Advanced Boiling Water Reactor

The first Generation III+ Reactor in Operation today

Hitachi-GE Nuclear Energy, Ltd.
Energy production technologies for sustainable future


Shimane 3, The Chugoku Electric Power Co., Inc.
Simple & Reliable Nuclear-Power Generation System

One of the world’s most common types of nuclear power generating plants, boiling water reactors, are characterized by a system wherein steam generated inside the reactor is directly passed to the turbine to simplify the process and equipment. Since the introduction of the boiling water reactor technology, from General Electric in the 1960s, Hitachi has participated in the design, development and construction of over 20 nuclear power plants within Japan.

Introduction of Technology from US in 1960s

Tsuruga 1 (The Japan Atomic Power Co.)
Fukushima I-1 (Tokyo Electric Power Company Holdings, Inc.)
Hamaoka 1 (Chubu Electric Power Co., Inc.)
Fukushima I-4 (Tokyo Electric Power Company Holdings, Inc.)
Tokai II (The Japan Atomic Power Co.)
Hamaoka 2 (Chubu Electric Power Co., Inc.)

Promotion of Domestic Plant
Shimane 1 (The Chugoku Electric Power Co., Inc.)

Primary Improvement
Promotion of Improvement and Standardization Program (1975 to 1977)
Fukushima II-2 (Tokyo Electric Power Company Holdings, Inc.)
Fukushima II-4 (Tokyo Electric Power Company Holdings, Inc.)
Hamaoka 3 (Chubu Electric Power Co., Inc.)
Shimane 2 (The Chugoku Electric Power Co., Inc.)
Kashiwazaki-Kariwa 5 (Tokyo Electric Power Company Holdings, Inc.)

Promotion of Secondary Improvement and Standardization Program (1979 to 1980)
Shika 1 (Hokuriku Electric Power Co., Inc.)
Hamaoka 4 (Chubu Electric Power Co., Inc.)
Kashiwazaki-Kariwa 4 (Tokyo Electric Power Company Holdings, Inc.)
Onagawa 3 (Tohoku Electric Power Co., Inc.)

BWR-2 ➤ BWR-3,4,5
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

**ABWR Development concept**

- Enhanced Safety
- Higher Operability
- Reduced Dose Equivalent
- Enhanced Cost Efficiency (Construction/Operation)

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The Chugoku Electric Power Co., Inc. Shimane 3

UK-ABWR

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**ABWR**

Application of Evolutonal Design and Standardization

The first and second ABWR in the world (Twin plant)
- Kashiwazaki-Kariwa 6 (Tokyo Electric Power Company Holdings, Inc.)
- Kashiwazaki-Kariwa 7 (Tokyo Electric Power Company Holdings, Inc.)

Succeeding ABWR plants
- Hamaoka 5 (Chubu Electric Power Co., Inc.)
- Shika 2 (Hokuriku Electric Power Co., Inc.)
- Shimane 3 (The Chugoku Electric Power Co., Inc.)
- Ohma (Electric Power Development Co., Ltd.)
- Higashidori 1 (Tokyo Electric Power Company Holdings, Inc.)

Completed Generic Design Assessment (GDA) for UK-ABWR in December 2017.
Advanced Boiling Water Reactor

ABWR Plant Realized through International Joint Development

Hitachi developed the ABWR in 1985, in collaboration with various international partners and support from power companies with experience in operating BWR plants. The main technological features employed are as follows:

1. Large scale, highly efficient plant
2. Highly economical reactor core
3. Reactor coolant recirculation system driven by internal pumps
4. Advanced control rod drive mechanism
5. Overall digital control and instrumentation
6. Reinforced concrete containment vessel

These features constitute a highly functional, enhanced safety nuclear reactor systems, with a compact, easy-to-operate, and efficient turbine that offers excellent performance.

Schematic Diagram of Advanced Boiling Water Reactor (ABWR)
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

### Key Specifications of BWR Nuclear Power Plants

<table>
<thead>
<tr>
<th>Item</th>
<th>ABWR</th>
<th>BWR-5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant Output</td>
<td>1,350 MWe</td>
<td>1,100 MWe</td>
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<tr>
<td>Reactor Thermal Output</td>
<td>3,926 MWt</td>
<td>3,293 MWt</td>
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<tr>
<td><strong>Reactor Core</strong></td>
<td></td>
<td></td>
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<tr>
<td>Fuel Assemblies</td>
<td>872</td>
<td>764</td>
</tr>
<tr>
<td>Control Rods</td>
<td>205 rods</td>
<td>185 rods</td>
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<tr>
<td><strong>Reactor Equipment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recirculation System</td>
<td>Internal pump method</td>
<td>External recirculation type</td>
</tr>
<tr>
<td>Control Rod Drive</td>
<td>Hydraulic / electric motor drive methods</td>
<td>Hydraulic drive</td>
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<tr>
<td><strong>RHR Containment Vessel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinforced concrete with built-in liner</td>
<td>Free-standing vessel</td>
<td></td>
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<tr>
<td><strong>Turbine Systems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Cycle</td>
<td>Two-stage reheat</td>
<td>Non-reheat</td>
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<tr>
<td>Turbine (final blade length)</td>
<td>52 inches</td>
<td>43 inches</td>
</tr>
<tr>
<td>Moisture Separation Method</td>
<td>Reheat type</td>
<td>Non-reheat type</td>
</tr>
<tr>
<td>Heater Drain</td>
<td>Drain up type</td>
<td>Cascade type</td>
</tr>
</tbody>
</table>

