Design of Monju Steam Generator

- with regard to Maintenance and Repair -

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Abstract

The steam generator design of "Monju" started in 1968 and since then, extensive research and design work has been done.

"Monju" steam generator consists of one evaporator and one superheater to each of the three independent cooling systems. Ultrasonic and eddy current tubing inspection devices have been developed for maintenance. And for failed tubes, welding or explosive plugging is applied.

Following the completed safety review and the coming design and construction licensing, "Monju" is expected to reach criticality in fiscal year 1990.

Introduction

"Monju" is the first power generating fast breeder reactor in Japan. The design, which started in 1968, is now in the final stage and the construction is targeted to reach initial criticality in fiscal year 1990.

In the steam generating system, the helical coiled tube type steam generator has been chosen and, at the same time, the straight tube type has been under consideration as a second choice.

Research work on the steam generator, using mock-up models, has been extensively done at Oarai Engineering Center. In 1971, a 1MW steam generator started testing and since 1974 2 different 50MW steam generators have been installed and tested. The first ran about 3500 hours and the second about 14,000 hours, now under endurance testing. In parallel to these mock-up tests, material tests, tube to tube-sheet welding tests, sodium-water reaction tests, development of leak detectors have been under way. These significant base technologies have been a great support to the development of the "Monju" steam generator.

"Monju" Power Station, which is rated at 714MWth, 280MW in electric power generation, has 3 separated once through cooling systems and each has one evaporator and one superheater. In 1984, the evaporator of "Monju" was awarded to Mitsubishi and the superheater to Hitachi.

Design of Steam Generator

The steam generator is composed of a separated evaporator and superheater, both helically coiled tube type with free

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surface sodium inside. The water steam cycle is a once through type and the reheater which was installed in the original design was eliminated.

The steam generator system is shown in Fig. 1 and the structure in Fig. 2. The input heat condition from the secondary sodium coolant system is 505°C sodium at the entrance of the superheater and 325°C at the exit of the evaporator. Steam condition at the outlet of the superheater is 487°C and 133 kg/cm^2g and the feed water during normal operation is 240°C. The material used for the evaporator is $2\frac{1}{4}$Cr-1Mo for both the heat transfer tubes and the shell of the evaporator. For the superheater, considering the high temperature, SUS321 material has been selected. The outer diameter of the heat transfer tube is 31.8mm and the number, 147. Sodium level control is done by cover gas pressure for the superheater and overflow line for the evaporator.

Specific numbers for the steam generator are shown in table 1.

In a rare case when water/steam leaks inside the steam generator and sodium-water reaction occurs, it will be detected by a hydrogen detector system which is installed both inside sodium and in cover gas. In order to accommodate the pressure rise, a pressure relief and reaction product separator system is prepared. They are normally isolated from the sodium system by a rupture disc at the cover gas. This system is shown in Fig. 3.

When the plant is shut down, for instance, by reactor scram, during power operation, the steam generator is isolated from the plant cooling system and the decay heat is removed by an air blast cooler which is installed in the secondary main cooling system, parallel to the steam generator.

Design Base Events of "Monju"

As a design base accident for the "Monju" steam generator, a double ended guillotine failure of a single heat transfer tube is the basic condition and in order to accommodate the successive rupture propagation, a maximum of 1 + 3 guillotine failures of neighboring tubes is considered. When the accident occurs, it is recognized by a rupture signal from the rupture disc and the steam generator is isolated from the cooling system. The water/steam will blow down and when the pressure reaches down to a certain degree, nitrogen gas is supplied.

In a case where the leak rate of water/steam is small, and the leak detection is done by the hydrogen detector, rather than by the burst of the rupture disc, manual scram of the reactor by the decision of the plant operator is achieved and, consequently, the steam generator is isolated from the cooling system.

In both cases mentioned, the sodium inside the steam generator will be drained after a total inspection of the system.

Valves and process instrumentation are shown in Fig. 4.

