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Design and Construction of Hamaoka Unit 5, 1380MWe ABWR

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Chubu Electric Power Co., Inc. is now constructing Hamaoka Unit 5, 1380MWe, the third Advanced Boiling Water Reactor (ABWR) in Japan. Unit 5 is scheduled to start commercial operation in January 2005. This paper is to explain design features and construction methods applied to Unit 5. The design of Hamaoka Unit 5 is basically the same as the preceding ABWRs, Kashiwazaki-Kariwa Unit 6 and 7 of Tokyo Electric Power Co. However some modifications and improvements had been made according to site specific condition, operating experience of ABWR, and recent technology developments.

KEYWORDS:ABWR, FMCRD, debris filter, SCC, construction method

I. Introduction

Chubu Electric Power company owns and operates four BWR plants, Hamaoka Unit 1 through 4, with total generation capacity of 3617 MWe which consists of 15 % of Chubu's generation capacity.

Chubu is now constructing Hamaoka Unit 5 which is the third ABWR plant in Japan. Design features and construction methods of Unit 5 are described below.

II. Outline of Hamaoka Unit-5 construction project

1. Plot plan of Hamaoka Unit-5

The layout and plot plan of Hamaoka Nuclear Power Station is shown in **Fig. 1**.

Figure 2 is the picture of Hamaoka Nuclear Power Station.

Unit 5 is located between Unit 4 and the east boundary of the site. Reactor building, Auxiliary building, and Heat Exchanger building stand along the coastline. Turbine building is at the north (land side) of Reactor building.

Cooling water is taken from deep sea through the water intake tower located 600m off shore. Cooling water pumps are laid on the intake pond and undersea tunnel connects the intake tower and the intake pond. Cooling water discharge is from the coastline.

Fig. 2 Birds eye view of Hamaoka Nuclear Power Station

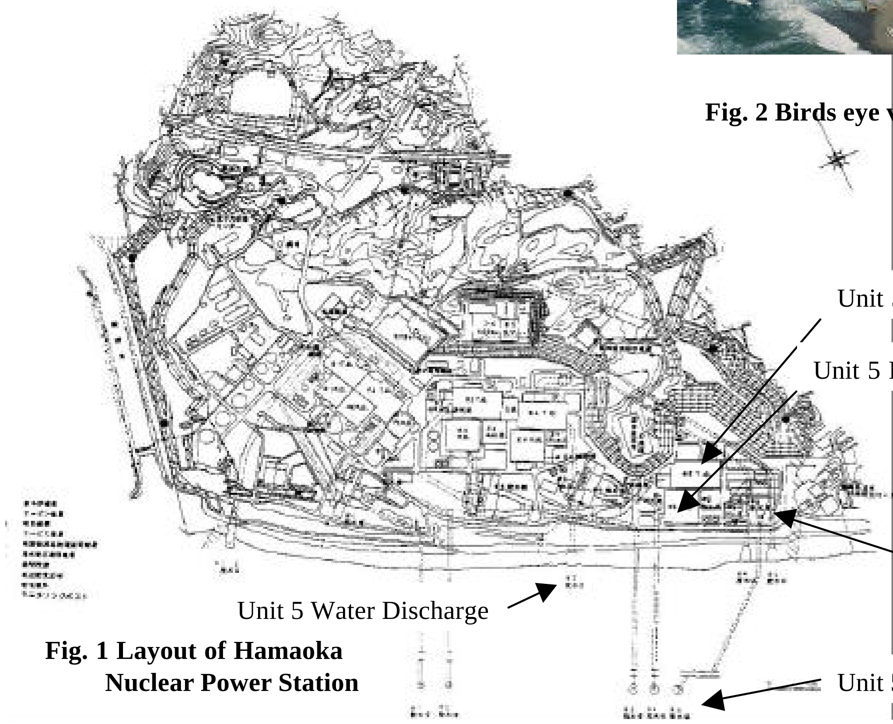

Fig. 1 Layout of Hamaoka Nuclear Power Station

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2. Basic design specification of Hamaoka Unit 5

The basic design specification of Hamaoka Unit 5 is shown in **Table 1** with comparison to conventional BWR, Unit 4.

