Advanced Boiling Water Reactor

The only 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.
## Nuclear Plant Technologies

- Boiling Water Reactor History and Line-UP ........................................... 3
- Advanced Boiling Water Reactor ......................................................... 5
- ABWR Countermeasures Against Fukushima Accident ...................... 9

## ABWR Structure, System and Component

- Reinforced Concrete Containment Vessel (RCCV) ............................. 13
- Reactor Internal Pump (RIP) ............................................................... 15
- Reactor Pressure Vessel (RPV) ......................................................... 17
- Reactor Internals .............................................................................. 19
- Control Rods, Control Rod Drives ................................................. 21
- Nuclear Fuel ................................................................................... 23
- Turbine and Generator .................................................................... 25
- Advanced NUCAMM-90 .................................................................. 27
- ABWR Instrumentation & Control Systems ..................................... 29
- Radioactive Waste Processing Systems .......................................... 31
- Automatic Equipment ..................................................................... 33

## Project Management Organizations

- Organization for Hitachi’s Nuclear Business .................................... 33
- Engineering Technologies ................................................................. 35
- Construction .................................................................................. 37
- Quality Assurance System ............................................................... 39
- Preventive Maintenance .................................................................. 41

## Research and Development

- Research and Development ............................................................... 43

## Achievements

- Hitachi’s Achievements in Nuclear Power ........................................ 45
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.)

BWR-2 ➤ BWR-3,4,5

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.)
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)

The Chugoku Electric Power Co., Inc. Shimane 3

---

**ABWR**

Application of Evolitional Design and Standardization

<table>
<thead>
<tr>
<th>The first and second ABWR in the world (Twin plant)</th>
<th>Succeeding ABWR plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kashiwazaki-Kariwa 6 (Tokyo Electric Power Company Holdings, Inc.)</td>
<td>Hamaoka 5 (Chubu Electric Power Co., Inc.)</td>
</tr>
<tr>
<td>Kashiwazaki-Kariwa 7 (Tokyo Electric Power Company Holdings, Inc.)</td>
<td>Shika 2 (Hokuriku Electric Power Co., Inc.)</td>
</tr>
<tr>
<td></td>
<td>Shimane 3 (The Chugoku Electric Power Co., Inc.)</td>
</tr>
<tr>
<td></td>
<td>Ohma (Electric Power Development Co., Ltd.)</td>
</tr>
<tr>
<td></td>
<td>Higashidori 1 (Tokyo Electric Power Company Holdings, Inc.)</td>
</tr>
</tbody>
</table>
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.
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>
</tr>
<tr>
<td>Reactor Thermal Output</td>
<td>3,926 MWt</td>
<td>3,293 MWt</td>
</tr>
<tr>
<td><strong>Reactor Core</strong></td>
<td></td>
<td></td>
</tr>
<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>
</tr>
<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>
</tr>
<tr>
<td><strong>RHR Containment Vessel</strong></td>
<td>Reinforced concrete with built-in liner</td>
<td>Free-standing vessel</td>
</tr>
<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>
</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>Drain up type</td>
<td>Cascade type</td>
</tr>
</tbody>
</table>

*Residual Heat Removal 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

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

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)

Reference: http://www.tepco.co.jp/nu/1d-np/plan/plan-j.html
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): $1.6 \times 10^{-7}$

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

- **Alternative PCV Spray/SFP Coolant Injection System**
- **Fire fighter truck**
- **Filtered water Storage tank**
- **DG or GTG**

- **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**

- **Enhanced PCV Venting System (COPS)**
- **Backup Building (B/B)**

- **Stack**
- **Filtered Vent**
- **Alternative AC Power Source**

- **DG or GTG**: Diesel Generator or Gas Turbine Generator

**Abbreviations:**
- 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

**Systems:**
- COPS: Containment Overpressure Protection System
- 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 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.
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

**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
- Approx. 12000mm
- 2650mm
- 2700mm
- Plate Hx
- Cooling water
- Pump

**Mobile Equipment**

- Fire Truck
- Power Truck
- Construction Machinery
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℃ for the drywell and 104℃ 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)

MARK II
(BWR-5)

Output power : 780MWe

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

RCCV (ABWR)

RCCV: Reinforced Concrete Containment Vessel

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>
<th></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
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
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

