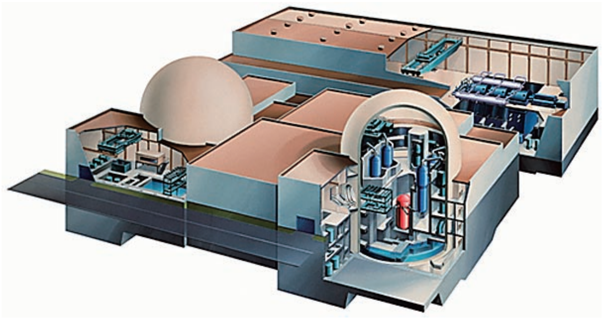

Global Deployment of Mitsubishi Standard APWR as an Effective Countermeasure Against Global Warming

SHIGEMITSU SUZUKI*1 YOSHIKI OGATA*1
YUKIO NISHIHARA*1 SHIRO FUJITA*1

With an increased requirement for nuclear power generation as an effective countermeasure against global warming, we established the APWR plant, a large-capacity Mitsubishi standard reactor combining our accumulated experience and technology as an integrated PWR plant supplier. The APWR plant has accomplished high reliability, safety and enhanced economy based on the technology that has been developed with the support of the government and utilities through the improvement and standardization programs of light water reactors. Currently, Tsuruga Units 3 and 4, the first two APWRs, are undergoing licensing, while we are making efforts to obtain standard design certification (DC) of US-APWR and preparing for the European Utility Requirements (EUR) compliance assessment of EU-APWR. Mitsubishi Heavy Industries, Ltd. (MHI) positions the APWR as a core technology that will contribute to the prevention of global warming and meet worldwide requirements.

1. Introduction

In the midst of the urgent necessity for various countermeasures and technological development against global warming, nuclear power generation is increasingly required, being a technology with zero CO_2 emissions. This paper outlines the large-capacity Mitsubishi Standard APWR (Advanced Pressurized Water Reactor) plant as an effective countermeasure against global warming and our recent efforts to disseminate the plant domestically and overseas.

2. APWR development and deployment

The development of the APWR was launched jointly by the Japanese government, five utility companies (Hokkaido Electric Power, Kansai Electric Power, Shikoku Electric Power, Kyushu Electric Power and The Japan Atomic Power Company) and suppliers in the early 1980s, under the Third Phase Improvement Standardization Program for Light Water Reactors. The development was aimed at establishing an advanced standard light water reactor with further enhanced reliability and safety, improved economy and siting efficiency with increased power, based on the results of the First and Second Phase Improvement Standardization Programs. This also involves our experience and techniques obtained through the design, construction and operation of existing PWR plants. Even after the completion of the national programs, the APWR design has been improved through up-rating by redesigning its core structure, optimization of safety systems by introducing high-performance accumulator tanks and other improvements by the continuous support of the utilities. Later, in March 2004, the Japan Atomic Power Company applied for the approval of changes in the reactor installation related to the addition of Tsuruga Units 3 and 4, the first two APWRs. As a result, the government started the safety assessment of these units.

On the basis of these units, we are making efforts to establish APWRs as a lineup of large-capacity standard PWR plants with excellent enhanced economy. This includes 1,600 and 1,700 MWe class APWRs whose design certification in the US has already been applied for, with high-performance steam generators and steam turbines. The APWRs have accomplished a large capacity increase of about 30% or more, compared with the current 4-loop PWRs (**Fig. 1**).

The main features of APWR plant components, as outlined in Section 3, are as follows.