The design of Hamaoka Unit 5 is basically the same as that of preceding ABWR, Kashiwazaki-Kariwa Unit 6 and 7 (K-6/7) of Tokyo Electric Power Co., with special features such as Reactor Internal Pump (RIP), Fine Motion Control Rod Drive (FMCRD), and Reinforced Concrete Containment Vessel (RCCV).

However some modifications and improvements had been made according to specific conditions of the site, operating experience of ABWR, and recent technology developments.

Although reactor thermal output of 3926MWt is the same as the preceding ABWR, electricity output of Unit 5 is increased from 1356 MWe to 1380 MWe by applying high efficiency turbine blade and other efficiency improvement measures.

Table 1 Basic design specification of Hamaoka Unit 5

	Hamaoka Unit 5	Hamaoka Unit 4
Reactor Type Thermal power	ABWR 3926MWt	BWR-5 3293MWt
Electricity output	1380MWe	1137MWe
Nuclear Fuel Average enrichment Amount of Uranium Discharge burn up	9×9 (zirconium liner) First loading: 3.4wt% Reloading: 3.7wt% 151MTU(872assemblies) First loading: 38GWd/t Reloading: 45GWd/t	8×8 (zirconium liner) First loading: 2.2wt% Reloading: 3.4 wt% 131MTU(764assemblies) First loading: 23GWd/t Reloading: 39.5GWd/t
Coolant Re-circulation System	10 Internal Pumps (RIP)	2 External Re-circulation Pumps & 20 Jet Pumps
Control Rod Drive Mechanism	Normal: Motor driven Scram: Hydraulic (FMCRD)	Normal: Hydraulic Scram: Hydraulic
Primary Containment Vessel	Reinforced Concrete CV with Liner (RCCV)	Self Standing Steel CV
Steam Turbine Type Rated Speed	Tandem Compound Reheat Type with Six Exhaust Flows 1800 rpm	Tandem Compound Reheat Type with Six Exhaust Flows 1800 rpm
Generator Capacity	1570 MVA	1280 MVA
Switch Yard Station	500kV	500kV
Transmission Lines	500 kV, 4 Lines	500 kV, 4 Lines

III. Design features of Hamaoka Unit-5

Examples of modifications and improvements made on Unit 5 are as follows.

1. Reactor system

(1) Seal-less Fine Motion Control Rod Drive (S-FMCRD)

In FMCRD, normal rod positioning function is provided by electric motor and ball spindle, whereas rapid shut down is achieved by hydraulic means. Thus, means of control rod operation is diversified.

Aiming further improvement in reliability and also cost reduction, Seal-less FMCRD (S-FMCRD) had been developed[1)] **(Fig. 3**). Major modifications applied in S-FMCRD are as follows..

-Application of magnet coupling to eliminate driving shaft penetration through reactor pressure boundary. This improves reliability of the pressure boundary.

-Adoption of induction motor with magnetic contactor drive in place of stepping motor with inverter to simplify power supply system.

S-FMCRD had been developed and verified by the joint study of Japanese BWR operating utilities and vendors. Hamaoka Unit 5 is the first to adopt it. Before manufacturing S-FMCRD for Unit 5, various tests are conducted to verify its design. Examples of these tests are as follows.

- operational function tests(continuous motion, step motion, scram function)
- confirmation of no significant effect of magnetic field to the surrounding equipment
- confirmation of stopping characteristics when brakes do not work
- disassembly and inspection of S-FMCRD after various tests

