DESIGN FEATURES OF TSURUGA 3 AND 4
THE FIRST APWR PLANT IN JAPAN

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ABSTRACT

The APWR is a light water reactor, which employs many innovations for improving safety, reliability and operability aspects. The main features of the design improvements of APWR are:

- Flexible core design to meet future requirement of operation with mixed oxide fuel (MOX) and high burn up
- Reliability enhancements in reactor internals, steam generators and other key components
- Safety enhancements in engineered safeguard systems which increase redundancy, diversity and independence
- Improvements in plant operation by employing the latest I & C system

In addition to the improvements in core design, safety, reliability and operability, many economic challenges have been addressed in progressing the design work of Tsuruga 3 and 4.

This report presents the design overview and approach of the economic challenges for Tsuruga 3 and 4 that will be the first units of APWR in Japan.

INTRODUCTION

The APWR was developed as a standard design for large scale PWR in the improvement and standardization program for LWR that was organized by MITI, the utilities (Hokkaido, Kansai, Shikoku, Kyushu Electric Power Companies and JAPC) and the manufacturers (Mitsubishi Heavy Industries and Westinghouse Electric Corp.).

The APWR is a plant in which outstanding improvements have been effected in terms of safety, reliability, operation, maintenance and economy, and APWRs are to be adopted in Tsuruga 3 and 4 which the Japan Atomic Power Company is planning to built.

OVERVIEW OF THE APWR DESIGN

To show the aspects of design modification employed in APWR, the general specifications are shown in Table 1, where the differences with the typical current 4 loop PWR are indicated. The first point to be noted is the electrical power output that is approximately 1,530 MW as one of the fruits of economic challenges.

Table 1 APWR Specification

Item	APWR	Current PWR
Electrical Output	approx. 1,530 MWe	1,180 MWe
Thermal Power	approx. 4,450 MWt	3,423 MWt
Fuel Type	17 x 17	17 x 17
No. of fuel assemblies	257	193
Fuel length	3.66 m	3.66 m
Radial reflector	Stainless steel	(N/A)
No. of loops	4	4
Loop flow rate	25,800 m^3/h/loop	20,100 m^3/h/loop
SG surface area	6,500 m^2	4,780 m^2
Containment vessel type	PCCV	PCCV
Turbine type	TC6F54	TC6F44

The core of the APWR consists of 257 fuel assemblies of an advanced 17 x 17 type and incorporates a number of improvements enhancing flexibility to meet future requirements such as MOX and High burnup fuel.

The radial reflector, consisting of eight stainless steel ring blocks, not only results in the fuel cycle costs reduction but also increases reliability of the reactor vessel and internals. This improved reliability results from reducing the neutron fluence on the reactor vessel wall and replacement of baffle former installed in the conventional reactor vessel. More than 2000 bolts to tie the baffle former assembly in a high fluence region are eliminated by the radial reflector design. (Refer to Figure 1.)

Regarding steam generators, the diameter of the tubes is reduced from 7/8 inch used in the current plants in Japan to 3/4 inch in order to achieve a more compact design. The tube material is Inconel TT690 which has better corrosion resistance to Stress Corrosion Cracking (SCC) and has already been adopted for the latest PWR. The additional reliability improvement has been gained by modifying the design of the anti-vibration bars in the U-bend region of the tube bundle, which suppress flow induced vibration. (Refer to Table 2.)

