

# The Nuclear Engineering Division of the TEPCO Systems Corporation Profile

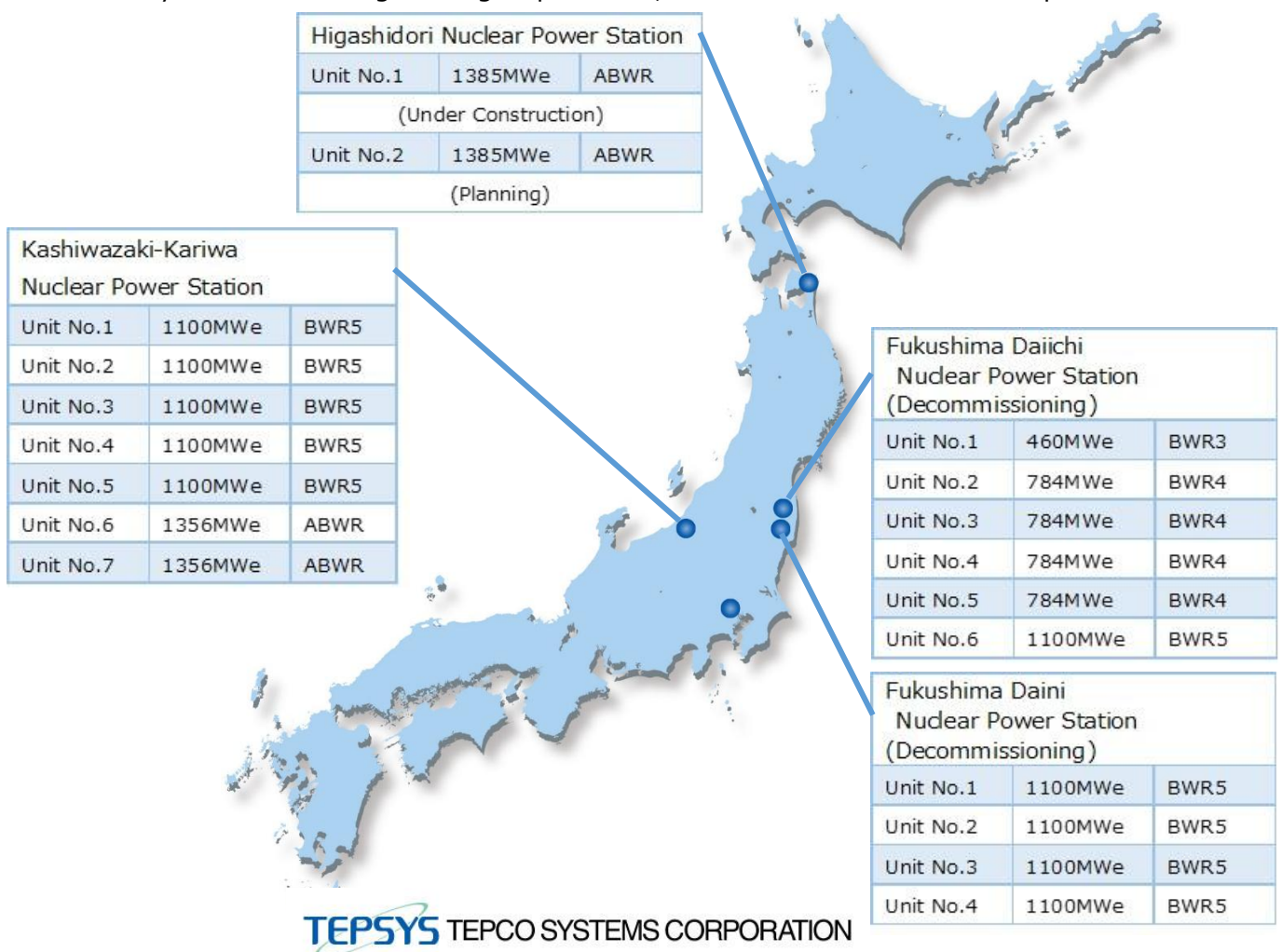
The Nuclear Engineering Division of the TEPCO Systems Corporation (TEPSYS) provides engineering services that are essential to enhancing nuclear safety and improving efficiency for Tokyo Electric Power Company Holdings (TEPCO)'s nuclear plants, ranging from core management and safety evaluations to the development of plant monitoring systems.

TEPSYS Nuclear Engineering Division started as an in-core fuel management department of Toden Software Inc. (TSI) in 1986, tasked with carrying out independent core management of TEPCO's nuclear reactor (BWRs).