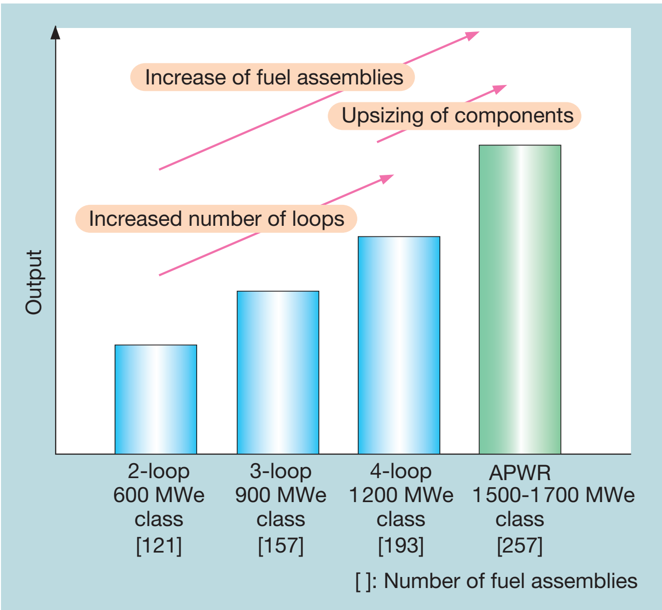

Fig. 1 Trend of PWR plant capacity

*1 Nuclear Energy Systems Headquarters

(1) Large reactor core and main components with large capacity (steam generator, primary coolant pump, pressurizer, and turbine)
(2) Advanced safety systems (four subsystems and refueling water storage pit installed in the reactor containment)
(3) New instrumentation and control systems (advanced digital main control board)

3. APWR technologies

3.1 Large capacity core

The APWR has adopted a large capacity core to accomplish high thermal power, and has increased the number of fuel assemblies from 193 in the current 4-loop type to 257 (**Fig. 2**). An advanced 17×17 fuel assembly has been adopted as the fuel bundle, and also a zircaloy grid that absorbs less neutrons, already used in existing plants has been incorporated for the effective use of uranium resources. Furthermore, the APWR allows the number of control rods to be set according to the quantity of loaded MOX fuel, so that the requirement for diverse operations, such as the use of a MOX core and high burnup can be met flexibly.

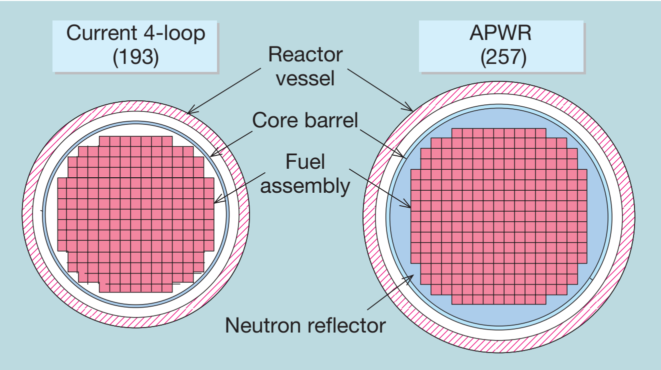

Fig. 2 Adoption of large core

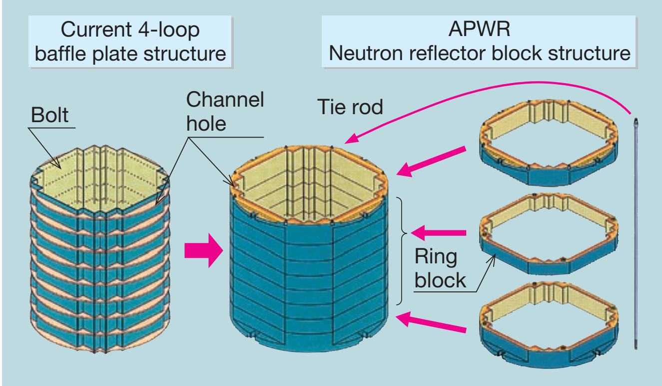

Fig. 3 Neutron reflector

3.2 Neutron reflector

The APWR's reactor internals employ a neutron reflector around the core for the effective use of uranium resources (**Fig. 3**). The neutron reflector has a simple structure that consists of stacked stainless steel ring blocks without weld lines and with few bolt connections, whereas the previous PWR has a baffle plate structure in which stainless steel plates are connected with many bolts. The new structure reduces neutron irradiation to the reactor vessel to about 1/3 and improves the reliability of the vessel.