- Head vent & spray nozzle
- Main steam outlet nozzle (with flow limiter)
- Low pressure flooder nozzle
- Low pressure flooder sparger
- High-pressure core flooder nozzle
- High-pressure core flooder sparger
- Top guide
- Fuel assembly
- Internal pump
- Control rod drive mechanism housing
- 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
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>
</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. | ![BWR-5 Steam Separator](image1)  
     ![BWR-5 Shroud Head Bolt](image2)  
     ![BWR-5 Top Guide](image3)  
     Shroud Head  
     Core Spray  
     RPV | ![ABWR Steam Separator](image4)  
     ![ABWR Shroud Head](image5)  
     High Pressure Core Flooder Sparger  
     Top Guide |
| 2   | - Top guide structure was changed from assembly of individual matching plates to one-piece high-structural-strength one-piece machined type. | ![BWR-5 Grid Plate](image6)  
     Assembled Grid Plate Type | ![ABWR Grid Plate](image7)  
     One-piece Grid Plate |
| 3   | - Inner diameter of core shroud has been increased to accommodate a larger number of fuel assemblies.  
     - Top guide and upper shroud are now integral. | ![BWR-5 Upper Shroud](image8)  
     ![BWR-5 Middle Shroud](image9)  
     ![BWR-5 Lower Shroud](image10)  
     Top Guide | Shell (Combined with Guide Plate)  
     Upper Shroud  
     Lower Shroud |
| 4   | - A structure with reinforcing beams and perpendicular reinforcing rods was changed to all reinforcing beams to increase strength. | ![BWR-5 Core Plate](image11)  
     ![BWR-5 Reinforcing Beam](image12)  
     ![BWR-5 Reinforcing Rod](image13) | Core Plate  
     Reinforcing Beam (Perpendicular) |
| 5   | - 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. | ![BWR-5 RPV](image14)  
     Clamps  
     Bellows  
     Shroud  
     Low Pressure Coolant Injection Pipe  
     Top Guide | ![ABWR Low Pressure Flooder Sparger](image15)  
     Top Guide  
     Shroud |
| 6   | Reactor Recirculation System | Jet Pump | Internal Pump |
Control Rods, Control Rod 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™)

※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

GNF2 Low Pressure Drop UTP
GNF2 High Performance Spacer
Defender™
GE14 & GNF2 Defender™ LTP Improved Debris Protection

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
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.

Shimane 3, Nuclear Turbine
Installation of Turbine
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).

![ABWR 60Hz TC6F-52 Turbine](image)

**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.

![Shimane 3, Generator Stator](image)  ![Shimane 3, Nuclear turbine Generator](image)
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 highly reliable products, based on proven design, are leading nuclear technology that enhance 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.
Radioactive Waste Processing Systems

Classification of Radioactive Waste and Process Flow

Gaseous Waste

- Off Gas
-Tank Vent Gas
- LCW
- HCW
- Spent Resin
- L/D, S/D

Solid Waste

- Combustible Waste
- Non-Combustible Waste
- Sludge
- CR/FCB etc...
- Spent Fuel

Liquid Waste

- Concentrated liquid waste
- Filtration (Evaporation)

Waste

- Drum
- Storage

Drum Inspection

- Disposal
- Discharge

LCW: Low Conductivity Waste
HCW: High Conductivity Waste
L/D: Laundry Drain
S/D: Shower Drain
CR: Control Rod
FCB: Fuel Channel Box

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

**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

**Site Bunker Facility**
- **Features**

**Waste Drum Inspection System**
- **Features**
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.
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
- Hitachi Plant Construction, Ltd.
- Global Nuclear Fuel-Japan Co., Ltd.
- BWR Operator Training Center Inc.
- Nippon Nuclear Fuel Development Co., Ltd.
- Hitachi Industrial Equipment Systems Co., Ltd.
  - Fabrication work of nuclear fuel
  - Studies concerning reactor safety analysis, waste treatment, instrumentation, and control

Hitachi Research Laboratory

- Energy and Environmental Systems Research Center
  - Studies concerning reactor safety analysis, waste treatment, instrumentation, and control
- Materials Research Center
- Mechanical Engineering Research Center
  - Development of materials
  - Studies concerning seismic design
Engineering Technologies

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

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

**Construction & Start Up**

**Operation & Maintenance**

**Reactor Decommissioning plan**

**Project Management Know-How**
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

Continuous BWR / ABWR construction for over 40 years!!