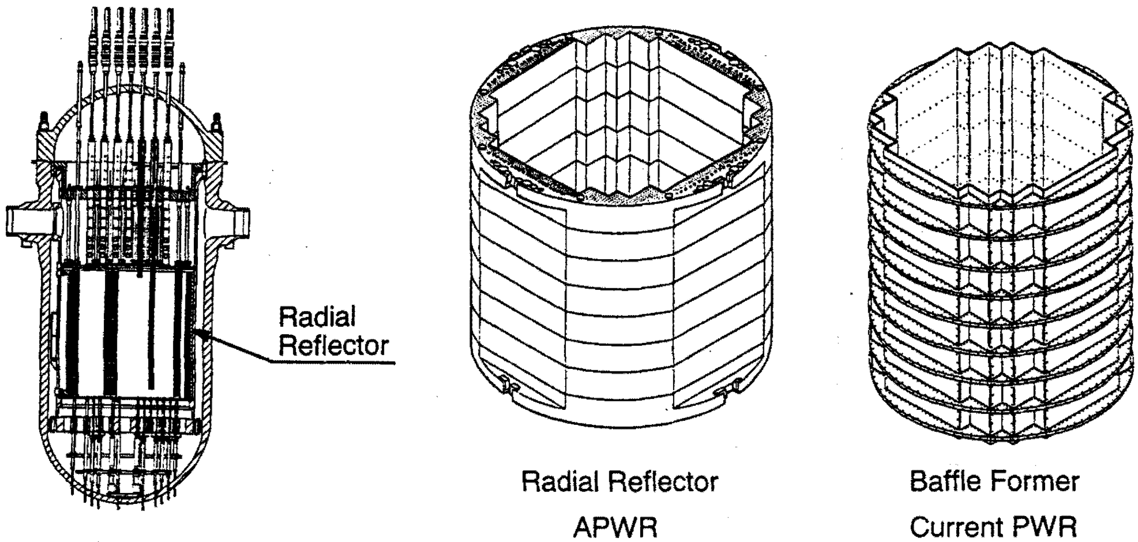
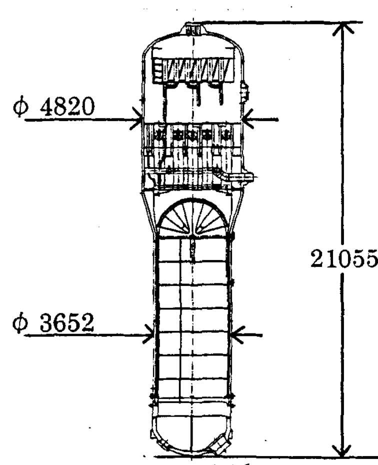
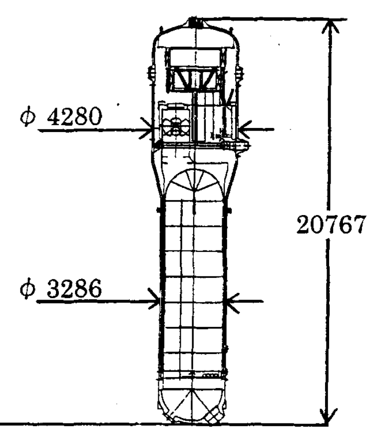


Figure 1 Radial Reflector

Table 2 Steam Generator

	APWR	Current PWR
Schematic drawing		
Tube size	3/4 inch	7/8 inch
Anti-vibration bars	9 points support	6 points support

The APWR safety systems are designed to consider not only design basis events but also events beyond design basis reflecting the experience gained from the TMI and Chernobyl accidents. The emergency core cooling system (ECCS) is configured to have four independent systems. In existing designs, ECCS injection flow is shared among high head and low head safety injection pumps, and accumulators. In the APWR design, however, low head safety injection pumps can be eliminated because of both direct vessel injection of the high head injection pumps (no 'spilling' line) and extended delivery characteristics of advanced accumulators. By locating the refueling water storage pit inside the containment vessel, it is not required to switch over from injection mode to recirculation mode. (Refer to Figure 2.)