*Residual Heat Removal System*
Application of "Evolutional Designs"

- Large capacity, high efficiency plant systems
- Emergency Core Cooling Systems with enhanced safety
- Highly economical reactor core
- Reactor recirculation system applying internal pumps
- Advanced Fine Motion Control Rod Drive System
- Advanced Main Control Room with Full Digital system and improved Human-Machine Interface & Automatic Operation
- Reinforced Concrete Containment Vessel

ABWR Reactor Building section view

1. Reinforced Concrete Containment Vessel
2. Reactor Pressure Vessel
3. Steam Dryer
4. Steam Separator
5. High Pressure Core Flooder Sparger
6. Fuel Assembly
7. Control Rod
8. Reactor Internal Pump
9. Fine Motion Control Rod Drive System
10. Control Rod Drive Mechanism Handling Machine
11. Main Steam Piping
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

- Hitachi's continuous involvement in construction of ABWR power plants (C/O: Commercial Operation)
  - 1st, 2nd ABWRs: Kashiwazaki-Kariwa 6&7 (C/O: 1996, 1997)
  - 5th ABWR: Shimane 3 (Under Construction)
  - 3rd ABWR: Hamaoka 5 (C/O: 2005)
  - 6th ABWR: Ohma 1 (Under Construction)
  - 4th ABWR: Shika 2 (C/O: 2006)
  - 7th ABWR: Higashidori 1 (Under Construction)


Source: Tokyo Electric Power Company Holdings, Inc.
ABWR Countermeasures Against Fukushima Accident

Enhanced Safety Features regarding Fukushima-daiichi NPP® accident

ABWR safety are based on the Defense in Depth (DiD) concept wherein multiple layers of protection are provided with each layer designed to provide the safety function with no reliance on the other layers. ABWR design is compliant with the international criteria by well-designed Safety Systems to achieve a sufficiently low core damage frequency. Furthermore, to accomplish an enhanced level of nuclear safety, supplementary safety enhancements against severe conditions have been incorporated. These enhancements on further layer in DiD are designed to address the Fukushima-daiichi NPP accident caused by the huge earthquake and subsequent tsunamis on March 11, 2011. The major enhancements are the further prevention of Station Black Out (SBO) and/or Loss of Ultimate Heat Sink (LUHS). Moreover, the enhanced functions ensure water supply into the reactor, PCV integrity, and SFP water level is maintained even in the event of SBO and/or LUHS. These enhancements, based on lessons learned from Fukushima Accident, provision and maintenance of Severe Accident Management Guidelines, ensure that the integrity of inherent safety features of the ABWR is retained even in the event of a severe accident.

※NPP : Nuclear Power Plant

| ABWR Safety | ● Diversified water injection methods  
|             | ● Large capacity of heat sink (pool)  
|             | ● Inactivated PCV  
|             | ● High seismic resistance  
|             | ● No large bore pipes lower than the top of fuel assemblies |

Core Damage Frequency (CDF): 1.6 ×10⁻⁷

(1) Secure Power Source
- Alternative DC Power Source
- Diversity of Power Source (Water-cooled DG, Air-cooled DG)
- Sealed building structure to secure components and power panels in case of flooding

(2) Secure water injection systems and ultimate heat sink
- Diversity of alternate water injection capabilities
- Enhancement of mobility by applying portable pumps
- Diversity of heat sink through use of portable heat removal system

(3) Prevention of PCV damage
- Prevention of PCV damage caused by elevated temperatures by enhancing the PCV cooling system

(4) Secure Spent Fuel Pool Cooling function
- Diversity of pool water injection method
- Accident Management operability enhancement by applying external water injection filler
- Incorporation of additional SFP temperature and water level monitoring systems in case of severe accident
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

Inherent Safety Features of the ABWR

Enhancements based on lessons learned from Fukushima Accident

Provision and Maintenance of Severe Accident Management Guidelines

Overview of Enhanced Safety Systems for Severe Accident

PCV: Primary Containment Vessel
SFP: Spent Fuel Pool
FP: Fire Protection System
MUWC: Make Up Water System (Condensate)
CSP: Condensate Storage Pool
D/W: Dry Well
W/W: Wet Well

DG or GTG

Enhanced PCV Venting System (COPS)
LPFL: Low Pressure Core Flooder System
HPCF: High Pressure Core Flooder System
RHR: Residual Heat Removal System
RCIC: Reactor Core Isolation Cooling System
SGTS: Standby Gas Treatment System
FLS: Flooder System
ABWR Countermeasures Against Fukushima Accident

Plant Layout Design with backup water injection systems, Mobile/Portable components for water injection and sources of power

ABWR, which is the Generation III+ reactor operating in the world, has achieved an incomparable level of safety with additional facilities for safety enhancement as well as plant layout designs to mitigate site specific external hazards.