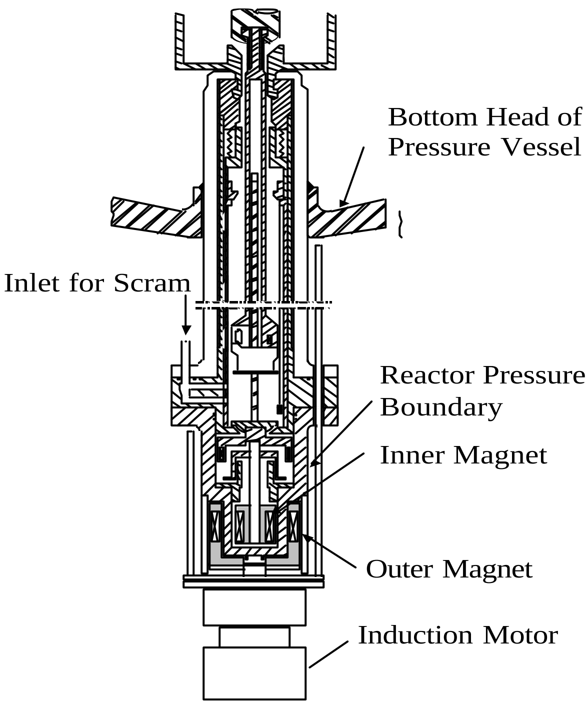


Fig. 3 Seal-less FMCRD

(2) Fuel support with debris filter

Several incidents of fuel leak had been reported concerning preceding ABWR. One of the reasons of fuel leak is believed to be due to the wire brush type debris brought into the reactor vessel during construction or maintenance work.

As to reduction of debris induced fuel leak, fuel assembly with debris filter is available and is utilized in many BWR plants in the world. But this type of filter has the straight hole and thus does not eliminate the whole risk associated with debris. In order to eliminate the risk of debris induced fuel leak, new type of fuel support with debris filters attached at the place of core support orifice was developed. **Figure 4** shows the outlook of the fuel support with debris filters. As shown in the cross section of the filter in figure-4, flow path bends 120 degree within the filter block and thus traps any wire type debris.

In order to make the pressure loss coefficient equal to that of current core support orifice, high pressure and high temperature flow tests were conducted and the number of the filter hole is determined.

Fig.-4 Fuel support with debris filter

(3) Countermeasures against Stress Corrosion Cracking of core internals

In addition to using low carbon stainless steel such as SUS316L as a countermeasure against SCC, residual surface stress reduction measures are applied to the welding part of core internals. Recent incidents of SCC found in SUS316L core internals and primary loop recirculation piping in many Japanese BWR plants indicate that when cold work is applied on surface, SUS316L may not be tough enough against SCC as usually believed to be .

Application of surface stress reduction will reduce the risk of SCC by converting residual surface tensile stress to compressive stress. Peening or polishing is applied as the means of stress reduction depending on dimensions and types of welding.

In addition to SUS316L components, peening is also applied to INCONEL core internals weldings.

Figure 5 shows the areas of core internals where residual stress treatment is applied.

Effectiveness of peening and polishing had already been verified by the joint study of BWR utilities and vendors of Japan.[2)] Prior to the actual application of peening to Unit 5, experimental peening and various tests such as measurement of surface residual stress and hardness, metallography examination, and SCC tests were conducted to confirm its effectiveness.

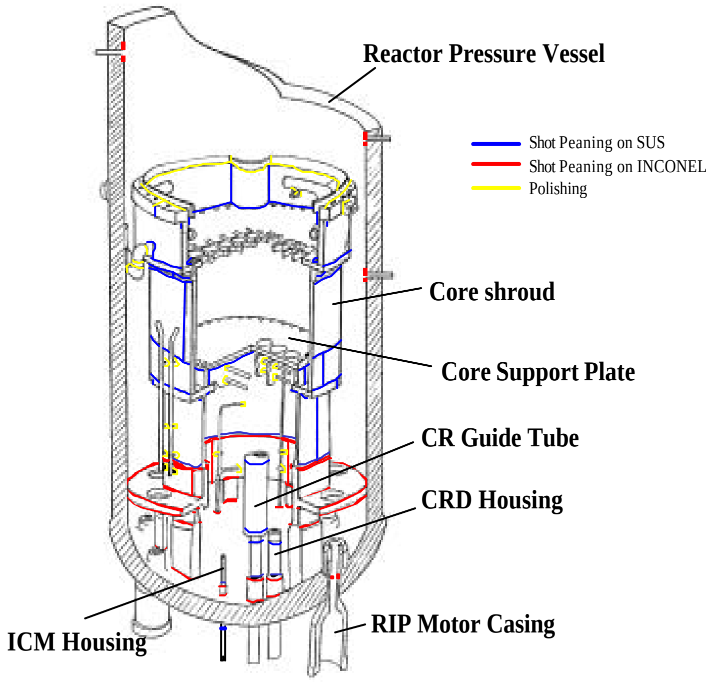


Fig. 5 Residual stress treatment of core internals

2. Turbine system

(1) Extension of electricity output by using high efficiency turbine blade and other efficiency improvement measures

Electrical output of Unit 5 is increased from 1356MWe of preceding ABWR to 1380MWe by applying high efficiency turbine blade and other efficiency improvement measures (**Fig. 6**).

