§7. Design Study on Heat Exchange System for Liquid Blanket Fusion Reactor

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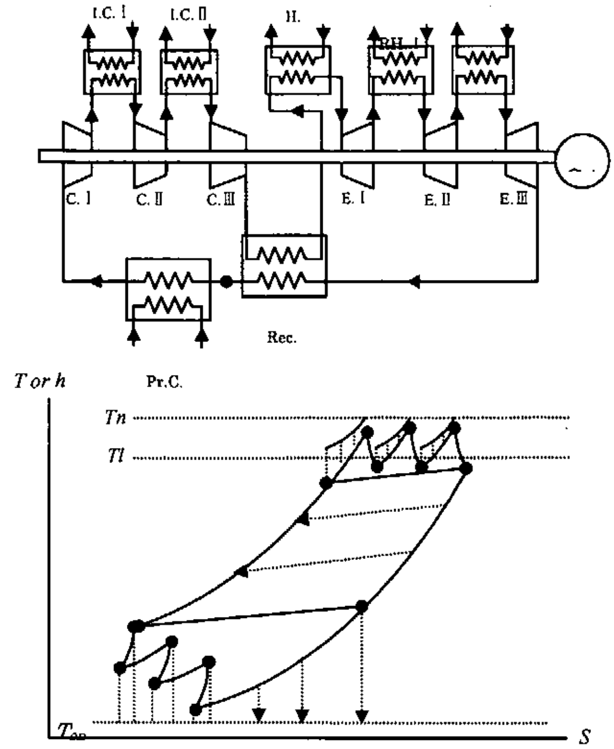

1. Gas-turbine systems for liquid blanket of FFHR

In the design of FFHR, the concept of molten salt FLIBE as a primary self-cooling/breeding material and helium gas turbine system as the secondary power cycle is examined. On the other hand, the operating temperature of the FLIBE is limited within 450~550℃. In gas turbine cycles, significant amount of generated power is inevitably consumed in compression work so that the net power extraction is impossible unless the cycle temperature at which heat is received is high enough. The only way of realizing net power output for such low temperature is through multi-stage compression/expansion, which makes the cycle T-S diagram approach to that of Carnot. Based on that, three-stage compression/expansion gas turbine cycle was examined so far and the maximum thermal efficiency of 37 % was demonstrated for common compression/expansion ratio of 1.5. Following this, research efforts were paid on the review of the related issues particularly with the development of closed-cycle gas turbine system.

2. Issues related to R&D of the HTTR

In the Japanese nuclear energy strategy, the HTGR has not necessarily been recognized as power generation reactor so that only limited research activity has been directed towards the closed cycle gas turbine system. In recent years, however, the HTGR as power reactor is being revived in relation to the environmental problems. Following this, some private sectors accepted the order of Pebble Bed and Modular Type High Temperature Gas-Cooled Reactor. Some key technologies in it are common with those of fusion reactors with helium gas turbine as the power cycle.

 # Heat exchanger

At least seven heat exchangers are required for three-stage compression/expansion closed cycle gas turbine system as shown in the first figure so that realizing high performance heat transfer as well as least pressure loss is crucially important with heat exchangers. For this, the plate–fin type heat exchanger is now being developed along with manufacturing procedures and some advances have been recorded.

#Modular structure

Considering the possible leakage of gaseous fission product through the gap between axis of rotary machinery and casing, the whole system must be contained within a vessel, which is also the case for fusion reactor system because we must be ready for the leakage of tritium from the coolant. Meanwhile, the poor heat transfer performance of the gas leads inevitably to large heat exchanger size and, therefore, to the huge container vessel. Therefore, the container vessel is divided into three parts, the reactor vessel, heat exchanger vessel and power conversion vessel. Similar consideration must be directed to the fusion system with gas turbine.

#Inter-cooler

In the design of the PBMR, one-stage compression without inter-cooler is adopted in order to prevent the water from leaking into the gas flow at the heat exchanger, which is in prominent contrast with the present concept. However, the former examination revealed that if the single stage compression is assumed, the attainable thermal efficiency does not reach 30%. Therefore, development of heat exchanger between gas and water is also important.

#Breakthrough of the upper temperature level

In the former estimation of thermal efficiency, the total pressure loss was assumed to be less than 10% of the system pressure. However, this estimation is too optimistic even taking the advances in heat exchanger technology into consideration. It is apparent that the most effective solution to this is the breakthrough of upper temperature limit of 550℃. Raising the upper temperature by 100K will bring about the drastic improvement of the thermal efficiency so that introducing vanadium alloy as the structural material may be crucial and inevitable.