Site Layout example (1)  Full View

Site Layout example (2)  Closeup View

- Emergency Operating Building
- Firetrucks, Power Trucks
- Back up building
- Administration Office
- Unit1
- Unit2
- Unit3
- RB
- Rwb
- SB
- TB
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

- **Countermeasures for flooding**

- **Example of Alternative Heat Removal System (Portable)**

- **Mobile Equipment**
Reinforced Concrete Containment Vessel (RCCV)

ABWR has increased its power output while also decreasing its containment size

RCCV consists of a steel liner inside of a reinforced concrete structure. The RCCV has two functions: contain pressure and prevent leakage. The concrete handles the functions of pressure containment and shielding, and the liner handles the function of leakage prevention. The RCCV is divided into a drywell and a suppression chamber by the diaphragm floor and the RPV pedestal. The suppression chamber contains a pool and an air space. Vapor flows, which are generated from a LOCA flow from the drywell space to the suppression pool through horizontal vent pipes embedded into the RPV pedestal. The design pressure of RCCV is 310kPa. The RCCV design temperature is 171°C for the drywell and 104°C for the suppression chamber. The RCCV is cylindrical and consists of a top slab, a shell and a foundation. The inside diameter of the RCCV is 29m, and the height from upper surface of the foundation to upper surface of the top head is 36m. The thickness of the RCCV shell is 2m and attached to the foundation.

- Reinforced Concrete Containment Vessel (RCCV) contains reactor pressure vessel.
- RCCV has reduced its volume and height to improve seismic resistancy.
- The RCCV compact structure and reactor building integration improves cost effectiveness.
- In case of RCCV pressure increase, steam is condensed in the Suppression Pool water and a nitrogen atmosphere can be developed in the PCV to prevent a hydrogen explosion.

※1 RPV: Reactor Pressure Vessel, ※2 PCV: Primary Containment Vessel

More cost-effective

**MARK I**
(BWR-3/4)

Output power: 780MWe

**MARK II**
(BWR-5)

Output power: 1,100MWe
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

Shimane 3 RCCV Liner module Installation

RCCV (ABWR)

RCCV: Reinforced Concrete Containment Vessel

Diaphragm Floor

RPV Pedestal

Drywell

Suppression Chamber

Vent Pipe

Output power: 1,350MWe (ABWR)
Reactor Internal Pump—High Reliability, High Performance

- The Reactor Internal Pump is directly mounted to the bottom of the nuclear reactor pressure vessel (as shown in figure below) and supplies coolant (water) to the reactor core.
- By controlling Reactor Internal Pump’s rotational speed, the reactor core flow and void coefficient are changed, thus controlling the nuclear power plant’s power output.
- In comparison to BWR’s with external pumps, motor driving power and radiation exposures can be reduced due to the elimination of external recirculation pipes.
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

### Hitachi Reactor Internal Pump Features

- **High Reliability:**
  - Adoption of Tilting Pad Bearing helps vibration stability.
  - Thicker nozzle yields high earthquake resistance. (Actual results from past nuclear power plants.)
  - The nozzle gap and the inspection window enable inspection of the welded area.
  - There is a testing facility to test the Reactor Internal Pump under the same conditions in an actual nuclear power plant.
  - In order to eliminate the shaft seal, the wet motor was adopted to connect the pump and motor using one shaft.

- **High Performance:**
  - 100% core flow is maintained even with only 9 pumps working.
  - High voltage motor is used to correspond to the high capacity needs.

### Technical Data

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Number of Pumps</td>
<td>10</td>
</tr>
<tr>
<td>Capacity</td>
<td>Approx. 8,300 m³/h*</td>
</tr>
<tr>
<td>Total Head</td>
<td>Approx. 46 m*</td>
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<tr>
<td>Speed</td>
<td>Approx. 1,600 min⁻¹*</td>
</tr>
<tr>
<td>Design Temp.</td>
<td>302 °C</td>
</tr>
<tr>
<td>Design Pressure</td>
<td>8.62 MPa</td>
</tr>
</tbody>
</table>

*Maximum at 120% core flow
Reactor Pressure Vessel (RPV)

Reactor Pressure Vessel Contains the Core of the Nuclear Power Plant

The reactor pressure vessel contains fuel assemblies, control rods, steam dryer, steam separator, and other components. With a large separation between the reactor and pressure vessel walls, BWRs feature low neutron irradiation embrittlement. Hitachi uses highly reliable vessel materials that further reduce irradiation embrittlement, by reducing the content of copper, sulfur, and phosphorous in these materials. Additionally, the single-block forging of bottom head and other components greatly reduces weld-line length to be covered by in-service inspections.
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