Examples of these measures are as follows.

-Although the length of turbine rotor blade of 52 1nches is the same as preceding ABWR, the blade shape is modified to improve rotating power.

-Turbine exhaust chamber dimensions are modified to reduce energy loss associated with exhaust flow.

-Reduction of the leakage loss at turbine internal seals.

All these measures combined, 24MWe increase of electricity output was achieved.

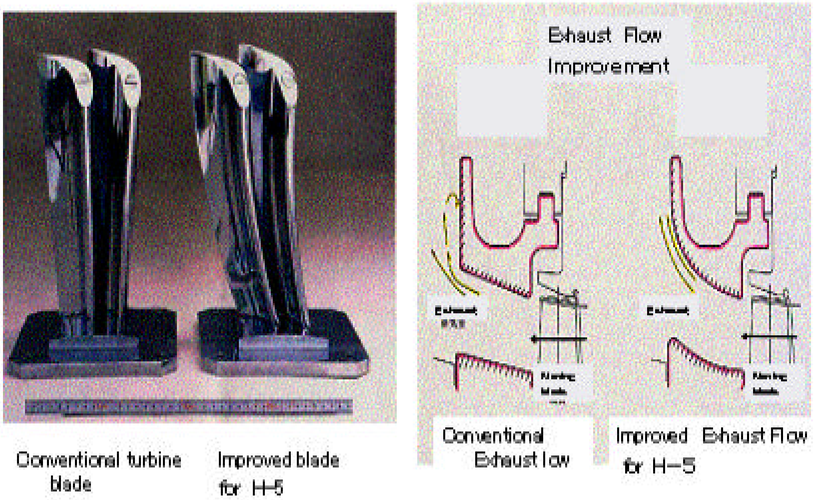


Fig. 6 Turbine efficiency improvement

3. Electric system, Instrument and control system

(1) Control Room design

Main control room of nuclear power plant is not only important for safe operation of the plant but also is useful in promoting public acceptance of nuclear power when it is shown properly to the visitor. In order to achieve this purpose the main control room of Unit 5 is given a high ceiling (ceiling height: about 5 meters) room design to allow a gallery room located in backside middle upper floor which offers visitors good view of the control room.

In developing control room design, psychological and physiological influence of such high ceiling control room to the operators was studied. Based on this study the concept for this type of control room was established as: a room giving a moderate tension to operators and also harmonized with "open", "familiar", "safe", "tensional" and "tireless" senses considering operators' view. [3)]

The features are as follows.

- Moderate tension : Cold color deep blue is used for a floor. The color of the floor near side walls is changed to light blue, which shows straight boundary.

-More open : A round surface is applied to a ceiling to produce space spreading toward the ceiling.

-Safe and familiar : Neutral color beige is used for side upper walls and a ceiling. Indirect lighting is adopted for both the side wall cutback and the front wall upper part.

-Tireless : Tile carpet is used for a floor to reduce walking sound and tiredness.

Figure 7 shows computer graphic image of the main control room view from the gallery room of Unit 5.

Fig. 7 Computer graphic image of the Main Control Room view from Gallery Room

(2) Simplified Reactor Internal Pump(RIP) power supply

RIP is driven by electric Adjustable Speed Drive(ASD). In Unit 5 simplified RIP power supply is adopted. "Simplified" means multi drive, i.e. one ASD drives two or three RIPs instead of one in preceding ABWR design. Therefore RIP power supply is composed of four ASDs. (**Fig. 8**).

Because transient analysis concerning RIP system is based on bus failure, the number of RIP postulated to trip in transient analysis remains the same and therefore there is no effect on plant safety analysis by this modification.