3.3 Advanced safety systems: best mix of active and passive systems

In the APWR, the emergency core cooling system (ECCS) has a 4-train configuration (4 × 50% capacity) instead of the conventional 2-train configuration (2 × 100% capacity) to improve safety. The new configuration increases the reliability of equipment operation in the case of an accident. The systems of each train are installed near the corresponding loop to reduce the quantity of piping and enhance the separation and independence of each train (**Fig. 4**).

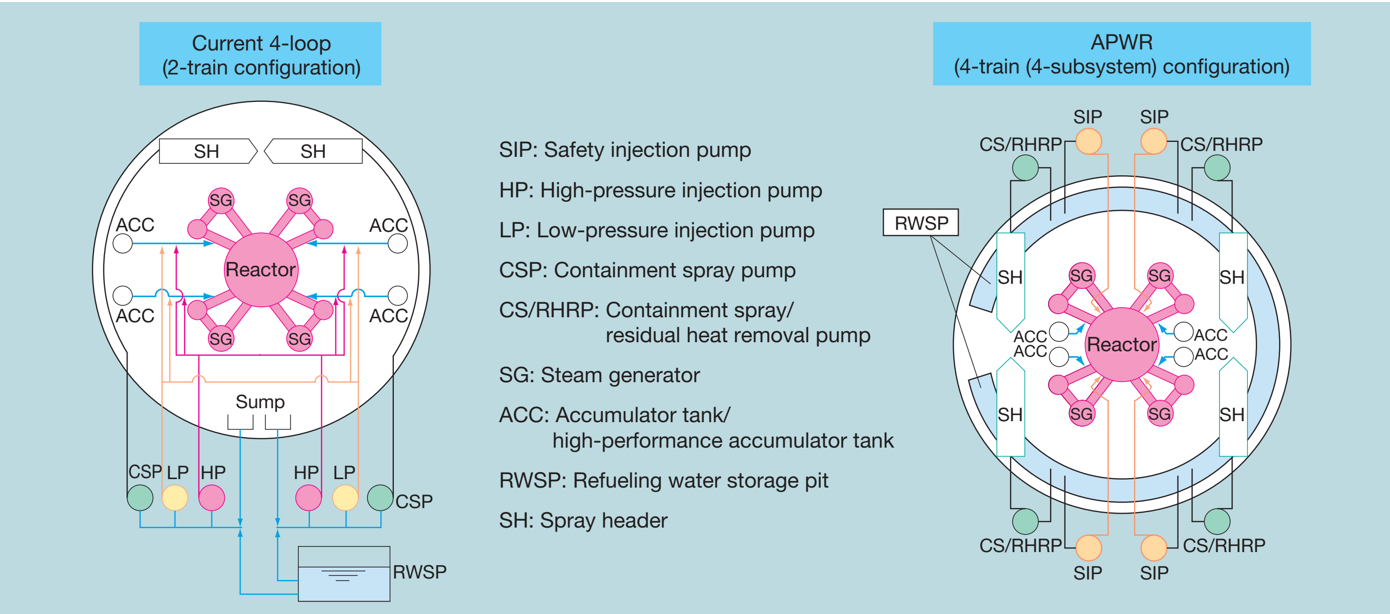

Fig. 4 Emergency core cooling system

In addition, a refueling water storage pit, conventionally installed outside the reactor containment vessel, is placed at the bottom of the containment vessel to serve as a water source for the ECCS during an accident. With this design, cooling water injected into the core during an accident can be automatically collected in the pit. This eliminates the switching operation of the core cooling water source and enhances safety.

Furthermore, a high-performance accumulator tank, new technology with a passive concept, has been adopted. The accumulator tank can change over from the large flow rate injection required for core cooling in the initial stage of a loss of coolant accident (LOCA) to the small flow rate injection required to maintain water level in the core in a passive manner without using external power. This is achieved by a flow dumper in the tank. The function of the conventional low-pressure injection system is integrated into the accumulator injection system. As a result, the low-pressure injection pumps are eliminated and the configuration of ECCS systems is simplified (**Fig. 5**).

