Hitachi's Work on Restarting Nuclear Power Plants

The achievement of carbon neutrality, which involves reducing carbon dioxide emissions to virtually zero as a measure against global warming, is recognized as a challenge facing the entire world. Furthermore, as energy markets are significantly destabilized due to the current international situation, the restarting of nuclear power plants as a means of dealing with these types of problems has become a priority within Japan. To contribute to carbon neutrality and the stable supply of electric power, Hitachi is strengthening its efforts towards restarting nuclear power plants while working to supply nuclear power systems that comply with new regulatory standards that offer the highest level of safety in the world. This article discusses Hitachi's efforts towards enhancing the safety of nuclear power plants before they are restarted, as well as the safety measures and construction technologies Hitachi is implementing to achieve the actual restart.

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1. Introduction

As the international movement towards decarbonation proceeds with a goal of carbon neutrality, while energy markets are destabilized by Russia's invasion of Ukraine, the restarting of nuclear power plants within Japan that can contribute to the achievement of a stable supply of electricity along with carbon neutrality has become a vital domestic issue as well.

Based on the lessons learned after the Fukushima Daiichi Nuclear Power Station accident, Hitachi has formulated a basic policy for boiling water reactor (BWR) plant safety measures while promoting the development of safety enhancement technology to further increase the margin of safety at nuclear power plants.[(1), (2)] At present, to successfully restart nuclear power plants, Hitachi is supporting compliance inspections based on new regulatory standards and conducted by electric power utilities, while promoting the adoption of safety equipment by nuclear power plants.

This article describes the safety measures Hitachi has worked to develop to facilitate the restarting of nuclear power plants, as well as the safety measures and construction technologies used to quickly implement safety equipment.

2. Installation of Safety Equipment to Enable Restarting

2. 1 Overview of Safety Equipment

This section provides an overview of the design basis accident response equipment and major accident response equipment Hitachi is promoting deployment of to further improve margins of safety at nuclear power plants, which will enable them to comply with the regulatory standards necessary for restarting nuclear power plants.

In addition to the development and design of this equipment, Hitachi also uses analytical techniques such as accident progress analysis to evaluate effectiveness and confirm that the equipment can function in such a way as to maintain safety even during an accident.

(1) Design basis accident response equipment

Hitachi has installed various types of equipment to handle a wide range of design basis events [internal fire, internal overflow, external incident (earthquake, tsunami, tornado, etc.)] to maintain the safety of a nuclear power plant in the event of a design basis accident. **Table 1** shows the main enhancements adopted.

(2) Response equipment for major accidents and other incidents

Hitachi is developing safety enhancement technology and designing equipment and systems with the goal of preventing severe core damage or damage to the containment vessel even if a major accident or other such incident occurs, and is working to install this in actual facilities. **Table 2** shows the main equipment used as safety countermeasures.

2. 2 Development of Safety Enhancement Technology

This section provides the details of the safety enhancement technology that Hitachi is applying in its safety equipment.

(1) Molten debris cooling system

If molten core fuel (molten debris) damages the reactor pressure vessel during a major accident and drops to the lower part of the containment vessel, it might corrode the concrete of the containment vessel floor, causing the loss of the containment vessel's boundary function. This equipment adopts material with a high level of thermostability that, when combined with equipment that pours water into the lower part of the containment vessel, prevents molten debris from coming into contact with the containment vessel boundary, thereby serving the purpose of maintaining the boundary function.

Two representative methods developed based on the characteristics of the containment vessel type are described below.

The sump protection system[3] is a molten debris cooling system for the containment vessel structure where the sump is located in the lower part of the containment vessel. Even if molten debris falls to the floor of the containment vessel, this structure will still protect the sump from the molten debris. The floor construction system is equipment for containment vessel structures with the sump installed outside of the pedestal that supports the reactor pressure vessel. Heat-resistant material is laid on the containment vessel floor to prevent the corrosion of the floor's concrete (see **Figure 1**). With either system, the channel leading to the sump is used to detect reactor coolant leakage during ordinary operation. This channel structure utilizes a solidification evaluation model based on experimental knowledge, and is designed with a slit shape and channel area that blocks the inflow of molten debris into the sump by solidifying it within the channel.