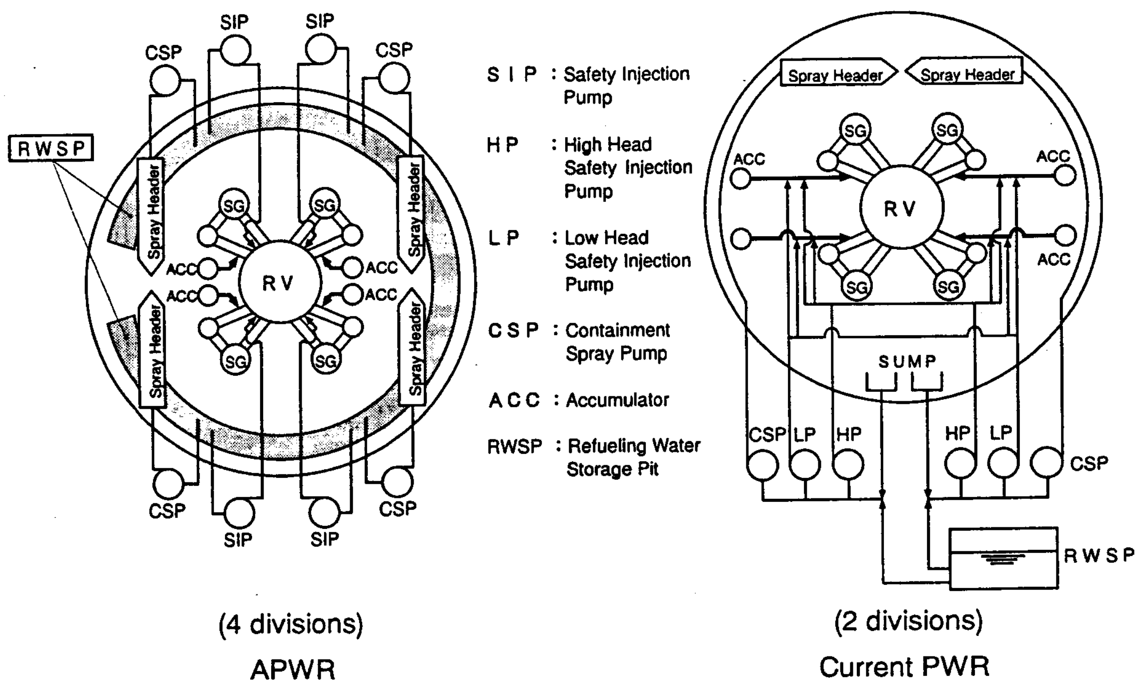


Figure 2 Configuration of ECCS

ECONOMIC CHALLENGES

Considering the recent intense pressure to reduce power generation costs, many economic challenges have been addressed in progressing the design work of Tsuruga 3 and 4.

The economic challenges are mainly divided into two areas.

One is uprating of the plant electric power. Another is systems and components rationalization.

Uprating of Plant Electric Power

The uprating of plant electric power is one of the most effective approaches for cost reduction.

To minimize the impact on the original APWR design, as study conditions, the designs of key components have been maintained, that is to say, the reactor vessel size, number of fuel assemblies and reactor internals are not changed.

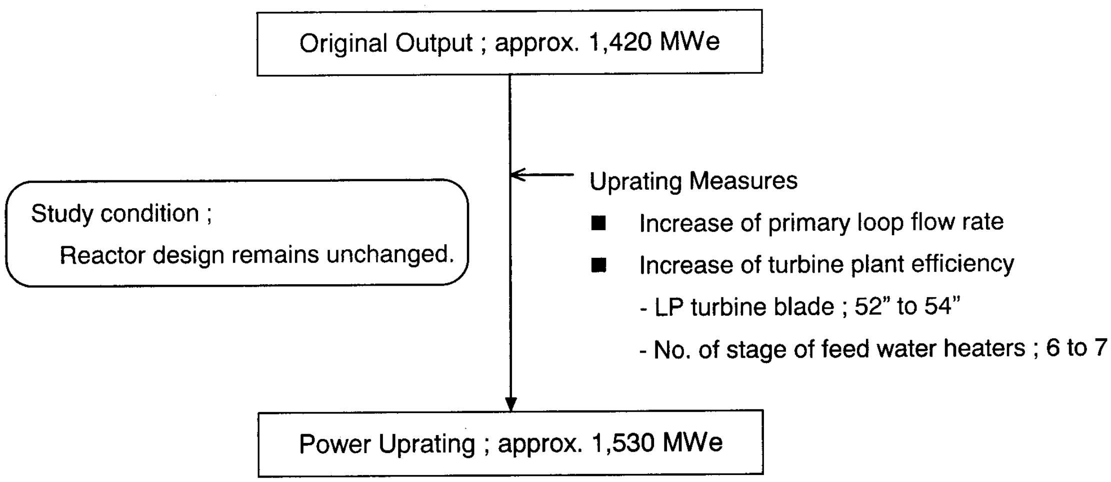
Two principal measures have been considered. One is to increase primary coolant flow rate and another is to increase turbine efficiency.

According to the results of Reactor Coolant Pump hydraulic tests, it is found that primary coolant flow rate can be increased. And further, as pressure drop inside the reactor vessel was determined through reactor vessel flow dynamic test, allowing the elimination of excess design margin of the primary loop drop pressure. Because of these two results, the primary loop flow rate has been increased from the original flow rate (24,100m^3/hr/loop) to 25,800m^3/hr/loop.

In the original APWR design, 52 inch blades were to be adopted for the last stage of low pressure turbine. However, the results of the design review of the turbine from the view point of plant efficiency improvement shows that 54 inch blades can be applied without any design change of the turbine casing.

According to these two modifications, generated electric power can be increased to approximately 1,530 MW from approximately 1,420 MW in the original design.