Flanges

Steam dryer
Steam separator
Feed water inlet nozzle
Feed water sparger
Core shroud
Control rods
Core plate
Reactor pressure vessel support skirt

In-core monitor housing

Section view of ABWR reactor building
**Key Components made by high accuracy manufacturing techniques**

Hitachi has designed and manufactured a large number of reactor pressure vessels (RPV) and reactor internal components. Stringent quality control standards guarantee the highest reliability possible. The expertise acquired to date in design, manufacturing and quality control ensures that the reliability of the RPVs and reactor internal components for ABWR facilities will continue to be every bit as in the past.

**Design & Manufacturing**

From small precisely machined components to large welded components, a wide variety of nuclear core equipment has been designed and manufactured by Hitachi.

![Structural sketch of reactor pressure vessel and reactor internal components](image-url)
Reactor Internal Components of ABWR

The ABWR reactor internal components are based on the design of the BWR-5 components which are the evolutionary improvement over the BWR-5 reactor internal components. A number of improvements were made to enhance the structural strength and higher performance. In particular, a square hole machining device utilizing extra-high precision technology was used on the grid plate to manufacture the component from one piece, ensuring outstanding structural strength.

Structural Comparison of BWR-5 and ABWR

<table>
<thead>
<tr>
<th>No.</th>
<th>Changes</th>
</tr>
</thead>
</table>
| 1   | • Steam separator changed from two stage to low-pressure-loss three stage type (AS-2B)  
     • Adoption of internal pumps eliminates large-diameter pipe breaks in bottom of reactor. This enables core to be constantly covered in water, allowing cooling system to be changed from spray to simple sparger type. |
| 2   | Top Guide  
     • Top guide structure was changed from assembly of individual matching plates to one-piece high-structural-strength one-piece machined type. |
| 3   | Core Shroud  
     • Inner diameter of core shroud has been increased to accommodate a larger number of fuel assemblies.  
     • Top guide and upper shroud are now integral. |
| 4   | Core Plate  
     • A structure with reinforcing beams and perpendicular reinforcing rods was changed to all reinforcing beams to increase strength. |
| 5   | Lower Pressure Flooder System  
     • Adoption of internal pumps eliminates large diameter pipe breaks in bottom of reactor, ensuring a constant core coverage under water. This eliminates the necessity of supplying water to the inside of the shroud, allowing cooling system to be changed to sparger type of outside of shroud. |
| 6   | Reactor Recirculation System  
     Jet Pump  
     Internal Pump |
Control Rods, Control Rod Drives

Contributing to reduction of plant start-up time, and low radiation exposure during maintenance

- Fine Motion Control Rod Drive (FMCRD) system utilizes two different power sources:
  - Electric motor drive for normal operation
  - Conventional hydraulic accumulator for emergency insertion (scram)
- Diversification of the power source enhances reliability.
- One way water purge system minimizes the contamination of FMCRD and Hydraulic Control Unit (HCU) and reduces radiation dose during maintenance.
- Fine control of control rod position by the electric motor reduces mechanical and thermal loads to fuel bundles, thereby increasing fuel reliability.
- Fine control of Control Rod position by the electric motor improves the load following capability of the plant electric power output.
- Simultaneous drive operation of control rods (gang mode operation) shortens the start up time of the plant.
- Reduction of the number of FMCRDs to be inspected shortens the time required for periodical inspection and radiation dose at refueling outages.

Control Rods, FMCRD before assembling, Hydraulic Control Units
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.
Optimized Design and Performance

The enhanced design of the GNF2 fuel assembly — based on pioneering technologies developed by GNF — provides customers with improved fuel utilization and increased performance and reliability. In addition to increased output and reduced fuel costs, the GNF2 advanced design offers the latest technology in corrosion and debris resistance. The advanced debris filter, the Defender™, is now standard on the GNF2 fuel assembly — increasing reliability and filtration to the best available in today’s market. The GNF2 fuel assembly has undergone rigorous testing and is expected to be even more reliable than other fuel designs — preventing more fuel failures than any other design due to the standard Defender™ filter.