In April 2004, we started afresh as the Nuclear Engineering Department of the TEPSYS, and we currently provide a wide range of analysis and evaluation services, including probabilistic risk assessments, core/plant monitoring systems, back-end evaluations, and structural reliability evaluations, in addition to our in-core fuel management work.

In April 2011, we changed to a two-department structure consisting of the Nuclear In-Core Fuel Engineering Department and the Nuclear Plant Engineering Department, providing analysis and evaluation services that contributed to enhancing safety and decommissioning at nuclear power stations, the importance of which has gained more recognition after the Great East Japan Earthquake.

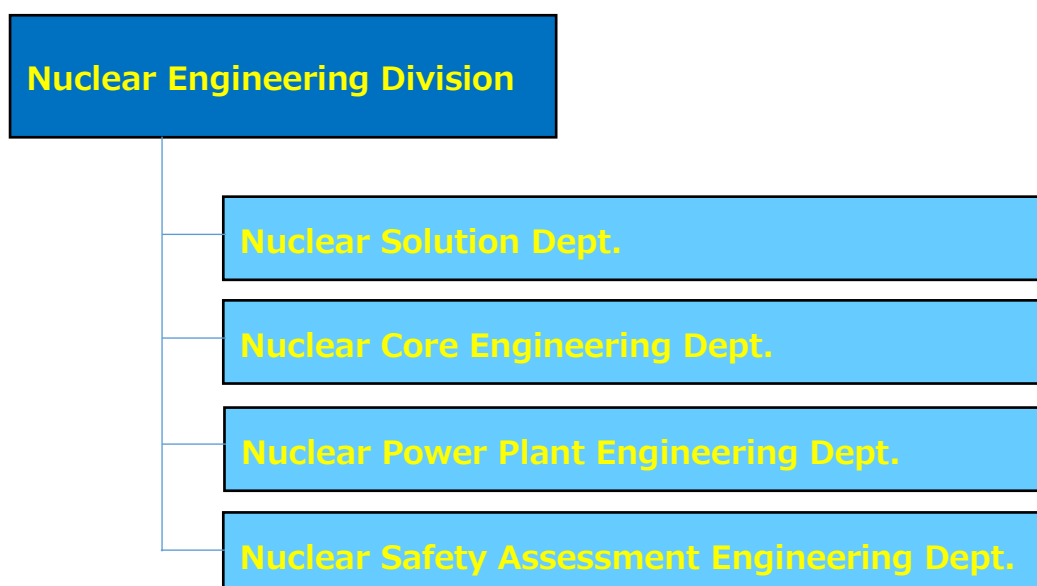
Following our reorganization into the Nuclear Engineering Division in April 2017, we currently provide analysis and evaluation services through a four-division structure consisting of the Nuclear In-Core Fuel Engineering Department, the Nuclear Plant Engineering Department, the Nuclear Safety Assessment Engineering Department, and the Nuclear Solutions Department.



## History of Nuclear Engineering Division

July 1986	In-Core Fuel Management Department created along with the establishment of Toden Software Inc. (TSI)
October 2000	In-Core Fuel Management service receives ISO 9001 certification from Lloyd's
October 2001	Merged with TSI to establish Tepco Systems Corporation (TEPSYS)
May 2003	Expanded ISO9001-certified business scope (core monitoring system, probabilistic risk assessment)
April 2004	Changed name to Nuclear Engineering Department
November 2006	ISO 9001 certification obtained for full departmental scope (provision of analytical services and system supply for nuclear power plants and related facilities)
April 2011	Reorganized into a two-department structure consisting of the Nuclear Core Engineering Department and the Nuclear Plant Engineering Department
April 2017	Restructured into the Nuclear Engineering Division consisting of three departments, including the Nuclear Core Engineering Department, the Nuclear Plant Engineering Department and the Nuclear Solutions Department
September 2017	Obtained ISO9001:2015 certification
April 2022	Reorganized into a four-department structure consisting of the Nuclear Core Engineering Department, the Nuclear Plant Engineering Department, the Nuclear Safety Assessment Engineering Department, and the Nuclear Solutions Department