Figure 3 Power Uprating



Systems and Components Rationalization

Value engineering studies on systems and components to reduce the capital cost of the plant have been performed. Through this value engineering review, more than two hundred (200) rationalizing opportunities were identified.

These opportunities were evaluated from the following points of view;

Safety

Impact on both design basis safety analyses and risk significant safety evaluation in the Probabilistic Safety Assessment are considered.

Reliability

Whether the systems and components are able to do their function is considered. The anticipated impact on system reliability, plant availability and structural integrity are addressed.

Operability

How the change will impact the operation of systems or components during normal operation, startup/shutdown, abnormal situation and refueling outage is considered. In addition, consideration is given to whether any new operational restrictions will result.

Maintainability

Whether there are any more preventive or corrective maintenance and testing needs associated with this modification is considered. This is evaluated in terms of the manpower and time required for maintenance, frequency of maintenance, and time period in which maintenance is possible. The occupational radiation exposure is also considered.

Licensability

Whether the modified design is expected to be accepted by Japanese authority or not is considered. Licensability by US NRC is also confirmed as a reference.

Considering the evaluation of feasibility, plant impact and cost savings, an overall decision was made for disposition of each V/E study and more than eighty (80) feasible ideas were selected, though some of them require further evaluation of the design change. The following is typical examples of design rationalization, which are categorized into four approaches.

Elimination of the stand-by equipment

There are many items of stand-by equipment installed in a plant. We reviewed actual reliability and operating results of the equipment and the effect of the elimination of the stand-by equipment to the operation of the plant.

For example, stand-by condensate pump and condensate booster pumps can be eliminated, because the occurrence of pump trouble is low enough. Even in case of pump trouble, the plant can be operated at 60% of full power.

For another example, stand-by waste water feed pumps in the radiation waste system can be eliminated without any big impact to the plant operation.

Relaxation of Design Conditions

Some design conditions and operating criteria are too conservative considering actual operating experience. By withdrawal of the conservatism, design rationalization can be achieved. For example:

In the current PWRs, the main steam relief valves shall not be actuated in case of unit load operation. When main steam relief valves actuation is allowed to reduce the main steam pressure, the required number of turbine by-pass valves is reduced from thirteen (13) to ten (10).

In the original design, a load following operation of 14-1-8-1 pattern (from full power to half load) was considered. When this function is given up, the capacity of the boron recovery system becomes half of the original one. Even in this rationalized design, 14-1-8-1 load following operation is possible during up to 60% of the fuel cycle.

Adoption of New Technology

New technology sometimes affects design rationalization. For example ;

Regarding the number of control rods, seventy-seven (77) rods are required by the original evaluation method under the design condition of 55 GWd/t, UO_2 fuel and 48 GWd/t, MOX fuel. When the advanced analysis method, with more precise reactivity calculation is applied, the number of control rods is reduced to sixty-nine (69).

The main coolant piping of the Advanced PWR is made of low alloy steel instead of stainless steel applied in the current PWR. When the Leak Before Break (LBB) concept is applied to the main coolant piping, which is the first challenge to apply to low alloy steel in Japan, pipe whip restraints can be eliminated.

Simplification of Systems and Components

Some facilities which have historically been operated very infrequently can be rationalized. The following are examples of cost reduction challenges by simplification of systems and components.

Two radiation monitors are installed in the charging pump room in the original design. They can be eliminated and replaced with mobile type monitors, since there have been few malfunctions in the past.

Though the containment recirculation fans have roughing filters before the cooling coil, the filters have never become dirty except during construction. With protection by temporary filters during construction, the roughing filters can be eliminated.

Table 3 Examples of Design Rationalization

Category	Example
Elimination of stand-by equipment	Condensate pumps Pumps of waste disposal system
Relaxation of design condition	Permission of MSRV actuation in case of unit load operation Relaxation of load following capability
New technology	Advanced analysis method for reactivity calculation LBB concept
Simplification	Reduction of radiation monitors Elimination of rough filters of CV recirculation fans

Besides the above uprating and design rationalization, reduction of construction period, reduction of refueling outage period, adoption of general purpose products, etc. have been taken into consideration as well.

CONCLUSION

The APWR has been developed in the Improvement and Standardization Program by the Japanese government and the industry groups, and incorporates design features which result in improved safety, reliability and operability. In addition to these technical enhancements, cost reduction challenges have been prioritized considering competitiveness with the other power generation methods. The first unit of APWR is expected to start operation during the early 2000s and the APWRs will fill an important role in the energy supply throughout the world.