**Increased Energy**
- Supports 24 months operation at 120% power
- High exposure capability(up to bundle average 60MWd/t)
- High Energy Bundle(High Fuel mass, High Enrichment pellet)

**Operating Flexibility**
- Increased Critical Power(High performance spacer design)
- Increased Mechanical Power Margin
- Low Pressure Drop(Low pressure drop UTP™ design)

**Fuel Reliability**
- Debris Resistance( Advanced Debris Filter - Defender™ LTP™ design)
- Hydrogen Resistance(Corrosion Resistance Cladding -GNF Ziron-)

※1 UTP : Upper Tie Plate , ※2 LTP : Lower Tie Plate
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

### Evolution of BWR Fuels

- **GE14**
- **GNF2**

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### Operational Optimization - N-Streaming -

**Recognizes Current Design Limitations**
- Traditional designs use 1-2 bundle types
- Local design requirements dictate bundle characteristics
- Same bundle uses in non-limiting locations

**Expands Design Space**
- Generate numerous bundle types from an equivalent set of rod types
- Perform core design using fuel rods versus the fuel bundles
- Solve local problems with unique designs

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Two Stream Design

- **Base**
- **U Rod**
- **Gad+U Rod**
- **Δvs. Base**

Six Stream Design

- **Base**

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**N-Streaming**

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Hitachi Turbine and Generator, Responsive to the World’s Needs

Since manufacturing the first unit in 1933, Hitachi, Ltd. has supplied numerous turbine generators to power stations throughout the world. These turbine generators are known for their high levels of efficiency and reliability. Hitachi has the integrated capacity to supply power stations with all critical deliverables from materials for construction to equipment for operations. Experts in power and electrical equipment, Hitachi not only provides turbine generators but also instrument and control equipment. Further, Hitachi is able to manage and control turnkey projects of power stations, including basic planning, design engineering, transportation, construction work, operations and other related work. We believe that Hitachi’s total capacity of supplying turbine generators and other equipment is of great benefit to the customers throughout the world.
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

**Hitachi Steam Turbines**

Hitachi Steam Turbines play an important role as a main facility of the electricity generation business. Hitachi Steam Turbines lead the business with many superior features such as high-performance long blades by loss reduction technologies and the Ultra Super Critical Steam Conditions (Steam pressure of 25MPa and Steam temperatures at 600°C/620°C).

**Hitachi Large Generator**

It is now more than 90 years since Hitachi’s reliable generators first debuted, yet Hitachi innovation has never slowed. Today Hitachi produces broad range of superior generators up to 1.6GVA class nuclear turbine generators.
Hitachi’s High Reliability Supports the Stable Operation of Nuclear Power Plants

Hitachi is committed to continuous improvements in the ease of operation and reliability of its nuclear power plant monitoring and control systems. We are working on increased reliability in the form of standardization of our digital control panels, and the increased utilization of multiple technologies and fault tolerance improvement technologies, as well as the use of optical multiple transmission technology in the creation of hierarchical information networks. Our integrated digital monitoring control system, NUCAMM-90, incorporates a background of digital technological development and expanded calculation capacity with a high level human interface and increased scope of automation.
Advanced NUCAMM-90 ABWR Instrumentation & Control Systems
(NUCAMM-90 : Nuclear Power Plant Control Complex with Advanced Man-Machine Interface 90)

● Large-Scale Display Board Facilitates Sharing of Information
  Overall plant status supplied as shared information.
  Warnings are displayed using hierarchies, for improved identification.

● Compact Main Control Board
  Main monitoring operations consolidated into a compact console.

● Expanded Automation Reduces Load on Operator
  Expanded automatic operations, including control rod operation, allows operators mainly overall plant monitoring operations.

● Integrated Digital Control System
  Improved reliability and ease of maintenance as a result of integrated digitalization, Electrical and physical separation between safety systems and non-safety systems.

FMCRD: Fine Motion Control Rod Drive  Optical Multiplex Transmission  Hard Wired

Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.
Radioactive Waste Processing Systems

Classification of Radioactive Waste and Process Flow

Gaseous Waste
- Off Gas
- Tank Vent Gas
- LCW
- HCW
- Concentrated liquid waste
- Recombination
- Noble Gas Hold-up
- Iodine Removal
- Discharge
- Recycle
- Storage
- Disposal

Liquid Waste
- Spent Resin
- L/D, S/D
- Incineration
- Ash
- Solidification
- Off Gas Recombiner
- Noble Gas Hold-up
- Concentrated liquid waste
- Hollow–Fiber Filtration
- Demineralization
- Evaporation
- Concentrated liquid waste
- Volume Reduction / Solidification
- Filtration (Evaporation)
- Discharge

Solid Waste
- Combustible Waste
- Non-Combustible Waste
- Sludge
- CR/FCB .etc...
- Storage Tank
- Site Bunker
- Spent Fuel
- Spent Fuel Storage Pool
- Recombination
- Noble Gas Hold-up
- Incineration
- Ash
- Solidification
- Off Gas Condenser
- Off Gas Preheater
- Off Gas Recombiner
- By combining Hollow Fiber Filtration with a Demineralizer, processed liquid can be reused or discharged to the environment

Solidification

Off Gas Recombiner Module
* This figure shows an example of existing Japanese plant module
* Two recombiners are installed in the latest ABWR design

Gaseous Waste Processing System
- Off Gas Recombiner fitted with a Sponge-Metal Catalyst to achieve high recombination efficiency
- Noble Gas Hold-up unit with a simplified and compact design
- Silver-Alumina Adsorbent used to achieve high Iodine removal efficiency