In developing large capacity ASD, design verification is conducted at various design and manufacturing stage. Verification is mainly concerning on the applicability of large scale ASD with water-cooling system and also on the control characteristics of ASD when driving multiple RIP.

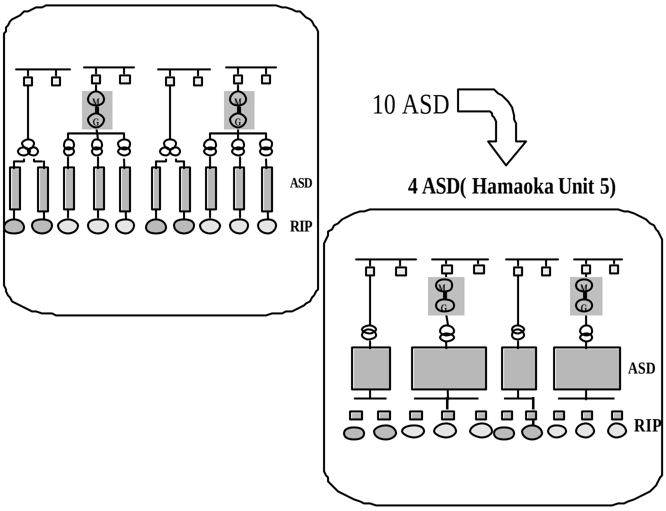


Fig. 8 RIP power supply system

4. Reactor Building aseismic design

The design basis earthquake of Hamaoka site is the largest among nuclear power plants in Japan Hamaoka is located in the area where earthquake of Magnitude 8 class occurs every 100 to 150 years. Hamaoka Unit 1 through Unit 5 are all designed and constructed to withstand this severe earthquake condition.

One of seismic design features adopted in Hamaoka is the combined type reactor building in which reactor building is surrounded by reactor auxiliary equipment building (**Fig. 9**). In combined type reactor building the mass center is lowered and thus seismic capability is improved.

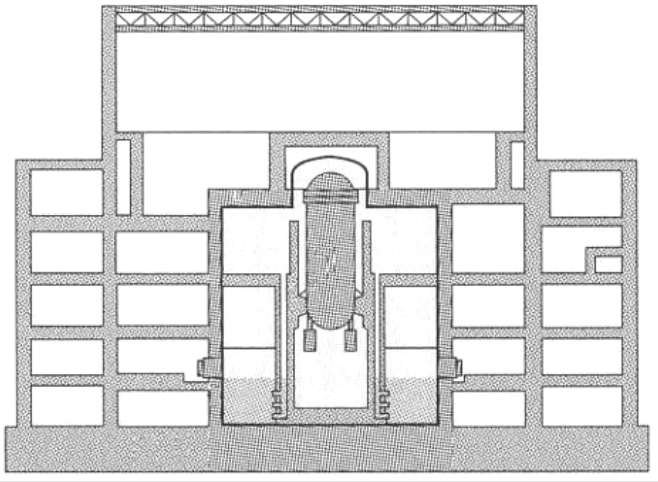


Fig. 9 Combined type Reactor Building

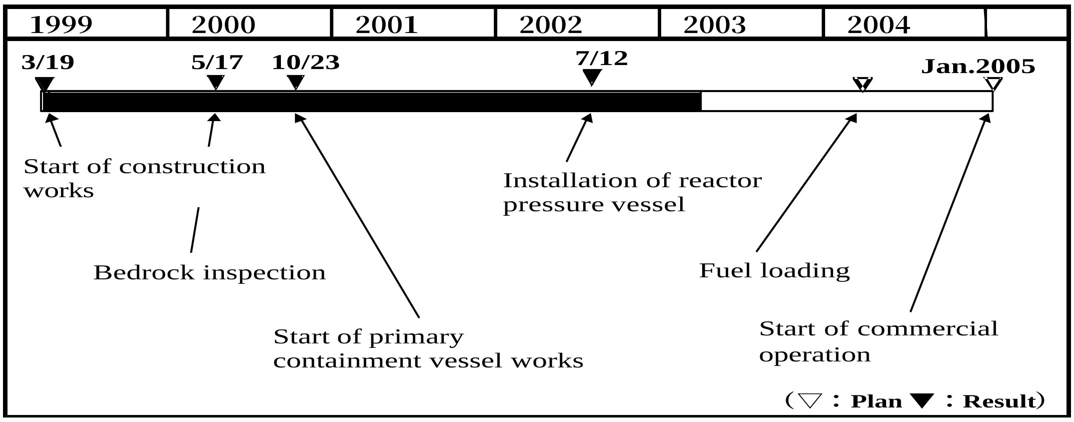
IV. Construction Methods

1. Construction schedule

Construction schedule of Unit 5 is shown in **Fig. 10**.