Design Considerations for Maintenance and Repair

During Normal Operation

The three steam generators belong to three independent cooling systems and are all located in the reactor auxiliary building where access is free. The evaporator and superheater are each located in separate rooms and the reaction products tank is installed on the roof of the building. This enables easy access for maintenance and repair. The steam generator is installed in each room in such a way that access is possible not only from the sides, but also from the top and from the bottom.

The hydrogen detectors are designed so that absolute correction can be done, as installed, independently from the system.

Small Leaks Occurrences

Inspection technology of heat transfer tubes, after small leaks have occurred, has been developed and established using either ultrasonic testing devices or eddy current testing devices for defect indication detection. However, in order to facilitate accessibility and have direct access to the water/steam inlet and outlet tube to tube-sheet area, a cap cover type structure has been introduced. Furthermore, to help make the insertion of the detector into the tube smoothly, certain limits to the curvatures of the tubes have been applied.

Tube plugging technology by explosives and by welding has been developed. The height of stand pipes are decided to enable easier access for the plugging.

Large Leak Accidents

When a large leak inside the steam generator occurs, inspection of heat transfer tube bundles and repair work is required. In order to do this, a flange structure is adopted at the top of the steam generator and this enables the tube bundle to be pulled out together without cutting off any part of the shell. This method of inspection and repair has already been applied and experienced at the 50MW mock-up steam generator facility. The space above the steam generator at the plant is left open and vacant in spite of the rather high elevation where it is installed, and this is to accommodate the withdrawal.

The layout of the steam generator is shown in Figs. 5 and 6. Fig. 7 shows the features that have been mentioned.

Conclusion

Following the conceptual design of the steam generator of "Monju," the related safety review, including the evaluation of the accident analysis, has been completed and ended. Detailed design is now under way and after receiving permission for design and construction, fabrication will start.

The steam generator is one of the most important components of a liquid metal cooled fast breeder reactor from the standpoint of functional requirement and safety. In order to establish a promising future for fast breeder reactors, the establishment of its technology and achievement of reliability has been and shall be sought.

Acknowledgement

The authors are grateful to all the design work and test work done in order to reach this stage of development work for the steam generator of "Monju."