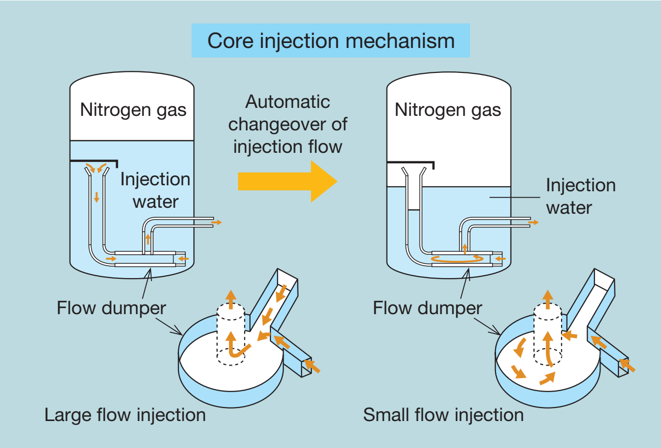

Fig. 5 High-performance accumulator tank

3.4 Advanced main control board and integrated digital control and protection system

Compact console panels are adopted in the advanced main control board to accomplish all monitoring and operations by touch screen displays. The operational switches of the plant components and the necessary operation information are consolidated on the screen to improve the operators' performance in monitoring and operating (**Fig. 6**). When an anomaly occurs in the plant, the panel's rich supporting functions automatically check the status of the plant and equipment operation and provide the necessary information. Compared with the conventional type, the advanced main control board is expected to reduce the operators' burden by about 30% and human error by about 50%.

3.5 Main components with increased capacity

Main components with increased capacity have been developed to cope with the increased core output, and various technologies to improve performance and reliability are being adopted and verified. According to the lineup of plant electricity output, a high-performance and compact steam generator (SG) with a substantially larger heat transfer area than that of the conventional 4-loop type is employed (**Fig. 7**). In order to minimize the increase of the outer dimensions of the SG with increased capacity, the tube diameter has been decreased from 7/8 to 3/4 inches to reduce the SG diameter, and an improved moisture separator with reduced stages has been adopted to reduce the SG height. This reduces the weight of the SG by about 10% or more compared with the larger SG based on the conventional design concept. To improve reliability, the number of anti-vibration bars installed at U-bends has been increased from 6 in the latest existing plants to 9 or more.

To provide high efficiency to the steam turbine, the last-stage blades of the low-pressure turbine has been extended by adopting 54 to 74 inch blades. The high-performance perfect three-dimensional (3D) blades have been adopted to reduce blade loss by perfect 3D flow design. Furthermore,

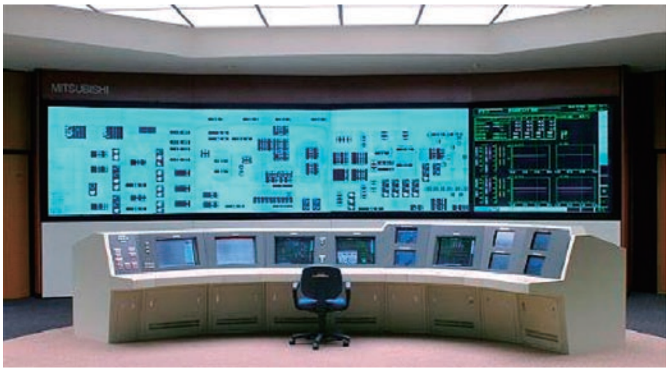

Fig. 6 Advanced main control board (prototype board)