Table 1 — Strengthening Design Basis Accident Response Equipment

The following measures are aimed at securing safety in the event of a major design basis event (earthquake, internal fire, or internal overflow).

Measure	Strengthening details
Earthquake measures	• Seismic strengthening such as construction of additional supports • Distribution of portable equipment • Confirmation of tolerance through vibration testing
Internal fire measures	• Use of fire-resistant and incombustible materials • Installation of fire detection equipment • Installation of fire extinguishing equipment • Protection of sections with fireproofing walls, etc.
Internal overflow measures	• Installation of watertight doors • Installation of weirs • Installation of leakage detectors, etc.

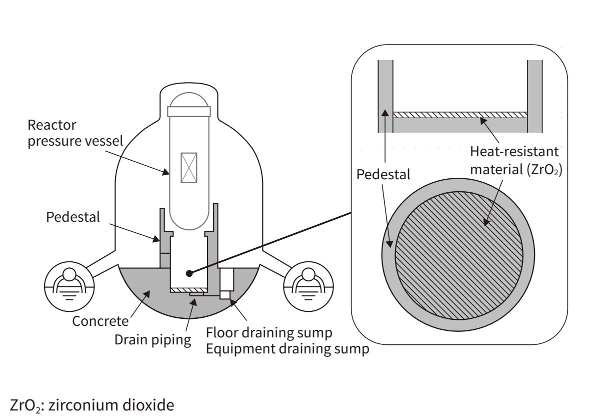
Table 2 — Overview of Equipment for Responding to Incidents Such as Major Accidents

This table lists the major safety equipment that should be introduced in the event of a major accident or similar incident to prevent major core damage and containment vessel damage, and to suppress the emission of radioactive substances.

Function	Major Safety Measure Equipment
Nuclear reactor cooling	• Alternative high-pressure water injection equipment • Alternative low-pressure water injection equipment • Decompression function enhancement equipment, etc.
Containment vessel damage prevention	• Containment vessel spraying equipment • Alternative nuclear reactor accessory cooling water equipment • Filter venting equipment • Water injection equipment in lower part of containment vessel • Molten debris cooling equipment, etc.
Damage prevention for nuclear reactor building, etc.	• Nuclear reactor building hydrotreating equipment • Hydrogen density monitoring equipment, etc.
Reduction of operator exposure	• Blow-out panel closing device, etc.

Figure 1 — Schematic Diagram of Molten Debris Cooling Equipment (Floor Construction System)

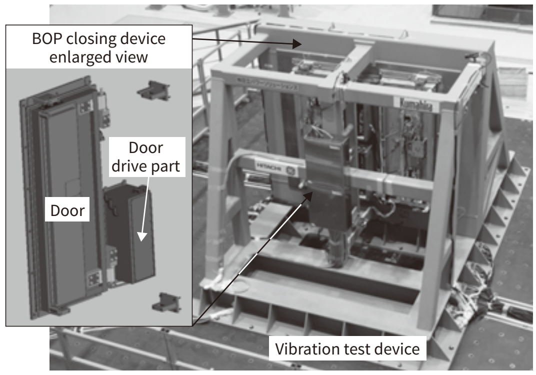
The containment vessel boundary is protected from molten debris through the adoption of heat-resistant material (ZrO_2) combined with the use of water injection equipment in the lower part of the containment vessel.



ZrO_2: zirconium dioxide

Figure 3 — Vibration Test of Side-opening BOP Closing Device

Retention of earthquake proof functionality was confirmed using a full-scale vibration test set with vibrating conditions far in excess of those that occurred during the Great East Japan Earthquake.