## Nuclear Engineering Division Organization

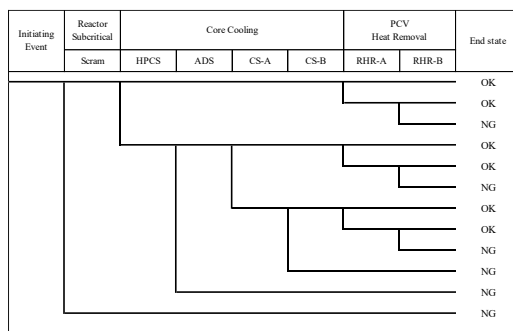


# Probabilistic Risk Assessment (PRA) Technology

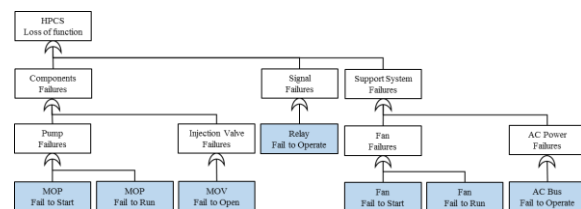
Probabilistic Risk Assessment (PRA) is a method used to quantitatively evaluate risks (likelihood and consequence) by analyzing the failures of component and human errors in large and complex systems such as power plants, chemical plants, and power distribution networks. This is achieved by representing the relationships between these factors using a logical model based on probability theory.

In nuclear power plants, there is a growing focus on using PRA to maintain and enhance safety, as well as to make rational decisions regarding the allocation and concentration of resources based on the severity of risks.

TEPSYS is one of the leaders in PRA for nuclear power plants in Japan, and is constantly working to develop new technologies to further expand the scope of application.

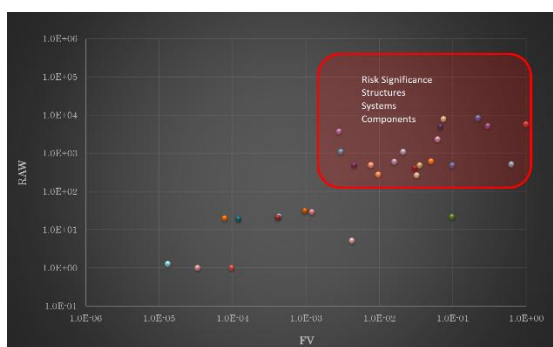


**Event Tree**  
A tree diagram showing the relationship between the flows of scenarios that lead to risks and the safety systems that prevent those risks.



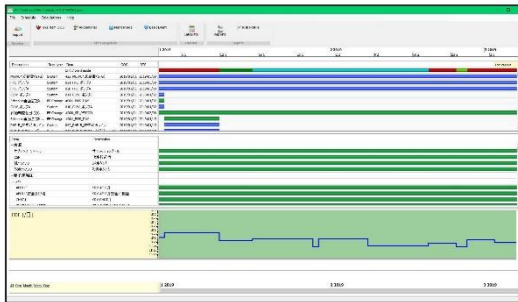
**Fault Tree**  
A tree diagram showing the logical structure of the relationships between the components that can cause loss of function.

## PRA Usage Scenarios



### ■ Supporting investment in safety measures

When introducing new SSCs, it is necessary to choose from various design proposals. By reflecting each design proposal in the PRA model and quantitatively comparing and analyzing their effects, it is possible not only to support the decision to select the most effective solution, but also to propose further improvement proposals through analysis. It can also support decision-making related to the rationalization of system operation, such as proposing measures to reduce excessive maintenance costs for components that have a small impact on risk with respect to current systems and operating procedures.



### ■ Real-time monitoring of system safety and efficiency

By building a model that can evaluate the risk to managed systems based on the daily usage and maintenance status of components, we provide a "risk monitor" that quantitatively compares and analyzes the impact on system risk, for example, when the system is unavailable due to maintenance. This makes it possible to formulate efficient maintenance plans while maintaining the safety of the system.

## Business Performance

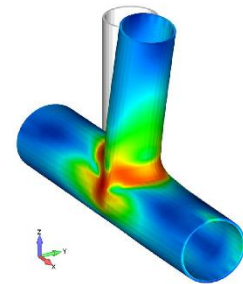
- Nuclear Power Plant PRA
  - ◇ Advanced PRA for voluntary and continuous safety improvement
  - ◇ PRA for compliance with new regulatory requirements in Japan
- Support for the use of risk-informed activities in nuclear power plants
- Support for the development and evaluation of a risk monitor that visualizes the daily risks of nuclear power plants

## Structural Design, Structural Integrity Evaluation, and Reliability Evaluation

Since the Great East Japan Earthquake, nuclear power plants have been required to meet higher safety standards for natural disasters such as earthquakes, tsunamis, and tornadoes, and work is underway to implement seismic reinforcements and install tornado protection structures. Additionally, due to increasing price competition with alternative energy sources such as solar power, development of in-house technology has been advancing within TEPCO group companies in the field of structural design. Against this backdrop, our company conducts structural design, seismic evaluation, and failure probability assessment for components such as vessels and piping using 3D models and design code formulas, with the aim of improving safety and reducing design and construction costs.