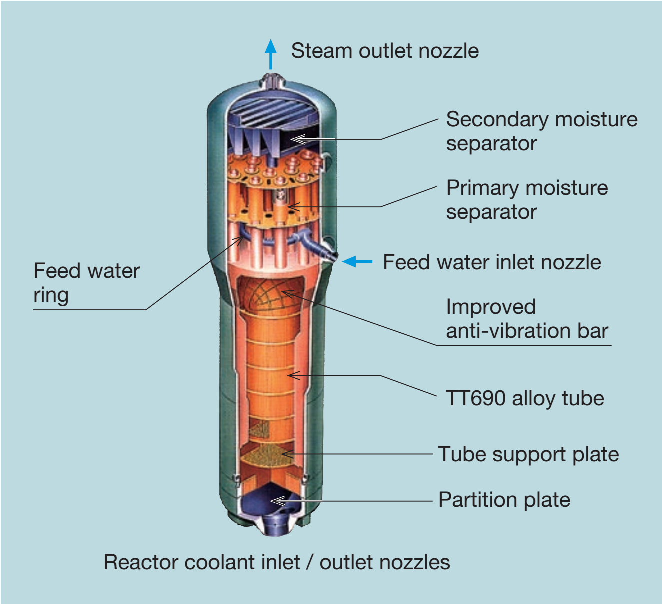

Fig. 7 High-performance, compact steam generator

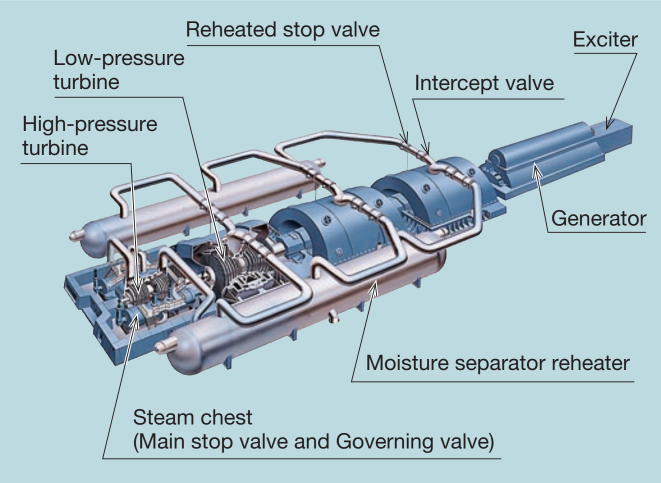

Fig. 8 Large-capacity, high-performance turbine generator system

integral shroud blades (ISBs) aimed at reducing vibration stress by forming an all-round stitch structure through contact with adjacent blades during revolution have also been adopted to enhance reliability. The developed blades were tested under actual steam conditions at own world's largest class test facility to verify their performance and reliability (**Fig. 8**). These new technologies are also being applied during the replacement of turbines in existing domestic and overseas plants.

4. Future efforts

4.1 Toward new domestic plants

As mentioned above, Tsuruga Units 3 and 4, as the first APWR units, are undergoing licensing, MHI will strive to deploy standard APWR plants with enhanced safety, reliability and economy by meeting the requirements of individual domestic utilities.

4. 2 Toward global deployment of standard APWR

The construction of new nuclear power plants has been interrupted for a long period of time in the US, however due to global warming and soaring oil prices, the need for nuclear power generation has been rising in recent years and demand for dozens of new plants by around 2030 is expected. On February 29, 2008, the Nuclear Regulatory Commission (NRC) accepted for docketing and started reviewing our application for the standard design certification (DC) of the US-APWR, an APWR design customized for the US utilities. Luminant Power, formerly TXU Power, headquartered in Dallas, Texas, decided to introduce this design to Commanche Peak Units 3 and 4, and other US utilities are also showing interest.

In Europe, with a growing trend for demands for nuclear power generation, MHI held a technical seminar on the EU-APWR, designed for European utilities, on March 13 and 14 in Brussels. The EU-APWR is aimed at compliance with the European Utility Requirements (EUR) for Light Water Reactors and will be reviewed as a 1,700 MWe class plant as is the case with the US-APWR.

These global deployment efforts respond to overseas safety regulations and power requirements on the basis of the APWR technologies developed in Japan and are expected to gain support globally from overseas utilities.

5. Conclusion

We have presented the established lineup of large-capacity Mitsubishi Standard APWR plants and related efforts domestically and overseas. The APWRs are standard plants developed by the combination of our accumulated experience and technology as a PWR manufacturer with support from the Japanese government and utility companies. We will make efforts to disseminate the standard plant as a core technology to combat global warming, while meeting the needs of overseas and domestic utilities.

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Shigemitsu Suzuki

Yoshiki Ogata

Yukio Nishihara

Shiro Fujita