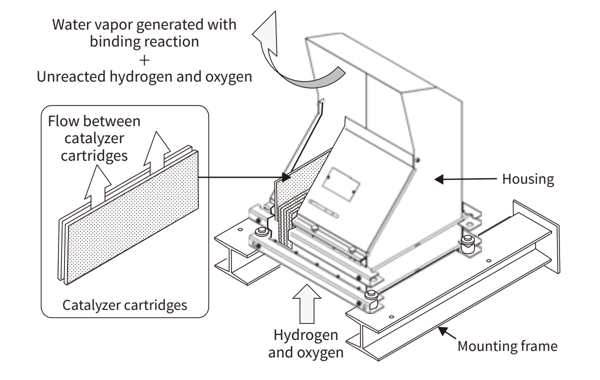
BOP: blow-out panel

(2) Hydrotreating equipment in the nuclear reactor building

Although the hydrogen gas that is generated as core damage progresses during a major accident is retained inside the containment vessel, as pressure increases inside the containment vessel, the gas may leak into the reactor building through the containment vessel's flange or other parts. One of the countermeasures to prevent leaked hydrogen from exploding inside the reactor building is the installation of a passive autocatalytic recombiner (PAR) (see **Figure 2**). A PAR is a device that recombines and passively hydrotreats combustible gas (hydrogen and oxygen gas) using a catalytic reaction, and which is designed to require no start-up operation by the operator or power supply. The locations for installing PAR devices are selected using three-dimensional flow analysis technology to identify suitable locations where sufficient hydrotreating performance can be achieved.

Figure 2 — Passive Autocatalytic Recombiner

A passive autocatalytic recombiner (PAR) is comprised of a housing and catalyzer cartridges, and causes a binding reaction in the combustible gas (hydrogen and oxygen) that flows in from the bottom due to natural circulation using each catalyzer cartridge's catalyzer (palladium) layer, in a structure that causes the resulting water vapor to be emitted from a port at the top.



(3) Blow-out panel closing device

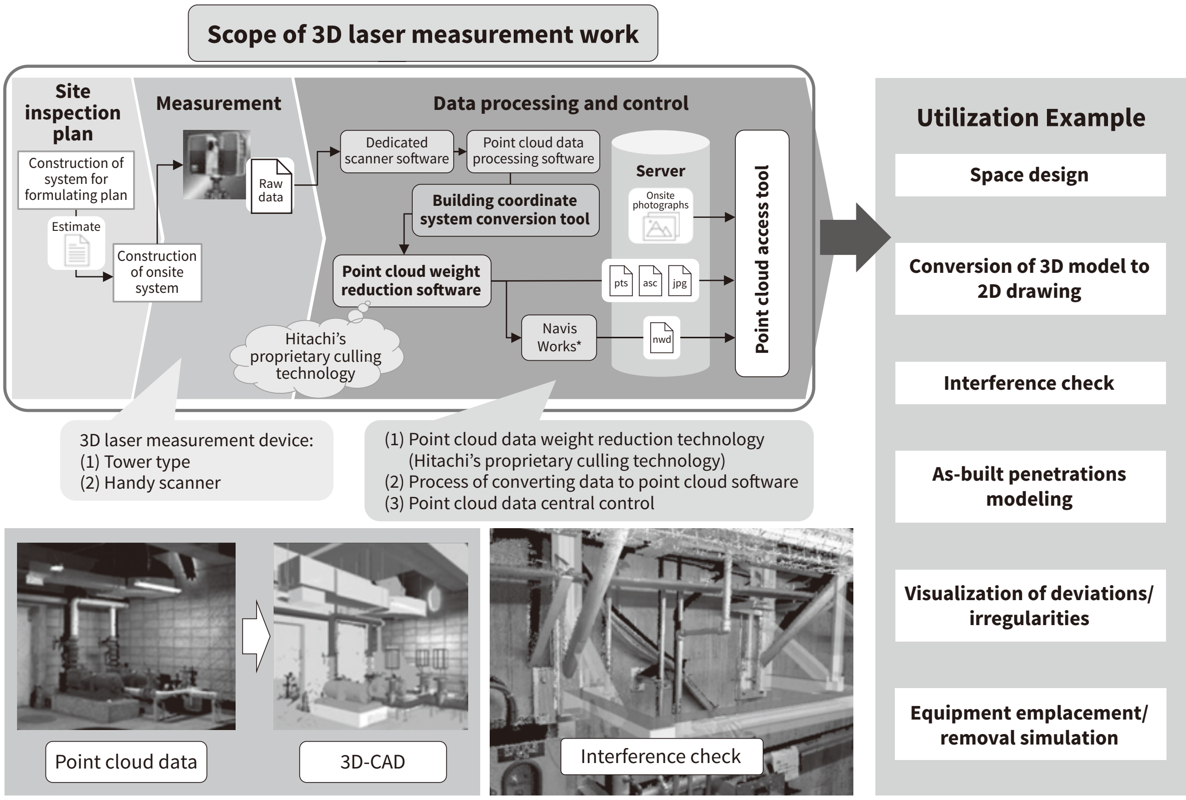
Blow-out panels (BOP) are installed as a pressure release mechanism to reduce pressure and temperature inside a reactor building in case of an accident at a nuclear power plant. On the other hand, the aperture part of an opened BOP may also become a conduit for the discharge of radioactive materials if a severe accident occurs. Therefore, to reduce the risk of explosion to operators during a severe accident, a BOP closing device was developed that can be closed quickly and maintains its closing functionality even during the motion caused by an earthquake.

