (test reactor, instrumentation, PIE)

(16) Engineering Ethics and Safety Culture

- Common features and perspective between engineering ethics and safety culture
- Methods of ethical decision making
- Case studies of engineering ethics
- Necessity of safety culture
- Elements of safety culture
- Fukushima Daiichi Nuclear Power Station (NPS) Accident in light of resilience engineering

(17) Material Engineering

- Role of nuclear material engineering
- Aging degradation of materials
- Radiation damage and atomic displacement
- Management of aging of nuclear plant materials

(18) Nuclear Fuel Cycle

- Overview of nuclear fuel cycle
- Characteristics of uranium
- Uranium resources and production of UF6
- Uranium Enrichment
- Uranium reconversion and fuel fabrication
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(19) Radioactive Waste Management

- Objects and principles of radioactive waste management
- Generation of radioactive waste
- Itemization of radioactive waste

- Low and high-level radioactive waste
- Transportation of waste
- Radioactive waste disposal

2.2 Exercise

(1) Neutron Experiment
- Neutron moderation and diffusion by scattering
- Neutron absorption reaction with matters

(2) JRR-1 Simulator Training

To experience a research reactor operation and to deepen the understating of nuclear reactor kinetics.
- Low power operation
- High power operation
- Temperature coefficient measurement
- Control rod calibration
- Simulation of excursion events

(3) Boiling Heat Transfer Experiment

To investigate the characteristics of the forced convection heat transfer and the boiling heat transfer and to experience the burnout phenomenon for a better understating of the thermal-hydraulic design of LWR.
- Transition from convective heat transfer to boiling heat transfer under sub-cooled condition
- Effect of flow velocity on convective heat transfer
- Relation between heat flux and degree of superheat on heated surface in boiling heat transfer

(4) Presentation
- Short lecture by participant on topics learnt in the course

2.3 Facility Visit

(1) Hitachi-GE Nuclear Energy, Ltd.

(2) Reactor Fuel Examination Facility (RFEF), JAEA

(3) Large Scale Test Facility (LSTF), JAEA

(4) Nuclear Safety Research Reactor (NSRR), JAEA

(5) Japan Research Reactor-3 (JRR-3), JAEA

(6) High Temperature Engineering Test Reactor (HTTR), Oarai Research and

Development Institute, JAEA

(7) Kashiwazaki Kariwa Nuclear Power Station, Tokyo Electric Power Co. Holdings, Inc.

(8) Takasaki Advanced Radiation Research Institute, National Institutes for Quantum Science and Technology, QST

(9) Naka Fusion Institute, QST

2.4 Group Work

(1) Lecture Materials and Lecture Skills

The participants learn how to make effective materials and how to deliver effective lectures. These skills are required as a lecturer at FTC to contribute to nuclear human resource development in their own countries. The PowerPoint data of Research Reactors of Asian Countries is used as a group work material. The participants are divided into group, and each group improves the lecture material and delivers its presentation. Each group presentation is evaluated and discussed by both Japanese experts and all participants.

3 Assignment

(1) Presentation on a specified topic from lectures, experiments or exercises

(2) Reports on the summary of lectures, exercises, experiments and facility tours