Liquid Waste Processing System
- Hollow Fiber Filter with high processing capability
- Secondary waste generation reduced by half
- By combining Hollow Fiber Filtration with a Demineralizer, processed liquid can be reused or discharged to the environment
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

- **Waste Solidification System**
  - Cement based solidification materials, improved mixer efficiency to achieve stable solid waste

  **Overview of Solidification System**

  ![Solidification System Diagram](image)

  **In-Drum Mixer**

  - **In-Drum Mixer**
    - **Cover**
    - **Features**
      - Minimization of secondary waste
      - Improved mixing efficiency
    - **Washing Spray Ring**
    - **High Speed Blade**
    - **Planetary Blade**

  **Features**

  - Minimization of secondary waste
  - Improved mixing efficiency

- **Site Bunker Facility**
  - **Features**
    - Stainless Steel Lined Pool
    - High Density Storage Rack
    - Fitted with a high-level waste Volume Reduction Equipment
    - Diversified Pool Water Cleanup System

  ![Site Bunker Facility Diagram](image)

- **Waste Drum Inspection System**
  - **Features**
    - Proven performance in BWR/PWR plants
    - Compact System
    - Fully automated handling and data processing
    - High maintainability

  ![Waste Drum Inspection System Diagram](image)
Remote-Automatic Equipment to Reduce Radiation Exposure and Manpower

To reduce radiation exposure and manpower, Hitachi has developed many remote-automatic maintenance and inspection equipment based upon proven robotic technologies.

**Refueling Machine**

Nuclear fuel is exchanged with new fuel during reactor shutdown to form the new reactor core. The refueling machine that performs this fuel exchange operation travels or moves laterally over the reactor well and spent fuel storage pool to move the fuel. The automatic refueling machine, developed by Hitachi, performs this operation with high precision by using a process computer that automatically controls the speed and position of the refueling machine in four-dimensions; bridge travel, trolley travel, grapple vertical and rotational. By simple operation instructions from the remote control room, the refueling operation can be done swiftly and safely.

**RIP (Reactor Internal Pump) Maintenance Equipment**

RIP Maintenance Equipment is roughly divided into the Elevator with guide screw under vessel and the grappling tool on the refueling floor. The elevator is driven by electrical motor that raises and lowers RIP motors. Grappling tool is connected to RIP hoist of Refueling machine to handle the Impeller.
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

**CRD Handling Equipment**
During the periodic reactor inspection, the FMCRD is inspected and maintained. FMCRD handling work is performed with the CRD Handling Equipment installed undervessel for its assembling/dis-assembling. Then, the dis-assembled FMCRD is inspected/maintained with Maintenance Equipment.

**Fuel Preparation Machine**
Loading preparations of new fuel and inspections of used fuel are performed under water using a fuel preparation machine. At Hitachi, development and practical use have been accomplished of an Improved Fuel Preparation Machine, not only with remote control and electric motor drive, but also with a new structure for ease of maintenance and inspection.

**In-Service Inspection Equipment**
This equipment is used to detect defects on the outer RPV (body, support skirts, flanges, nozzles and their corners), pipes and RIP nozzles by using ultrasonic probes. In consideration of the broad range of thicknesses and number of steel grades to be inspected in the RPV and pipe, an incidence angle fixation probe is utilized. However, for the RIP nozzle, a phased array probe is used.
Hitachi’s Unified Company-Wide Nuclear Business System Based on Hitachi Technology

Together with all partners in the Hitachi group, Hitachi-GE Nuclear energy has established a comprehensive line-up of nuclear power service including planning, design, manufacturing, installation and maintenance of nuclear power generation plants; furthermore, we also provide training programs for plant operators. At present, Hitachi is making diligent efforts to further improve the related technology through the introduction of economically efficient light water reactor and the practical use of fast reactor while continuing to promote research and development.
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

**Affiliated Companies**

- **Mitsubishi Hitachi Power Systems, Ltd.**
  - Steam turbines, generators
  - Reactor pressure vessel, etc.

- **Hitachi Plant Construction, Ltd.**
  - Planning and execution of site installation
  - Fabrication work of nuclear fuel

- **Global Nuclear Fuel-Japan Co., Ltd.**
  - Training of operators

- **BWR Operator Training Center Inc.**
  - Development of nuclear fuel and related technology

- **Nippon Nuclear Fuel Development Co., Ltd.**
  - Switch boards

- **Hitachi Industrial Equipment Systems Co., Ltd.**

**R & D**

- **Hitachi Research Laboratory**
  - Studies concerning reactor safety analysis, waste treatment, instrumentation, and control

- **Energy and Environmental Systems Research Center**
  - Development of materials

- **Materials Research Center**
  - Studies concerning seismic design

- **Mechanical Engineering Research Center**
The design stage of nuclear power plant requires overall coordination of broad range of engineering tasks, including conceptual design, layout design, equipment carry in/out plan, shielding plan, as well as the plant construction, operation and maintenance plan. Schedule management, workforce management and QA/QC management are also important during each task phase.