Hitachi is developing both sliding and side-opening BOP closing devices, both can be installed according to the structure of the particular nuclear reactor building. After a BOP is opened, operators can use a mechanism to shut the BOP with an electric motor. Sliding BOP closing devices are large, motorized doors 5 m in size that can close an opened BOP using a single device. Side-opening BOP closing devices has a compact form and is designed to be suitable for use with various different BOP shapes by combining multiple devices.

Both sliding and side-opening closure devices were subjected to actual-size vibration tests in a vibration test facility, and the retention of earthquake-proof functionality was confirmed even in the case of an earthquake stronger than the Great East Japan Earthquake. Furthermore, an air leakage test was conducted after the vibration test to confirm airtightness that exceeds what is required by standards (see **Figure 3**). Also, to confirm the soundness of the side-opening BOP closing device's functionality during an accident and to improve the dependability of functions, Hitachi is confirming operations by conducting tests in a simulated environment that exposes the device to conditions such as radiation, high temperature, and high humidity.

Figure 4 — Process for Utilizing Point Cloud Data from 3D Laser Measurement Technology

By utilizing 3D laser measurement technology to collect point cloud data onsite and managing it with dedicated tools, not only is it possible to apply the technology to design work, but applications can also be expanded to construction planning and other tasks as well.



3D: three dimensional 2D: two dimensional CAD: computer-aided design

* Navisworks is a registered trademark or trademark of Autodesk, Inc. and/or its subsidiaries and/or affiliated companies in the United States and/or other countries.

3. Safety Measure Construction Technology

This section describes Hitachi's efforts towards streamlining the construction of safety measures utilizing three-dimensional (3D) laser measurement technology that it is developing as a means of quickly introducing large-scale safety equipment into nuclear power plants.

3. 1 Developing a Point Cloud Data Platform through 3D Laser Measurement Technology

Hitachi is utilizing point cloud data acquired using 3D laser measurement technology as part of nuclear power plant engineering, procurement, and construction (EPC) work to measure dimensions, produce three-dimensional computer-aided design (3D-CAD) data, and create working drawings for purposes such as constructing a new piping route onsite. To this end, Hitachi also developed a point cloud access tool to serve as infrastructure for the cross-sectional sharing of point cloud data between design departments. These tools manage multiple point cloud data formats on a centralized server while supporting the diverse usage patterns of different users with dedicated viewers and functions that link with external tools. Also, to enable users to utilize large amounts of point cloud data, the tools achieve faster processing through techniques that cull data, leaving valid data behind, and also enhance the interface. **Figure 4** shows the process for utilizing point cloud data using 3D laser measurement technology, and **Table 3** provides examples of how to utilize the data.

3. 2 Application to the Study of Streamlining Safety Measure Construction

As part of the process of preparing to restart nuclear power plants, Hitachi is proceeding with the installation of the various types of safety equipment described in the previous section in actual plants. During this safety measure construction period, it is also necessary to conduct a wide range of different conversion work in parallel, including the piping of equipment within the nuclear power plant, air conditioning, electricity, instrumentation, seismic strengthening, fireproofing, and so on. Temporary equipment used in the conversion work such as scaffolding, material storage

Table 3 — Examples of Utilizing 3D Laser Measurement Data

It is possible to utilize onsite information as point cloud data for use in a variety of different design and construction tasks.