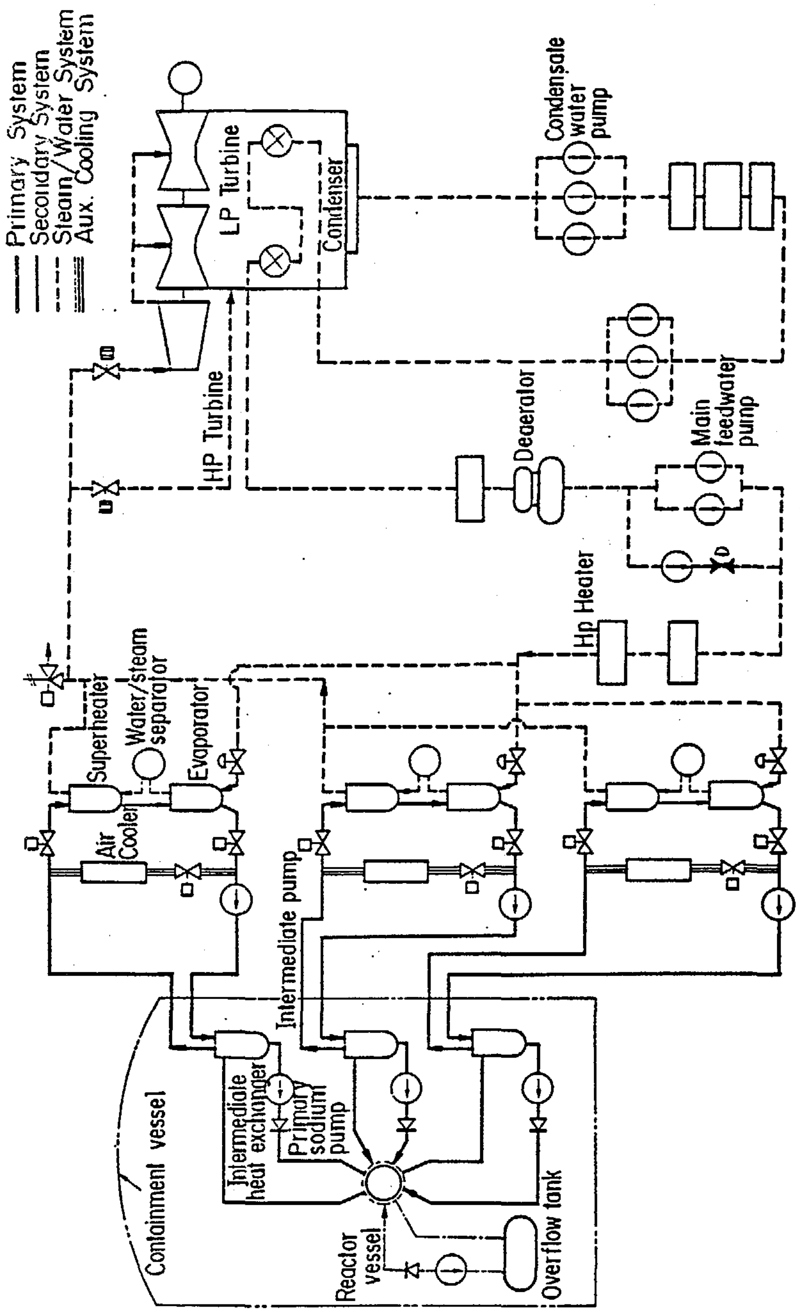

Fig. 1 Schematic Flow Diagram of the Plant

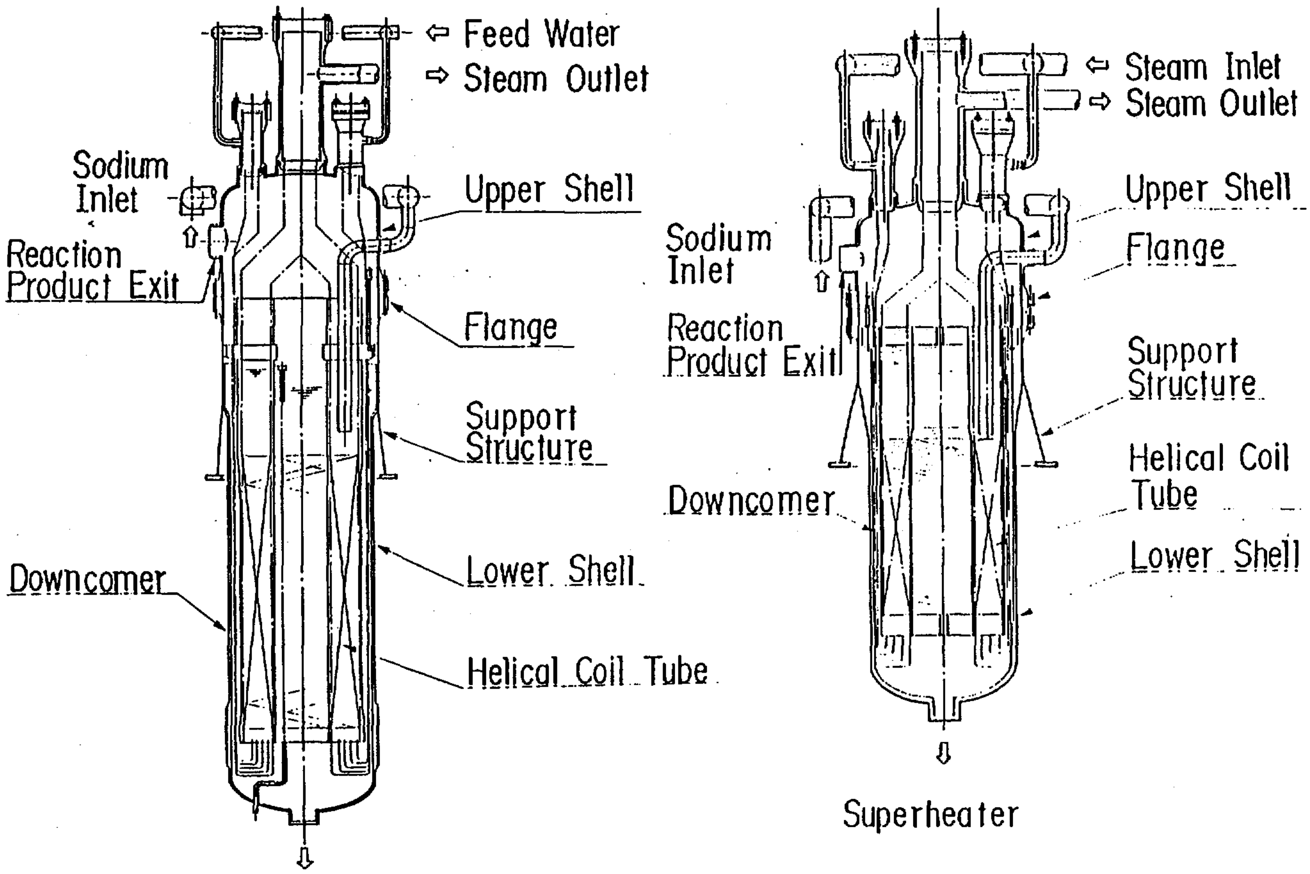

Fig. 2 Steam Generator

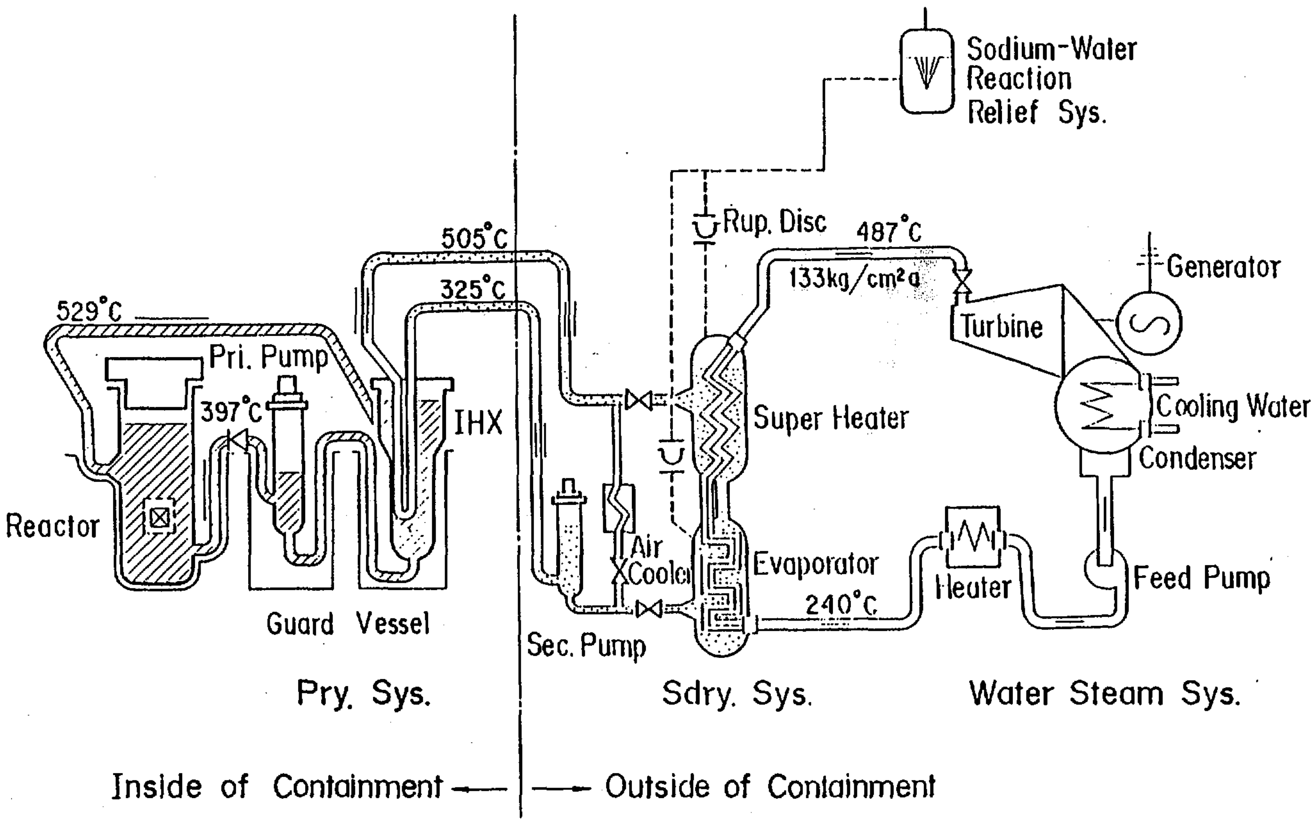

Fig. 3 Steam Generator System of Monju