In order to perform these tasks efficiently, Hitachi has developed an "Advanced Integrated CAE System" to actualize high-quality and efficient works. This system works based on not only the plant engineering database but also the accumulated experiences and management know-how of the previous projects.

Also, it is enhanced day by day through the actual projects as our core in-house engineering system.
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

**Our Policies**
- Execute as planned
- Simulate in advance
- Highest quality and safety
- On schedule/on budget
- Ultimate plant usability;
  - Constructability
  - Operability
  - Maintainability
Hitachi’s Proven NPP Construction

To improve the construction period, safety and quality, Hitachi has continuously improved its construction technologies since the first BWR Nuclear Power Plant (NPP) construction in 1970’s. Now, Hitachi has 4 main construction strategies. These strategies contribute to Hitachi’s excellent execution of NPP projects.

**NPP Construction**
Safe / Quality / On-Schedule / On-Budget

- Modularization with Very Heavy Lift Crane
- Open-top & Parallel Construction Floor Packaging
- Front-Loaded Construction Engineering Detailed Schedule Management
- Integrated Construction Management System

**Hitachi’s Construction Strategies**

1st Generation
- Open-Top Construction with Tower Crane

2nd Generation
- VHL for Block & Modular Construction

3rd Generation
- Expanded Open-Top & Parallel Construction
- Expanded Block & Modular Construction

4th Generation
- Advanced Construction Technologies
- Standardized Modular Construction Method

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Large Module Installation by VHL®
(Weight : 650 MT)
※VHL : Very Heavy Lift

---

Reactor Building Base-Mat Composite Module
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

5th Generation

- Composite-Module and Block & Module’s Enlargement
- Fully Integrated Design & Engineering & Management
- Real-time Technology for Logistics and Progress Control

4D Visual Construction System

Plan

Implement

Open-Top Construction

Visualized Construction Sequence (Front-Loaded Engineering)
Hitachi Guarantees the High Quality of the Products, which are Supported by Hitachi’s Time-Tested Array of Technologies

In order to ensure construction of high quality, highly reliable nuclear power plants, Hitachi has established a consistent quality assurance system, which extends to design, manufacture, inspection, installation, and even preventative maintenance after delivery. In addition, ISO9001 certification was first obtained in 1999.

The Manufacture of Nuclear Power Equipment Requires Advanced Technology
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

**QMS operation for Plant Delivery**

**Quality management system at Hitachi-GE and the Hitachi Group**

**PDCA cycle used in Hitachi-GE’s QMS**

(The activities shown in the diagram are typical example)

- **Management review**
  - [Analysis and improvement]
  - Analysis of accidents and failures
  - QF Plant Committee

- **PDCA cycle for product realization**
  - Act
  - Plan
  - Do
  - Check

- **Resource management**
  - [Monitoring and measuring]
  - NZD activities
  - QF task activities

**QMS and Hitachi Group companies**

- Hitachi Works, Hitachi, Ltd.
  - (Thermal power/industrial division, Kokubu Production Headquarters)
- Hitachi, Ltd.
  - Information & Control Systems Division
- Kure Division, Babcock-Hitachi K.K.
- Hitachi Plant Technologies, Ltd., etc.

**Note** NZD: Nuclear Zero Defect, QF: Quality First

**Quality Control Activities**

- **Research and Development**
  - Design Reviews

- **Planning**
  - Design Reviews

- **Design**
  - Design Reviews

- **Purchasing**
  - Prior Reviews

- **Manufacture**
  - Inspection

- **Installation**
  - Inspection

- **Pre-Operation**
  - Prior Reviews

- **Periodical Inspection**
  - Design Reviews

- **Inspection**
  - Technical Support for Operating Plants

- **Preventative Maintenance**
  - Important Point Check for Periodical Inspection / Modification

- **Overall Construction Inspection**
  - Validation

- **Internal Audits**
  - Prior Reviews
  - Overall Construction Inspection
  - Validation
Hitachi’s Preventive Maintenance Technologies ensure Optimum Performance

Hitachi offers high valued service with the most advanced inspection, stress relaxation, and repair technologies, utilizing our abundant product manufacturing experience and IT in order to contribute to the high reliability of nuclear power plants.

Hitachi BWR Reactor Preventive Maintenance Technology Center

Hitachi’s underwater technicians can train the maintenance works remotely 20 meters above the bottom of RPV or below a forest of structures under RPV in the simulated facility.

Inspection Technologies

Hitachi has developed various inspection technologies and systems.

Sensing Technologies (UT, ECT, RT)

Developing many sensors and inspection systems adapted for various materials, shapes and environments, and use them in the real plants.

FBH : Flat Bottom Holes

Flexible Multi Coil ECT Sensor

Inspection Mechanics and Systems

Developing and use remote and automated inspection equipment for the nuclear power plant facilities.