### Analysis Codes

- General-purpose finite element method (FEM) codes:  
ABAQUS, LS-DYNA
  - General-purpose thermal-fluid analysis code: STAR-CCM+
  - Probabilistic fracture mechanics analysis codes:  
PEPPER\*, PEPPER-M\*, GENPEP\*
  - Flaw initiation probability analysis code: GENPRO\*
  - Fuel behavior analysis codes: FEMAXI, ANIER\*
- (\*: Developed in-house)



Piping tee stress analysis

### Project Experience & Solutions

- Structural design and various evaluations—including pressure resistance, seismic performance, tornado missile impact, drop impact, failure probability, thermal behavior, hydrogen concentration, overflow propagation, and tsunami resistance—for nuclear power plant components such as vessels, piping, and shielding systems
- R&D related to the development of codes for nuclear generation facilities
- Development of probabilistic fracture mechanics analysis codes
- Study on risk-informed optimization of inspection and design



Tsunami-induced buckling of tank

## Publications and Patents

- Radiation Shielding Apparatus and Radiation Prediction Apparatus (Japanese Patent No. 7188881, December 5, 2022, joint patent with Tokyo Electric Power Company Holdings, Inc.)
- Application of finite element analyses to limit load assessment of JSME fitness-for-service code (Transactions of the JSME, Vol. 87, No. 903, 2021)
- Reliability-Based Optimization of Number of Flaw Inspections and Measurements (Journal of the Japan Society of Maintenology, Vol. 20, No. 1, 2021)
- Proposal of nuclear power plant piping maintenance method based on reliability evaluation (Journal of the Japan Society of Maintenology, Vol. 18, No. 4, 2020)
- Study on Elastic-plastic fracture mechanics assessment method of a pipe having multiple circumferential surface cracks for the Rules on Fitness-for-Service of JSME (Transactions of the JSME, Vol. 85, No. 876, 2019)
- Study on initial crack assumed in the flaw tolerance approach applied to piping of nuclear power plants (Transactions of the JSME, Vol. 85, No. 874, 2019)
- Safety factor for flaw evaluation of a pipe having a circumferential surface flaw (Transactions of the JSME, Vol. 81, No. 824, 2015)
- Buckling pressure assessment methods of bellows with thin wall reinforcing rings (Transactions of the JSME, Vol. 80, No. 815, 2014)
- Fracture Assessment for Pipes Having Circumferential Flaws Subjected to Seismic Load (Transactions of the JSME, Vol. 78, No. 791, 2012)



Portable Radiation Shielding Apparatus: Mobile Shield MRS® (developed in-house)



Filtered Venting Vessel for the Kashiwazaki-Kariwa Nuclear Power Station (developed in-house)

[Source] TEPCO Website

<http://www.tepco.co.jp/kk-np/>

(accessed December 1, 2014)

# Plant Equipment Diagnosis Technology Using Signal Analysis

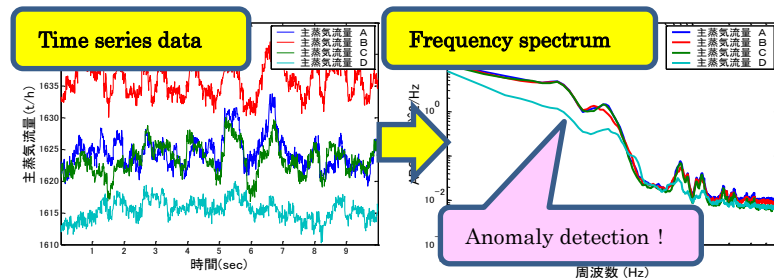
A technology that analyzes minute fluctuations contained in plant signals (pressure, water level, flow rate, etc.) obtained from operating nuclear power plants to diagnose the condition of instruments and devices.

Codes Used, etc.

