Advanced Boiling Water Reactor

The only generation III+ Reactor in Operation today

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

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 (The Tokyo Electric Power Co., Inc.)
- Hamaoka 1 (Chubu Electric Power Co., Inc.)
- Fukushima I -4 (The Tokyo Electric Power Co., 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.)

**BWR-2 ▶ BWR-3,4,5**

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

**BWR-5**
- Improved Version

**ABWR Development concept**
- Enhanced Safety
- Higher Operability
- Reduced Dose Equivalent
- Enhanced Cost Efficiency (Construction/Operation)

**ABWR Application of Evolutional Design and Standardization**
- The first and second ABWR in the world (Twin plant)
  - Kashiwazaki-Kariwa 6 (The Tokyo Electric Power Co., Inc.)
  - Kashiwazaki-Kariwa 7 (The Tokyo Electric Power Co., 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 (The Tokyo Electric Power Co., Inc.)

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

**Key Specifications of BWR Nuclear Power Plants**

<table>
<thead>
<tr>
<th>Item</th>
<th>ABWR</th>
<th>BWR-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>1,350 MWe</td>
<td>1,100 MWe</td>
</tr>
<tr>
<td>Reactor Thermal Output</td>
<td>3,926 MWt</td>
<td>3,293 MWt</td>
</tr>
<tr>
<td>Reactor Rods</td>
<td>205 rods</td>
<td>185 rods</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>
</tr>
<tr>
<td>Reactor Containment Vessel</td>
<td>Reinforced concrete with built-in liner</td>
<td>Free-standing vessel</td>
</tr>
<tr>
<td>RHR* System</td>
<td>3 systems</td>
<td>2 systems</td>
</tr>
<tr>
<td>Turbine Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Cycle</td>
<td>Two-stage reheat</td>
<td>Non-reheat</td>
</tr>
<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>Draw up type</td>
<td>Cascade type</td>
</tr>
</tbody>
</table>

* Residual Heat Removal System

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

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**Schematic Diagram of Advanced Boiling Water Reactor (ABWR)**

[Diagram showing various components and systems of the ABWR, including Standby Liquid Control System (SLC), Reactor Pressure Vessel, Reinforced Concrete Containment Vessel, Main Steam Piping, Feed Water Piping, Control Rod Drive Unit, Hydraulic Control System, Control Rod Drive Pump, High Pressure Turbine, Generator, Condenser, Low Pressure Condensate Pump, Condensate Demineralizer, Condensate Filter, Condensate Storage Tank, and To Off Gas System.]
Advanced Boiling Water Reactor

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**

- Reinforced Concrete Containment Vessel
- Reactor Pressure Vessel
- Steam Dryer
- Steam Separator
- High Pressure Core Flood Sparger
- Fuel Assembly
- Control Rod
- Reactor Internal Pump
- Fine Motion Control Rod Drive System
- Control Rod Drive Mechanism Handling Machine
- Main Steam Piping

**Hitachi’s continuous involvement in construction of ABWR power plants**

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)


Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.
ABWR Countermeasures Against Fukushima Accident

Further Enhanced Safety Features regarding Fukushima-daiichi NPP® accident

ABWR safety features 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.

ABWR Safety Features

- 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 x 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

Inherent Safety Features of the ABWR

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

Enhancements based on lessons learned from Fukushima Accident

Provision and Maintenance of Severe Accident Management Guidelines

Overview of Further Enhanced Safety Systems

NPP: Nuclear Power Plant
Nuclear Plant Technologies

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 only 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.

Countermeasures for flooding

- Back up building
- Elevated Ground Level (Decided based on the site condition)
- Ground level is decided based on the site conditions
- Water Proof Door
- Water Proof Penetrations

Example of Alternative Heat Removal System (Portable)

- Hose Connection
- Pump
- Cooling water
- Approx. 1200mm
- 2650mm
- Plate Hx
- 2700mm

Mobile Equipment

- Fire Truck
- Power Truck
- Construction Machinery

Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.
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 38m. 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 resistance.
- 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

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

More cost-effective

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

Output power : 760MWe

**MARK II**
(BWR-5)

Output power : 1,100MWe

**RCCV (ABWR)**

Output power : 1,350MWe (ABWR)

Shimane 3 RCCV Liner module Installation
ABWR Structure, System and Component

Reactor Internal Pump (RIP)

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

<table>
<thead>
<tr>
<th>Technical Data</th>
<th>Value</th>
</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>
</tr>
<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

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.
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.
ABWR Structure, System and Component