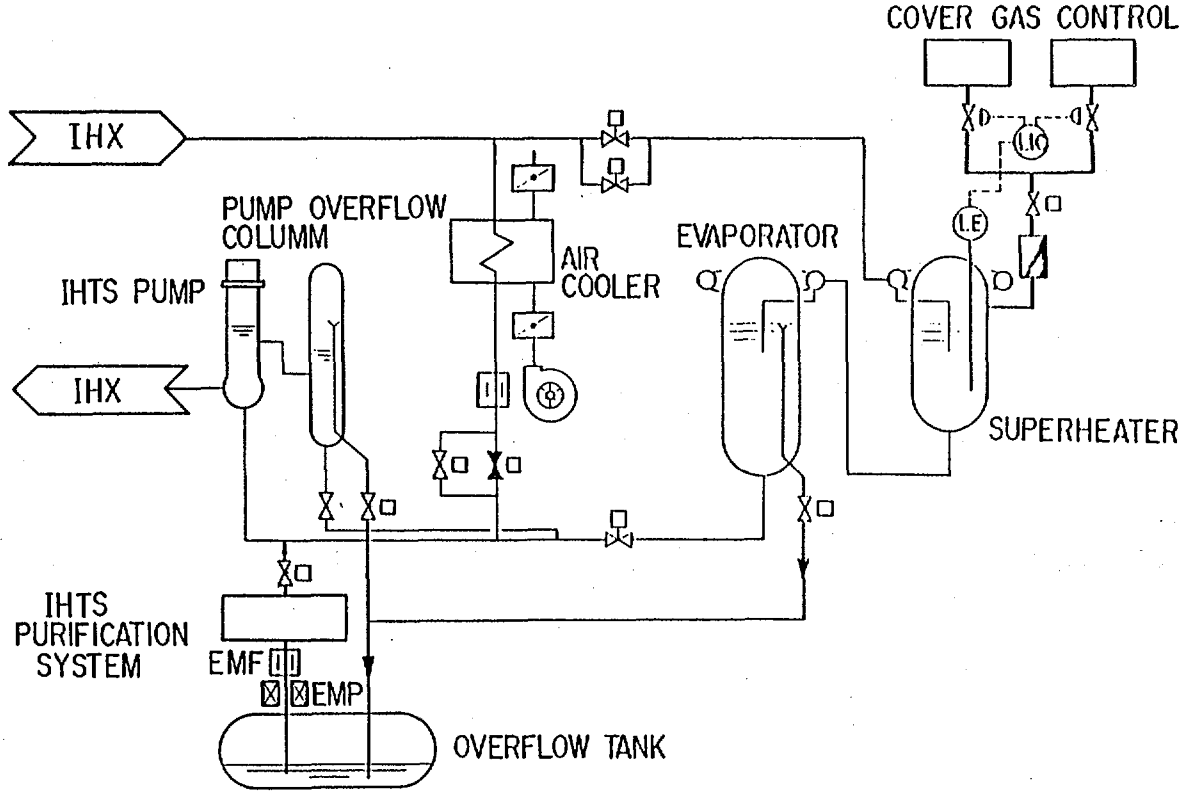

Fig. 4 Valves and Ins:ıumentation

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PLANT LAYOUT OF MONJU

1 Spent resin room
2 Concentrated miscellaneous waste tank room
3 Monitor tank room