MATLAB, JAVA

Business Achievements  
& Product Name

Plant equipment  
diagnostics



References & Patents

- Jet pump flow measurement pipe breakage detection method and device (Patent No.JP4413910B)
- LPRM signal cable misconnection detection method and device (Patent No.JP5190282B)
- LPRM signal cable misconnection detection method and device at startup (Patent No.JP5260407B)
- Sealing capacity detection method and device (Patent No.JP4885258B)
- [www.jsm.or.jp/ejam/Vol.4No.2/NT/NT46/article.html](http://www.jsm.or.jp/ejam/Vol.4No.2/NT/NT46/article.html)

Development and Implementation of Various Systems for Nuclear Facilities

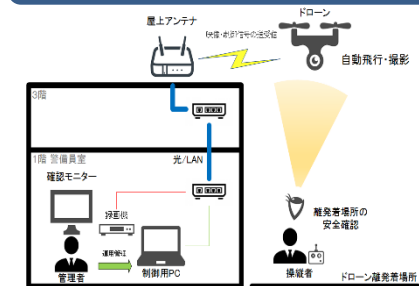
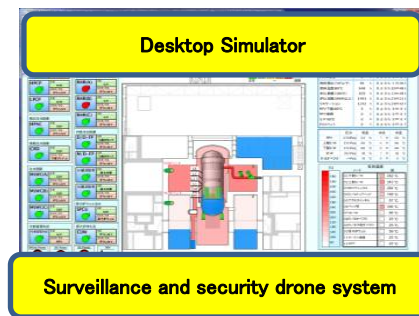
By combining nuclear engineering and IT technologies, we develop and provide software that makes it easy to perform analyses and evaluations that were previously difficult for anyone other than experts to use, as well as various systems for plant monitoring and investigation. For example, we provide simulators that make it easy to use the severe accident analysis code (MAAP), software that allows simple shielding calculations, and drones that can monitor and guard large sites.

Codes Used, etc.

Severe accident analysis codes : MAAP  
 FORTRAN, Python, MATLAB

Business Achievements & Product Name

- Severe Accident Desktop Simulator



([www.jsm.or.jp/ejam/Vol.9No.3/NT/NT86/86.html](http://www.jsm.or.jp/ejam/Vol.9No.3/NT/NT86/86.html))

- Site boundary dose rate evaluation system : ARES  
 ([www.jsm.or.jp/ejam/Vol.6No.3/NT/NT66/66.html](http://www.jsm.or.jp/ejam/Vol.6No.3/NT/NT66/66.html))
- Simple shielding calculation software : FLEXDOSE  
 ([www.jsm.or.jp/ejam/Vol.8No.1/NT/NT77/77.html](http://www.jsm.or.jp/ejam/Vol.8No.1/NT/NT77/77.html))

## Analysis Technology for Thermal-Hydraulic Behavior of Nuclear Power Plants or Cores, Nuclear-Related Facilities, etc.

Nuclear power plants generate electricity by using heat produced from nuclear fission to convert water into steam, which drives turbines. TEPCO SYSTEMS provides engineering services to analyze various phenomena caused by complex phase transitions between water, steam, and gas using a variety of thermal-hydraulic analysis codes, CFD codes, and other simulation tools. Recent notable projects include performance assessments of additional safety equipment at the Kashiwazaki-Kariwa Nuclear Power Plant and analysis of the progression of the Fukushima Daiichi Nuclear Power Plant accident. We aim to contribute to the improvement of nuclear power plant safety by utilizing simulation technology to meet the diverse needs of our customers. In addition, we contribute to the development of simulation technology through various activities with academic societies and other organizations, while striving to continuously enhance our technical capabilities.

### Codes Used

- Severe accident analysis code: MAAP
- Reprocessing facility severe accident analysis code: FATE
- Forest fire simulation codes: FARSITE, FlamMap
- General-purpose thermal hydraulic analysis codes: GOTHIC, STAR-CCM+, FLUENT
- Sub-channel analysis code: NASCA
- Building fire simulation codes: CFAST, FDS, FDTs, PyroSim

### Work Achievements

- PRA event progression analysis (L1 / L1.5 / L2)
- Improvement of accident response procedure manual
- Building hydrogen/steam leakage behavior analysis
- Spent fuel pool accident analysis
- Boric acid water mixing analysis
- Reprocessing facility accident progression analysis
- Forest fire evaluation
- Severe accident training
- Development of decision support tools for nuclear disaster prevention
- Design considerations for additional safety equipment

- Investigation and review of unresolved issues related to the Fukushima Daiichi Nuclear Power Plant accident
- Building fire evaluation
- Aerosol dispersion/migration analysis
- Hydrogen behavior analysis related to debris storage