Pipe Inspection System

Remotely Operated Underwater Vehicle (Extraction Type)

Remotely Operated Underwater Vehicle (Swimming Type)
Stress Relaxation Technologies
Hitachi’s stress relaxation technologies improve the reliability of nuclear power plants.

Stress Improvement of Inner surface of pipes by Induction Heating Stress Improvement (IHSI)

Stress Improvement of RPV Internals by Water Jet Peening (WJP)

Repair Technologies
Hitachi has developed and applied various repair technologies and systems.

Remote Repair Technology of RPV Bottom Head Equipment
Multi-purpose steam source test facility (HUSTLE)

Hitachi is accelerating R & D to develop superior technology and products in its key nuclear businesses of new plants, components, maintenance, and uprates, making full use of the test facility which provides two phase flow under BWR's actual pressure and temperature.

**Features**

- One of the biggest facilities in Japan
- BWR's actual operating condition (Up to 7MPa/290°C)
- Two-phase flow
- Steam recirculation with steam compressor

![System configuration](image)

![Layout of the facility](image)

![Test center of HUSTLE](image)

![3D Cut Model of the Steam compressor](image)
Testing
Various tests are performed to confirm performance and quality of nuclear core equipment.

- Reactor Internal Pump Test Facility
- Reactor Internal Pump
- Reactor Pressure Vessel

High-Performance Test Facility of Control Rod Scrammability under Seismic Conditions

- High-Performance Control Rod Seismic Scrammability Test Facility

- Shakers
- Reaction Wall
- Seismic Isolators
- Hydraulic Pumps
- 4 Fuel Assemblies, 1 Control Rod Drive, 1 Control Rod, and Test Vessel

- This test facility can perform seismic scrammability tests for all BWR type reactors.
- Parallel and horizontal excitation by two hydraulic shakers can demonstrate seismic response behavior.
- Seismic isolators are used for supporting the reaction wall in order to minimize the vibration influence to the surrounding areas.

Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.
Hitachi's Achievements in Nuclear Power

Hitachi is Committed to Apply the Latest Technology to Construct Advanced Power Stations

Since we took part in the construction of Japan’s first light water reactor - The Japan Atomic Power Co.’s Tsuruga Nuclear Power Station Unit No.1 - Hitachi has installed 20 nuclear power plants in total. We are also in the process of constructing a further three plants.

■ Achievements in Nuclear Power Plant Delivery

### Japan

- **Tokyo Electric Power Company Holdings, Inc.**
  - Kashiwazaki-Kariwa Nuclear Power Station
    - Unit 4 (’94), Unit 5 (’90), Unit 6 (’96), Unit 7 (’97)
- **Hokuriku Electric Power Co., Inc.,**
  - Shika Nuclear Power Station
    - Unit 1 (’93), Unit 2 (’06)
- **The Japan Atomic Power Co.,**
  - Tsuruga Power Plant I
    - (’70)
- **The Chugoku Electric Power Co., Inc.,**
  - Shimane Nuclear Power Station
    - Unit 1 (’74) (Closed down)
    - Unit 2 (’89)
    - Unit 3 (Under construction)

### Overseas

- **Europe**
  - Core internals
    - Leibstadt (’80)
- **Pakistan**
  - Turbine power generator
    - Karachi (’72)
- **China**
  - Turbine power generator, condenser, moisture separator/heater, etc.
    - Qinshan III unit 1, 2
- **Thailand**
  - Radioactive Waste Treatment System
    - Ongkharak Nuclear Research Center
- **South Korea**
  - Generator replacement
    - Kori
- **Taiwan Region**
  - Reactor containment vessel
    - Chinshan unit 1, 2 (’73, ’74)
  - Spent fuel storage rack
    - Chinshan unit 1, 2 (’78)
  - Spent fuel storage rack
  - Lungmen
  - Radioactive-waste disposal facility
  - Water treatment system
- **U.S.**
  - Nuclear reactor pressure vessel
    - Hope Creek (’74)
  - PLR & RHR piping replacement
    - Vermont Yankee (’85)
  - PLR & RHR piping replacement
    - Peach Bottom (’85)
- **Thailand**
  - Radioactive Waste Treatment System
    - Ongkharak Nuclear Research Center

*(Operating) ( ) : Year of delivery
(Under planning / Construction) ( ) : Under construction
(Under decommissioning, Closed down) ( )*
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

## History of Hitachi’s Nuclear Power Plant Construction

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</thead>
<tbody>
<tr>
<td>Change Over from Imported Reactors to Domestic Reactors</td>
<td>Improvement &amp; Standardization Program</td>
<td>Advanced Boiling Water Reactor</td>
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<tr>
<td>Facility Capacity</td>
<td>(kWe)</td>
<td>20,000,000</td>
<td>15,000,000</td>
<td>10,000,000</td>
<td>5,000,000</td>
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* : Joint construction project