4 Miscellaneons waste collector tank room
5 Components cleaning area
6 Fuel storage pool
7 Pool water cooling and purification room
8 Fuel clegning equipment room
9 Fuel inspection equipment room
10 Ventilator and conditioner room
11 EVST room
12 Cold trap room
13 FFDL room
14 Fuel handling facilities operation room
15 Main control room
16 Relay room
17 Low voltage switchgear room
18 Piping room
19 IHX
20 Primary sodium pump
21 Primary Argon gas system room
22 Reactor vessel
23 SG room
24 Maintenance cooling system room
25 Preheat power system room
26 Switchgear room
27 High voltage switchgear room

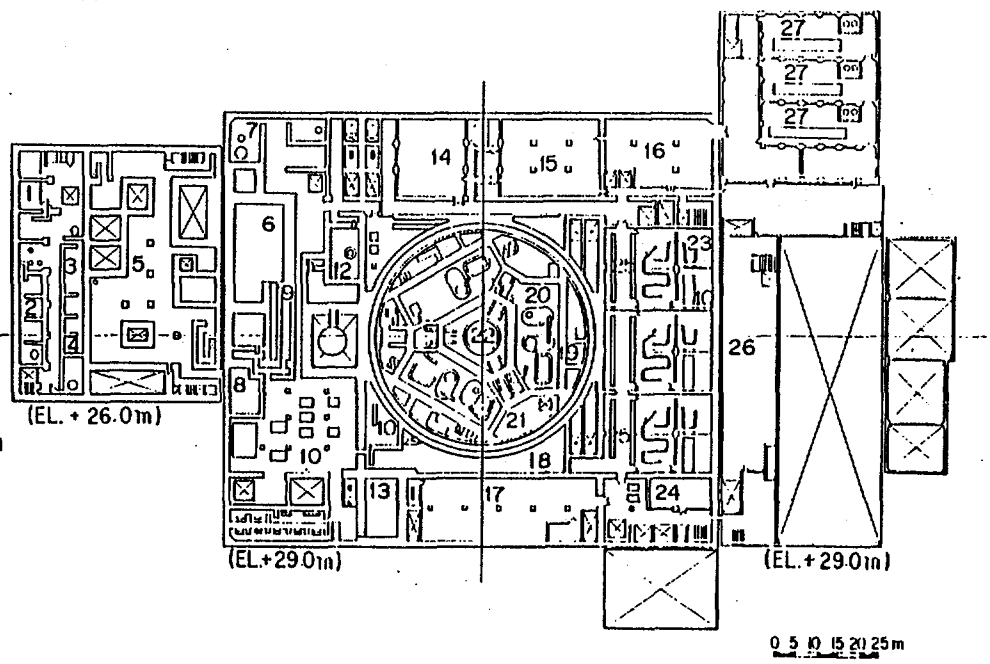
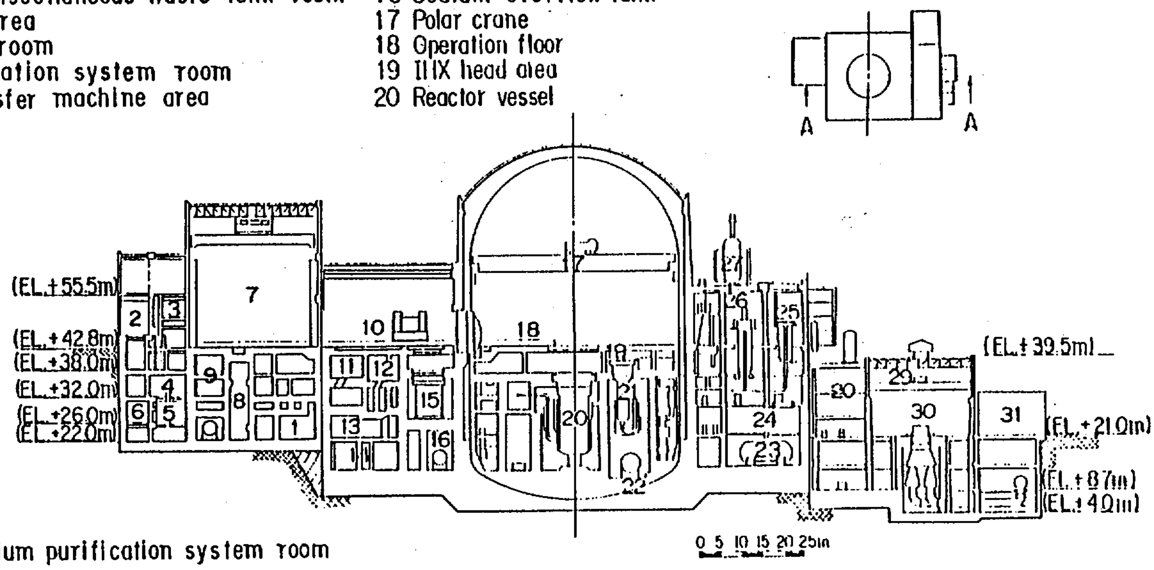