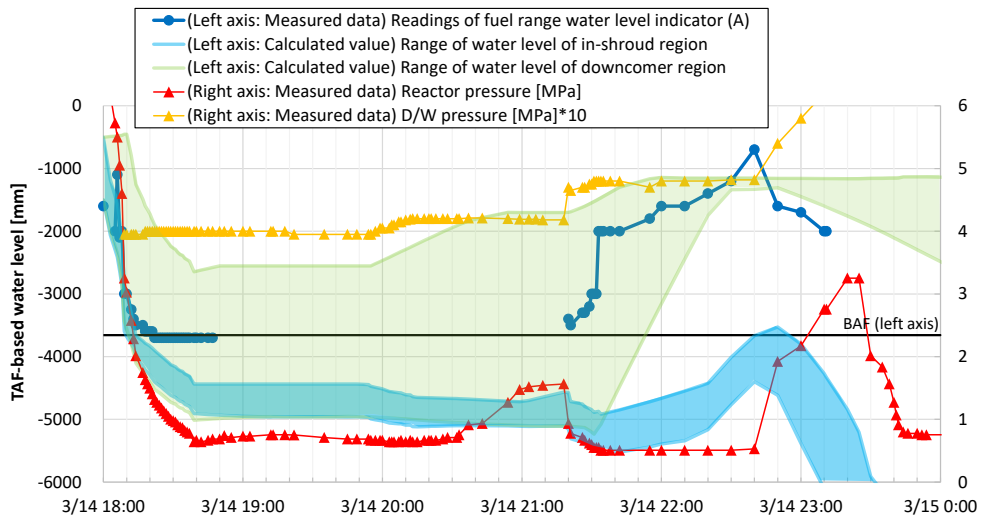


Fig. Estimated range of reactor water level in the accident at Fukushima Daiichi NPP (Unit 2)

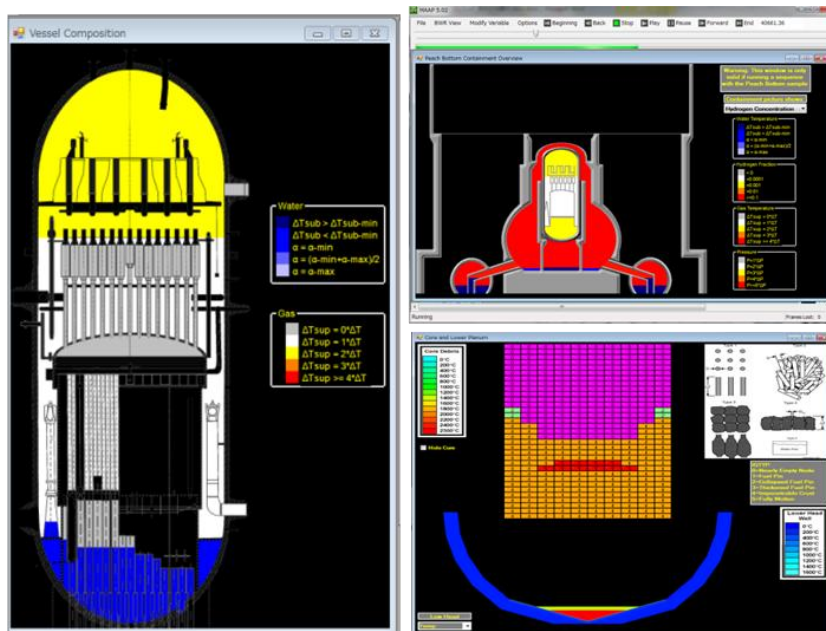


Fig. Plant behavior analysis during core damage (MAAP code used)

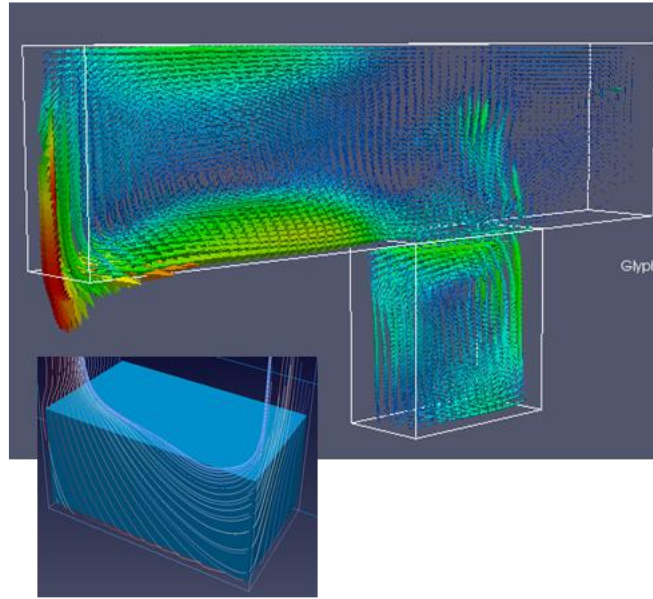


Fig. Detailed thermal-hydraulic analysis in the spent fuel pool

## Dose Assessment Techniques for Radioactive Waste Management at the Fukushima Daiichi and Daini Nuclear Power Station

Radioactive materials released during the Fukushima Daiichi Nuclear Power Station accident contaminated both the surrounding environment and the plant site. Within the site, radioactive contamination was identified on structural surfaces and equipment, posing radiological hazards to workers and adversely affecting operational safety.