Construction period is planned as 55 months from the bedrock inspection in May 2000 to the start of commercial operation in January 2005. About 83% of the total construction work has been completed as of May 2003.

In order to improve quality and also reduce construction cost, various construction methods have been applied as described in the following.



Percentage of Completion : 83.4%(as of May 31 2003)

Fig. 10 Construction schedule of Hamaoka Unit 5

2. Construction methods

(1) Utilization of CAD to the planning and scheduling of construction work

In Unit 5 project, 3D-CAD is not only fully utilized in equipment layout design but it is also widely used in planning and scheduling of construction work from the early stage of the project. The data is also shared with civil company to coordinate mutual interface. Trough this pre-engineering, construction procedures and schedules are optimized, rework at the site can be minimized and also temporary construction equipment such as scaffolds can be shared with civil companies. **Fig. 11** shows an example of 3D-CAD simulation used in construction planning.

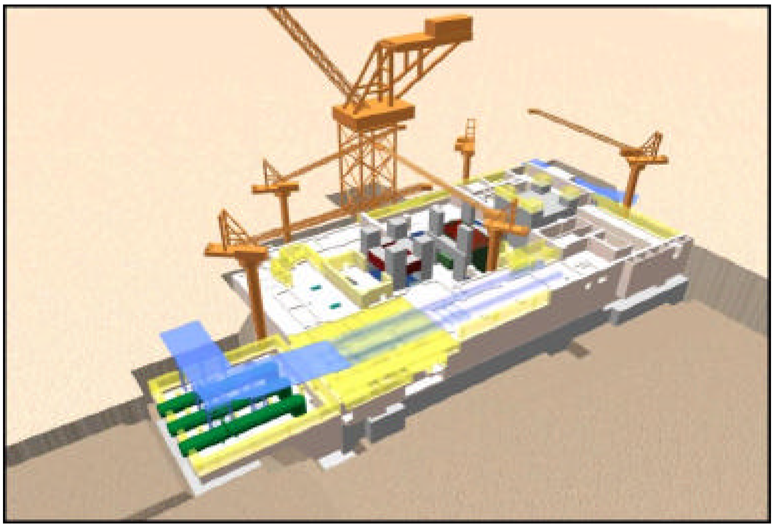


Fig. 11 Example of 3D-CAD simulation of construction sequence

(2) Expansion of large block construction method

The use of large block construction method is effective in reducing manpower of fieldwork. Therefore large block application had been fully expanded in the past construction project depending on the technology available. In Unit 5, large block method is applied on 20% more equipment than in Unit 4.

Figure 12 shows an example of large condenser block applied for the first time at Unit5. In conventional construction method condenser is built into a structure nearby and pulled into turbine building. Application of high tension steel to the condenser body made it possible to have hot-well and lower condenser structure manufactured in the factory and put into the place in one large block.

Fig. 12 Large block construction method applied on condenser

(3) Expansion of module construction method

In module construction method equipments and piping in certain area or a room is assembled as a module at the factory and put into place in site before construction work of upper floor starts. In the construction of Unit 4 in early '90s, this method was used in limited area (about 20%). In Unit 5, deck plate method is applied to about 60% floors and thus module installation is more widely adopted **Fig. 13** shows the example of the module.

Module planning begins in early engineering stage with the use of 3D-CAD system extensively so that module design could be integrated into the overall layout design.

Fig. 13 Module construction method

V. Conclusion

Hamaoka Unit 5 is now at the final stage of equipment installation work. Fuel loading and startup operation will begin in April 2004 and start up operation is planned to continue for nine months before commercial operation starts in January 2005. Newly designed items will be fully tested and verified during the start up operation.

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