Utilization Example	
Taking measurements for space design	Taking measurements on desktop and conducting site inspection
Converting 3D models into 2D drawings	Modeling for considering the relocation or addition of supports
Data for checking interference	Confirming interference with plan piping (CAD)
Visualization of deviations/irregularities	Measurement of complicated equipment shapes
As-built penetrations modeling	As-built display of penetration information
Simulation of equipment emplacement/removal	Interference confirmation and routing plan for transport

areas, temporary power supplies, and welding machines are also arranged around the inside of the power plant, and the layout information for locations of related equipment changes every day while construction proceeds.

To conduct this safety measure construction work safely and smoothly, it is extremely important to check for interference and plan routes according to the state of the power plant equipment so as to identify equipment that may interfere with the equipment delivery route and to formulate plans to avoid interference. Not only does this make it possible to smoothly transport equipment both in and out of the plant, but also to prevent damage to existing and newly delivered equipment due to collisions during movement.

This section introduces a study on the streamlining of a construction plan utilizing 3D laser measurement technology, based on the concrete example of an interference confirmation and routing plan for equipment loading/unloading as part of the installation of new panels.

The following six tasks must be performed to formulate an interference confirmation and routing plan before panel update construction can begin.

(1) Confirm the shape of panels to update from the drawings and specifications.

(2) Inspect the sites under consideration for the panel loading/unloading route.

(3) Identify potential obstacles and create a list of this equipment. Issue a request to the relevant design department and ask them to consider plans for avoiding interference.

(4) Inspect the sites to facilitate the relevant design department's consideration of plans for avoiding interference.

(5) Have the relevant design department create, summarize, and list interference avoidance plans based on its considerations, and reflect this in the construction plans and work drawings.

(6) If there is interfering equipment that cannot be avoided, adjust the panel specifications to enable the main panels to be brought in separately and assembled.

Since these tasks are greatly affected by backtracking work caused by situations such as when a site cannot be investigated due to other conversion work or the power plant operation plan, or by delayed confirmation of whether or not interference can be avoided, they entail a risk of drawing out the construction process. Also, since onsite inspections are mandatory, there are risks such as radiation exposure during inspections of controlled areas and construction accidents during onsite inspections.

Utilizing point cloud data from 3D laser measurement technology here enables advanced information control, and is thought to help streamline the interference confirmation and routing plan as shown in **Table 4** by shortening schedules while improving work safety. At present, the application of 3D laser measurement technology is still in the demonstration and experimentation stage, and its effectiveness as a utilized technology is being confirmed. Hitachi plans to incorporate 3D laser measurements into actual work on a trial basis in the future, and to promote further efforts towards the streamlining of safety measure construction work.

Table 4 — Effectiveness of 3D Laser Measurement Technology

Expected effects include shortening of work schedules, advanced information management, and improvements in work safety.

Shortening of work schedules	• Reduced onsite measurement work and shortened onsite inspection time • Transport routes can be simulated based on the latest information (simplifying modification and reconsideration of dimensions and routes)
Advanced information management	• By inputting removal conditions based on the onsite as-built environment (work area, removed object dimensions, truck height, and so on), it is possible to confirm the line of flow of removed objects (bird's-eye view or immersed) • Confirming subject equipment, attributes, positions, and scopes as digital data by utilizing vector data information extracted from point cloud data/CAD model/working drawings • Combined management of latest area information prevents omission during summary for interfering object countermeasure proposals
Improved work safety	• By reducing the amount of onsite work, it is possible to reduce the risk of construction disaster or exposure in the management sector • Simplifies the sharing of information related to the removal route procedures among onsite work instructors and workers

4. Conclusions

The restart of nuclear power plants is an extremely important option for securing a stable domestic supply of electric power while achieving a decarbonized society. Not only does the technology introduced in this article comply with the regulatory standards of nuclear power plants, but it can also greatly contribute to the enhancement of safety and shows promise as a way of safely and smoothly constructing safety measures.

Hitachi will continue to contribute to ensuring a stable supply of electricity and achieving carbon neutrality through its efforts to restart nuclear power plants.

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