Decontamination activities have been carried out at the plant site to reduce ambient dose rates and support safe working conditions. Contaminated water has been treated using purification systems, including the Advanced Liquid Processing System (ALPS), to remove radioactive nuclides and reduce overall radioactivity.

The radioactive waste generated through these processes—including volume-reduced waste packages and filters used in water treatment—contains high levels of radioactivity. Accordingly, appropriate shielding and centralized management are required to ensure radiological safety.

TEPSYS conducts dose assessments and designs shielding measures to minimize occupational exposure from radioactive waste, in accordance with the ALARA (As Low As Reasonably Achievable) principle.

In 2019, TEPCO decided to decommission the Fukushima Daini Nuclear Power Station. Preparatory activities for decommissioning are currently in progress.

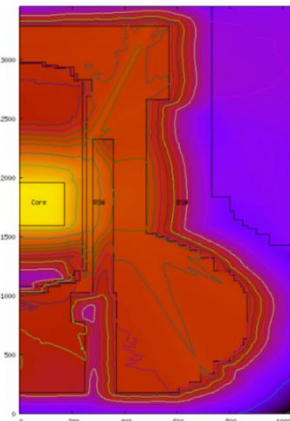
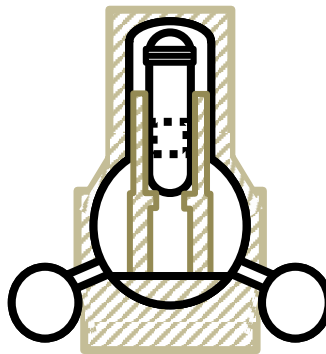
To support the development of the decommissioning plan, TEPSYS analyzes neutron flux distributions during plant operation and estimates the radioactive inventory through activation calculations.

Codes

Dose calculation: MCNP, QAD

2D Sn neutron transport calculation: DORT

Nuclide generation and decay calculation: ORIGEN



**Neutron flux distribution**

Business Achievements

- Dose assessment from radioactive waste at the Fukushima Daiichi Nuclear Power Plant
- Estimation of radioactive inventory in waste generated from nuclear power plants

Dose Assessment Techniques for Severe Accident Scenarios

Since the Fukushima Daiichi Nuclear Power Station accident, Japan’s Nuclear Regulation Authority (NRA) has required nuclear facilities to strengthen their capabilities for managing severe accidents—beyond design basis events that may result in core damage and containment failure.

To support effective mitigation of such events, it is essential that plant personnel are able to carry out necessary response actions under radiologically controlled conditions. In line with this requirement, measures such as the deployment of dose-reduction equipment and the preparation of emergency response plans are being implemented.

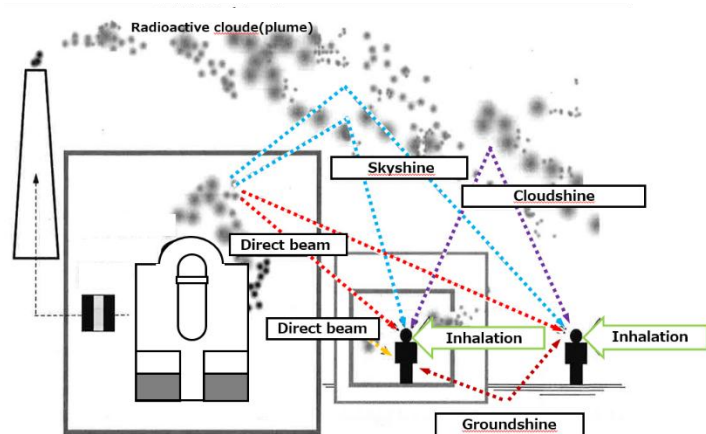
TEPSYS performs prospective dose assessments to estimate potential occupational exposure under hypothetical severe accident conditions. These assessments serve as a technical foundation for the design of radiation protection measures and the development of operational procedures to ensure exposures remain as low as reasonably achievable (ALARA).