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.
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 Control Activities

**Research and Development**
- Design Reviews
- Internal Audits
  - Important Point Check for Periodical Inspection / Modification
  - Technical Support for Operating Plants

**Planning**
- Design Reviews

**Design**
- Design Reviews
- Internal Audits
  - Validation

**Purchasing**
- Internal Audits
  - Overall Construction Inspection

**Manufacture**
- Prior Reviews

**Inspection**
- Prior Reviews

**Pre-Operation**
- Prior Reviews

**Periodical Inspection**
- Design Reviews

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

**Internal Audits**
- Prior Reviews

**Installation**
- Prior Reviews

**Note** NZD: Nuclear Zero Defect, QF: Quality First
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)**
Our highly reliable products, based on proven design, are leading nuclear technology that enhance the safety of nuclear power plants.

**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
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

- 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.

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)

Electric Power Development Co., Ltd., Ohma Nuclear Power Station
(Under construction)

Tokyo Electric Power Company Holdings, Inc.
Higashidori Nuclear Power Station
Unit 1 (Under construction)

Tohoku Electric Power Co., Inc., Onagawa Nuclear Power Station
Unit 3 ('02)

Tokyo Electric Power Company Holdings, Inc.
Fukushima Nuclear Power Station I
Unit 1 ('71), Unit 4 ('78)

Tokyo Electric Power Company Holdings, Inc.
Fukushima Nuclear Power Station II
Unit 2 ('84), Unit 4 ('87)

The Japan Atomic Power Co., Tokai Power Plant 2 ('78)

Chubu Electric Power Co., Inc., Hamaoka Nuclear Power Station
Unit 1 ('76), Unit 2 ('78), (Closed down) Unit 3 ('87), Unit 4 ('93), Unit 5 ('05)

Operating ( ) : Year of commercial operation
 Under construction
 Under decommissioning, Closed down

Overseas

Europe
Core internals
Leibstadt ('80)

Pakistan
Turbine power generator
Karachi ('72)

China
Turbine power generator, condenser, moisture separator/heater, etc.
Chinshan 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)

Operating ( ) : Year of delivery
 Under planning / Construction
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**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(kWe)</td>
<td>20,000,000</td>
<td>15,000,000</td>
<td>10,000,000</td>
<td>5,000,000</td>
<td>0</td>
</tr>
<tr>
<td>Facility Capacity</td>
<td>Change Over from Imported Reactors to Domestic Reactors</td>
<td>Improvement &amp; Standardization Program</td>
<td>Advanced Boiling Water Reactor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Hitachi has installed a total of 20 power plants 18,811,000 kWe**
- **Hamaoka 1** *(Chubu Electric Power Co., Inc.)*
- **Tsuruga 1** *(The Japan Atomic Power Co.)*
- **Fukushima I-1** *(The Tokyo Electric Power Co., Inc.)*
- **Shimane 1** *(The Chugoku Electric Power Co., Inc.)*
- **Hamaoka 1** *(Chubu Electric Power Co., Inc.)*
- **Ohma** *(Electric Power Development Co., Ltd.)*
- **Shimane 3** *(The Chugoku Electric Power Co., Inc.)*
- **Shika 2** *(Hokuriku Electric Power Co., Inc.)*
- **Hamaoka 5** *(Chubu Electric Power Co., Inc.)*
- **Onagawa 3** *(Tohoku Electric Power Co., Inc.)*
- **Kashiwazaki-Kariwa 5** *(Tokyo Electric Power Company Holdings, Inc.)*
- **Kashiwazaki-Kariwa 4** *(Tokyo Electric Power Company Holdings, Inc.)*
- **Kashiwazaki-Kariwa 6** *(Tokyo Electric Power Company Holdings, Inc.)*
- **Kashiwazaki-Kariwa 7** *(Tokyo Electric Power Company Holdings, Inc.)*
- **Hamaoka 4** *(Chubu Electric Power Co., Inc.)*
- **Shika 1** *(Hokuriku Electric Power Co., Inc.)*
- **Shimane 2** *(The Chugoku Electric Power Co., Inc.)*
- **Kashiwazaki-Kariwa 3** *(Tokyo Electric Power Company Holdings, Inc.)*
- **Hamaoka 3** *(Chubu Electric Power Co., Inc.)*
- **Kashiwazaki-Kariwa 2** *(The Japan Atomic Power Co.)*
- **Hamaoka 2** *(Chubu Electric Power Co., Inc.)*
- **Tokai II** *(The Japan Atomic Power Co.)*
- **Fukushima I-4** *(Tokyo Electric Power Company Holdings, Inc.)*
- **Fukushima II-3** *(Tokyo Electric Power Company Holdings, Inc.)*
- **Fukushima II-2** *(Tokyo Electric Power Company Holdings, Inc.)*
- **Kashiwazaki-Kariwa 1** *(Kansai Electric Power Co., Inc.)*

* : Joint construction project