Reactor Internals

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

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>
<th>BWR-5</th>
<th>ABWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Steam separator changed from two stage to low pressure-loss three stage type (AS-2B)</td>
<td>Steam Separator (Two stage type)</td>
<td>Steam Separator (Three stage AS-2B type)</td>
</tr>
<tr>
<td>2</td>
<td>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.</td>
<td>Shroud Head Bolt</td>
<td>Shroud Head Bolt</td>
</tr>
<tr>
<td>3</td>
<td>Top guide structure was changed from assembly of individual matching plates to one-piece high-structural-strength one-piece machined type.</td>
<td>Top Guide</td>
<td>Combined with Guide Plate</td>
</tr>
<tr>
<td>4</td>
<td>Inner diameter of core shroud has been increased to accommodate a larger number of fuel assemblies.</td>
<td>Core Shroud</td>
<td>Upper Shroud</td>
</tr>
<tr>
<td></td>
<td>Top guide and upper shroud are now integral.</td>
<td>Core Shroud</td>
<td>Upper Shroud</td>
</tr>
<tr>
<td>5</td>
<td>A structure with reinforcing beams and perpendicular reinforcing rods was changed to all reinforcing beams to increase strength.</td>
<td>Core Plate</td>
<td>Core Plate</td>
</tr>
<tr>
<td>6</td>
<td>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.</td>
<td>Low Pressure Flooder System</td>
<td>Low Pressure Flooder Sparger</td>
</tr>
</tbody>
</table>

Steam Separator
Top Guide
Shroud

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

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™)

Evolution of BWR Fuels

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

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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Turbine and Generator

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.

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.

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

Our integrated digital 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

Our highly reliable products, based on proven design, are leading nuclear technology that enhances the safety of nuclear power plants.

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.

Main Control Room Overview
Radioactive Waste Processing Systems

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

**Solid Waste**
- Combustible Waste
  - Off Gas Reheater
  - Noble Gas Hold-up
- Non-Combustible Waste
  - Iodine Removal
- Sludge
  - Storage / Solidification
- Spent Fuel
  - Spent Fuel Storage Pool

**Gaseous Waste**
- Tank Vent Gas
  - Solidification
- Low Conductivity Waste (LCW)
  - Solidification
- High Conductivity Waste (HCW)
  - Solidification
- Spent Resin
  - Hopper
- Cask
  - Decontamination Unit
  - Diversified Pool Water Cleanup System

**Liquid Waste**
- Low Conductivity Waste
  - Solidification
- High Conductivity Waste
  - Solidification
- Laundry Drain
  - Storage / Solidification
- Shower Drain
  - Storage / Solidification
- Control Rod
  - Site Bunker
- Fuel Channel Box (FCB)
  - Recycling

**Gaseous Waste Processing System**
- Off Gas Reheater 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

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

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

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

**Overview of Solidification System**

**In-Drum Mixer**
- Features
  - Minimization of secondary waste
  - Improved mixing efficiency

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- High Density Storage Rack
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**Waste Drum Inspection System**
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  - Proven performance in BWR/PWR plants
  - Compact System
  - Fully automated handling and data processing
  - High maintainability
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. Grappiling tool is connected to RIP hoist of Refueling machine to handle the Impeller.

- **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 it’s 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.

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Organization for Hitachi’s Nuclear Business

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.

Registered Office
Hitachi Works
Tokyo HQ
Akihabara Daibiru

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

**Concept to Reality**

- HITACHI’s IT Technologies Streamline Nuclear Plant Life-long Management

Our Policies

- Execute as planned
- Simulate in advance
- Highest quality and safety
- On schedule/on budget
- Ultimate plant usability;
  - Constructability
  - Operability
  - Maintainability

---

**Plant Engineering Database**

**EPC Project Experience / Project Management Know-How**

Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.
Hitachi has continuously improved its construction technologies since the first BWR Nuclear Power Plant (NPP) construction in the 1970s. Now, Hitachi has 4 main construction strategies. These strategies contribute to Hitachi’s excellent execution of NPP projects.

**Hitachi’s Proven NPP Construction Strategies**

- **1st Generation**
  - Open-Top Construction
  - Modularization with Very Heavy Lift Crane

- **2nd Generation**
  - VHL for Block & Modular Construction
  - Open-Top & Parallel Construction
  - Floor Packaging

- **3rd Generation**
  - Expanded Open-Top & Expanded Block & Modular Construction
  - Front-Loaded Construction Engineering
  - Detailed Schedule Management

- **4th Generation**
  - Advanced Construction Technologies
  - Standardized Modular Construction Method
  - Integrated Construction Management System

- **5th Generation**
  - Composite Module and Block & Module’s Construction
  - Enhanced Design & Engineering
  - Progress Control
  - Real-time Technology for Logistics and Management

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

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

Quality Assurance System

The Manufacture of Nuclear Power Equipment Requires Advanced Technology

Nuclear Power Quality Assurance Activities

Nuclear Power Quality Assurance Committee

- Nuclear Power Project Administration Regulations
- Nuclear Power OCHIBO Committee
- Nuclear Equipment Accident Prevention Committee
- Construction Plant Reliability Activities
- Operation Plant Reliability Activities
- Various Reliability Improvement Activities

Nuclear Power Quality Assurance System

- Hitachi-GE Nuclear Energy, Ltd. Nuclear Systems Quality Assurance Division
- Hitachi-GE Nuclear Energy, Ltd. Hitachi Works
- Hitachi Ltd.
- Power Systems Company
- Thermal Power Systems Division
- Power & Industrial Systems Division
- Infrastructure Systems Company
- Research Institutes
- Related Companies, etc.