Codes

Atmospheric dispersion  
calculation: WDOSE2

Internal/external exposure  
calculation: DOHA

Dose calculation: MCNP, QAD,  
G33



Business Achievement

- Assessment of occupational radiation exposure of workers during emergency operations at the Kashiwazaki-Kariwa Nuclear Power Station

# Boiling Water Reactor (BWR) In Core Fuel Management

TEPSYS offers comprehensive in-core fuel management services. Our advanced solutions are meticulously designed to optimize reactor performance, enhance safety, and reduce operational costs. We also provide licenses for the core loading pattern optimization code FINELOAD-3 to domestic and overseas power companies. Additionally, we offer the core monitoring system CORSAGE.

■ Calculation Codes

Steady-state core analysis:

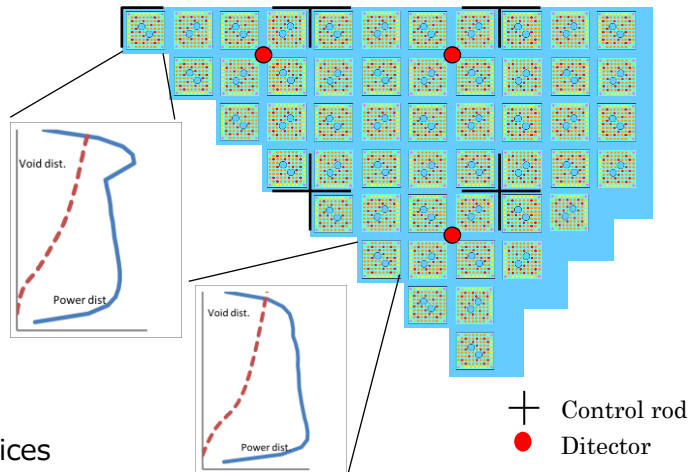
CASMO5/SIMULATE5

Scram analysis: SIMULATE5-K

Stability analysis: LAPUR-TSI

Loading pattern optimization

code: FINELOAD-3



Example of reactor analysis model

■ In-Core Fuel Management Services

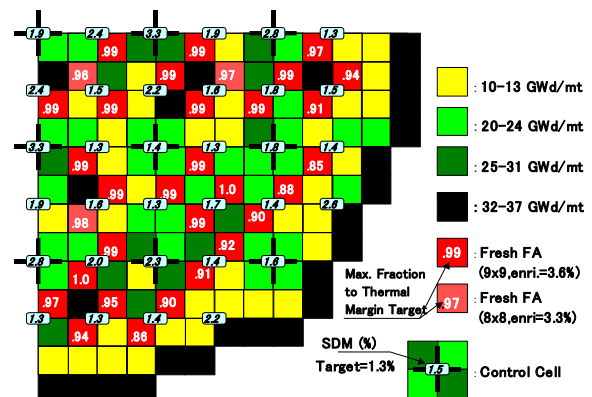
Reload core design

Startup planning

Fuel bid evaluation

■ Loading Pattern Optimization Code FINELOAD-3

The FINELOAD-3 system optimizes fuel loading patterns to enhance fuel economy and automates control rod patterns based on the user-specified control rod sequence. TEPSYS provides licenses for the FINELOAD-3 system and can customize the system to meet user requirements.



Example of optimized loading pattern

■ Core Monitoring System CORSAGE

The CORSAGE core monitoring system features the advanced analysis code SIMULATE5, providing precise and reliable monitoring of core conditions. CORSAGE is designed with dual-redundancy, providing high reliability and ensuring continuous operation.

■ Track Record

- Successful final reload core design for more than 140 cycles operated by TEPCO HD
- Evaluation of core characteristics for the ABWR initial core loading
- Evaluation of high burn-up fuel and MOX fuel
- Provision of the CORSAGE system to seven plants operated by TEPCO HD
- Provision of the FINELOAD-3 system license to utilities and fuel vendors

■ R&D

- Criticality evaluation of spent fuel pool
- Criticality safety assessment of fuel debris
- V&V activities for our analysis codes following the Japan Electrical Association's code

■ References

S. Jagawa, "Boiling Water Reactor Loading Pattern Optimization Using Simple Linear Perturbation and Modified Tabu Search Methods", NSE:138,67-77(2001)  
JNST [www.jsm.or.jp/ejam/Vol.4No.3/NT/NT48/tepc.html](http://www.jsm.or.jp/ejam/Vol.4No.3/NT/NT48/tepc.html)