Fig.5 Horizoı·ıl Cross Sectioı ·f Main Buildings

1 Ventilator and conditioner room
2 Maintenance room
3 Switchgear room
4 Monitor tank room
5 Miscellaneous waste collector tank room
6 Concentrated miscellaneous waste tank room
7 Maintenance area
8 FHM cleaning room
9 Cleaning ventilation system room
10 Ex-vessel transfer machine area
11 Fuel canning room
12 Fuel cleaning room
13 Fuel inspection equipment room
14 Gaseous radwaste processing system room
15 Ex-vessel storage tank
16 Sodium overflow tank
17 Polar crane
18 Operation floor
19 IHX head area
20 Reactor vessel



21 IHX
22 Dump tank
23 Storage tank
24 Secondary sodium purification system room
25 Superheater
26 Evaporator
27 Reaction product storage tank
28 Switchgear room
29 Crane
30 Turbine generator
31 Transformer area

Fig. 6 Sectional View of Main Buildings

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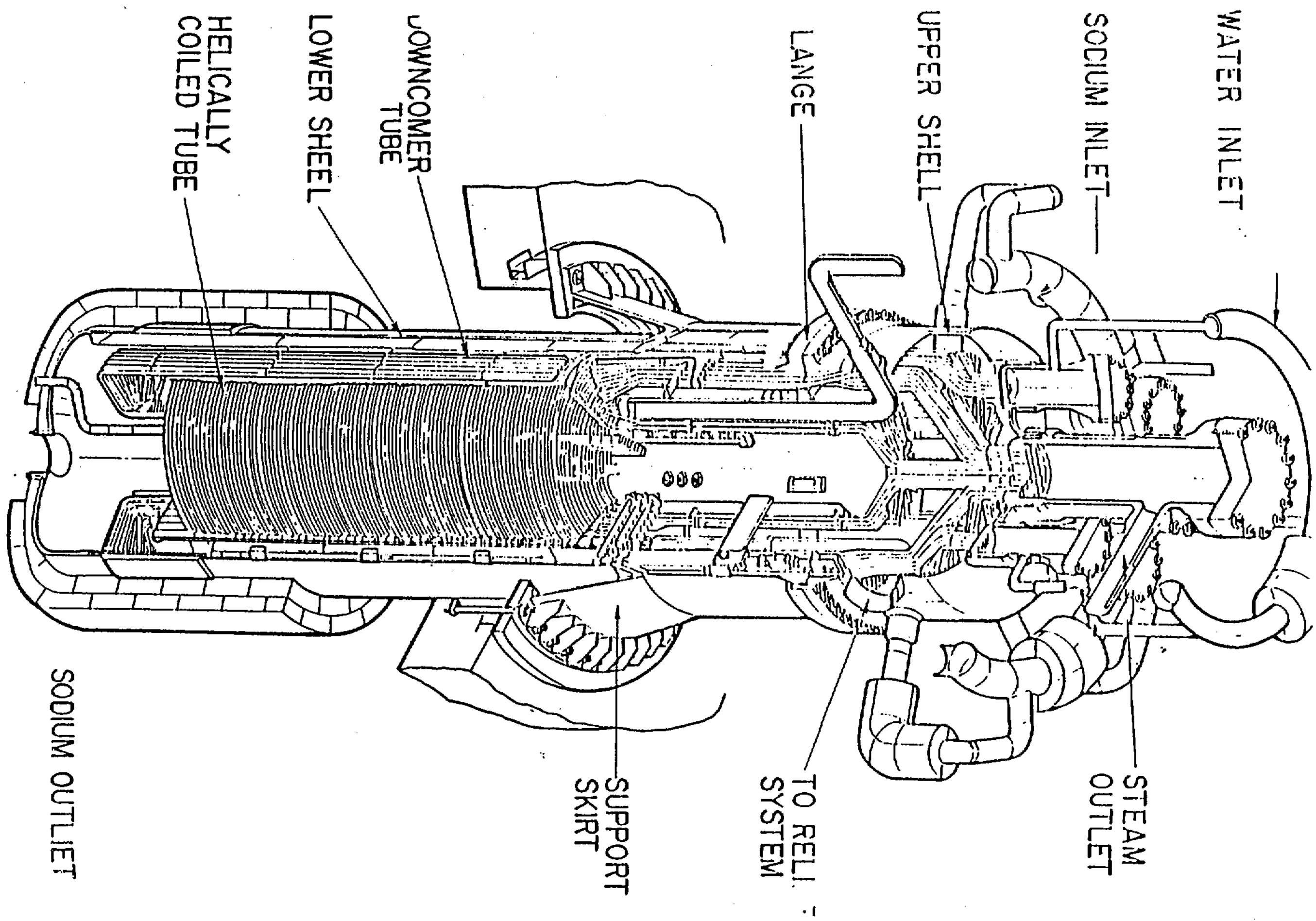

Fig. 7 Monju Steam Generator (EV)

Table 1 Design Specification

	Superheater	Evaporator
Type	Helical Coil	Helical Coil
No. of Unit/Loop	1	1
Thermal Power	~47 MWt/Unit	~191 MWt/Unit
Sodium Side Condition		
Flow Rate	3.73×10^6 kg/h	3.73×10^6 kg/h
Inlet Temperature	505°C	469°C
Outlet Temperature	469°C	325°C
Steam Condition		Water Condition
Flow Rate	3.79×10^5 kg/h	3.79×10^5 kg/h
Inlet Temperature	367°C	240°C
Outlet Temperature	487°C	369°C
Outlet Pressure	133.0 kg/cm²a	
Tube Bundle		
Tube Outer Diameter	31.8mm	31.8mm
Tube Thickness	3.5mm	3.8mm
No. of Tubes	147	147
Material Tube	321ss	STBA 24
Shell	304ss	SCMV 4
Sodium Level Control	Pressurized Cover Gas	Over Flow System
Component Class	Class 3	Class 3

Question and Answer

Session 2 Paper No.8

Paper Title : Design of MONJU Steam Generator

1. Anderson

Q. The concensus of opinion in Europe is that the D.B.A. should be 1 DEGF. You said that in Japan 1+3 DEGF should be considered. What is the reason for this ? (DEGF: Doubled Ended Guillotine Failure)

A. Results of tests at Oarai Engineering Center and the leak propagation analysis using specific computer code tell us that we are still not prepared to go to the 1 DEGF basis.

2. Salgo

Q. Have you more conservative DBA criteria had any impact on the design of the steam generator and of the secondary circuit ? For instance of the wall thickness of the shell or the reaction product relief system.

A. The largest difference is the sizing of the reaction product relief system.