PDCA cycle for product realization

Act

Plan

Do

Check

Management review

[Analyses and improvements]

Analysis of accidents and failures

QF Plant Committee

Resource management

QF activities, Quality objectives (business plan)

PDCA cycle for product realization

Act

Plan

Do

Check

QF Plant Committee

QF activities, Quality objectives (business plan)

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.

Important Point

Check for Periodical Inspection / Modification

QF: Quality First

NZD: Nuclear Zero Defect

QMS operation for Plant Delivery

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

Quality Control Activities

Internal Audits

Important Part Check for Periodical Inspection / Modification

Technical Support for Operating Plants

Internal Audits

Research and Development

Design Reviews

Design

Purchasing

Inspection

Inspection

Inspection

Installation

Pre-Operation

Design

Purchasing

Research and Development

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

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 examples)

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Important Point

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QF: Quality First

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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**

**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.

**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**

**Remote Operated Underwater Vehicle (Extraction Type)**

**Remote 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)**

**Remote Repair Technology of RPV Bottom Head Equipment**

Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.
Research and Development

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

Testing
Various tests are performed to confirm performance and quality of nuclear core equipment.

- 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.
Achievements in Nuclear Power Plant Delivery

**Japan**

- The Tokyo Electric Power Co., Inc., Kashiwazaki-Kariwa Nuclear Power Station
  - Unit 4 (’94), Unit 5 (’95), Unit 6 (’96), Unit 7 (’97)
- Hokuriku Electric Power Co., Inc., Shika Nuclear Power Station
  - Unit 1 (’93), Unit 2 (’95)
- The Japan Atomic Power Co., Tsuruga Power Plant I
  - Unit 1 (’88), Unit 2 (’90)
- The Tokyo Electric Power Co., Shimane Nuclear Power Station
  - Unit 1 (’74), Unit 2 (’89), Unit 3 (under construction)
- The Tokyo Electric Power Co., Hamaoka Nuclear Power Station
  - Unit 4 (’76), Unit 2 (’89), Unit 3 (’87), Unit 4 (’93), Unit 5 (’05)
- The Japan Atomic Power Co., Tokai Power Plant 2
  - Unit 1 (’77), Unit 2 (’79), Unit 3 (’87), Unit 4 (’93), Unit 5 (’03)
- Chubu Electric Power Co., Inc., Hamaoka Nuclear Power Station
  - Unit 1 (’76), Unit 4 (’78), Unit 3 (’87), Unit 5 (’93)

**Overseas**

- South Korea
  - Generator replacement
  - Kori
- Europe
  - Core internals
  - Lednaell (’80)
- Pakistan
  - Turbine power generator
  - Karachi (’72)
- Taiwan Region
  - Reactor containment vessel
  - Qinshan II unit 1, 2 (’73, ’74)
  - Reactor containment vessel
  - Qinshan II unit 1, 2 (’73, ’74)
- China
  - Turbine power generation; condenser, moisture separator/heater, etc.
  - Qinshan III unit 1, 2
- Thailand
  - Radioactive Waste Treatment System
  - Onagawa Nuclear Research Center

**History of Hitachi’s Nuclear Power Plant Construction**

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<tr>
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<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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<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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<tr>
<td>Facility Capacity</td>
<td>18,811,000 kWe</td>
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</tbody>
</table>

- **Tsuruga** (The Japan Atomic Power Co.)
- **Fukushima** I (The Tokyo Electric Power Co., Inc.)
- **Shimane** (The Chugoku Electric Power Co., Inc.)
- **Hamakaa** I (Chubu Electric Power Co., Inc.)
- **Kashiwazaki-Kariwa** 7 (The Tokyo Electric Power Co., Inc.)
- **Kashiwazaki-Kariwa** 6 (The Tokyo Electric Power Co., Inc.)
- **Kashiwazaki-Kariwa** 4 (The Tokyo Electric Power Co., Inc.)
- **Shikaa** 1 (Hokuriku Electric Power Co., Inc.)
- **Hamaoka** 4 (Chubu Electric Power Co., Inc.)
- **Shiika** 2 (Hokuriku Electric Power Co., Inc.)
- **Hamakaa** 3 (Chubu Electric Power Co., Inc.)
- **Fukushima** I-4 (The Tokyo Electric Power Co., Inc.)
- **Kashiwazaki-Kariwa** 5 (The Tokyo Electric Power Co., Inc.)
- **Shiika** 3 (Hokuriku Electric Power Co., Inc.)
- **Fukushima** II-4 (The Tokyo Electric Power Co., Inc.)
- **Fukushima** II-2 (The Tokyo Electric Power Co., Inc.)
- **Hamakaa** 2 (Chubu Electric Power Co., Inc.)
- **Kori** (Chubu Electric Power Co., Inc.)
- **Shiika** 1 (Hokuriku Electric Power Co., Inc.)

- **Hitachi** has installed a total of 20 power plants totaling 18,811,000 kWe.

- **Change Over from Imported Reactors to Domestic Reactors**
- **Improvement & Standardization Program**
- **Advanced Boiling Water Reactor**

- **Joint construction project**