SIV7.2

原型炉に向けた炉工学研究の進展と大学における工学基盤
SIV7．２ ブランケット研究の進め方と工学基盤
7.2 Development Strategy of DEMO Blanket and Its Engineering Basis

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This symposium intends to consider the strategy for the development of first power generating fusion reactor and to identify the most important technical issues toward it. Among them, there is no doubt that blanket is a key element, because of its function of tritium breeding and energy conversion. ITER TBM is the major step toward it, and the Broader Approach emphasizes material development as the part of DEMO R&D project. However if fusion would be a potentially viable energy source, technology development for blanket as an integrated system is the major defect in the world fusion development path. In comparison with the fission power plants, blanket itself corresponds to the fuel assembly, and the power train, such as steam generator, CVCS, turbine and heat rejection are the core of the energy generation. Not only technical difficulty, confident safety and attractiveness to the market also depend on the technical feature of the blanket and its power system.

It should be noted that a well-organized integral strategy is needed to be launched. In parallel with ITER-TBM program, some of the fundamental issues for power reactor blanket should be evaluated and research activity must be started. Engineering issues require large scale facilities. Basic studies such as material developments will also be needed not only for better understanding of scientific feature of the blanket materials, but also to establish design data base and technical standards. Universities are expected to play major roles in both engineering and fundamental studies, although some of the large scale facilities need special arrangements as nationally supported projects. They will include blanket systems test facility for neutron irradiation, tritium and activated material handling, and energy transfer loop. Some may be considered to be a part or extension of the blanket programs, but most are not covered. Integration with divertor systems as energy conversion component is also needed.

For the electricity generation plant, target parameters for DEMO are considered to be considerably higher than that of ITER energy flux and density, that requires further improved performance of energy conversion and transfer from in vessel components. Heat exchanger / steam generator and power train design together with tritium confinement under the normal and off-normal conditions are major concerns, because environmental impact will be emphasized in the future market. For this target, we propose development and testing of blanket systems at lower power density, lower pressure and smaller scale nuclear testing will be an alternative option other than DEMO after ITER.

In the technical options of the blanket, liquid concepts are considered as attractive but more advanced design. However in the fact, liquid breeder such as liquid metal or molten salt provides easier and simpler blanket design as the first step of nuclear testing. Kyoto University proposes high temperature liquid LiPb blanket concept for the use of fusion-biomass hybrid that requires Q<5 plasma with lower power density in the blanket, while only ambient pressure is involved. Figure 1 shows the concept of the system.

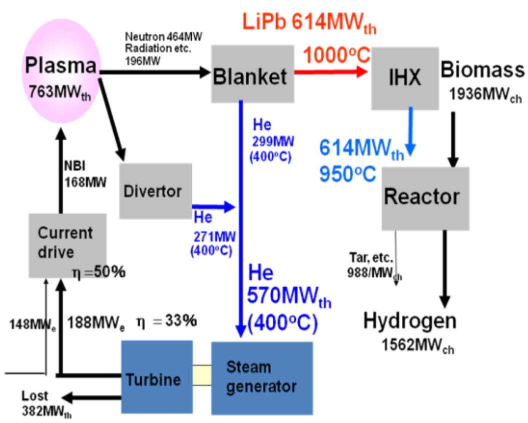

Fig.1 Energy balance of the fusion reactor for biomass fuel production.

Liquid LiPb blanket transfers heat from the small power fusion reactor to the chemical reactor to convert biomass to hydrogen. With fusion output Pf to be 760MW, the plant can provide positive net energy production of 1560MWch (chemical) as fuel, while additional 150MW of external electricity is needed. Feasibility of the high temperature blanket, that seems to be challenging, is one of the key issue of this concept. High temperature LiPb liquid metal blanket combined with SiC/SiC material is designed and being tested to make this option possible. The conceptual design of the blanket structure was made using neutronic and thermal hydraulic analyses. Figure 2 shows the simplified flow diagram of the LiPb-He dual heat transfer loop in Kyoto University, and its photo.

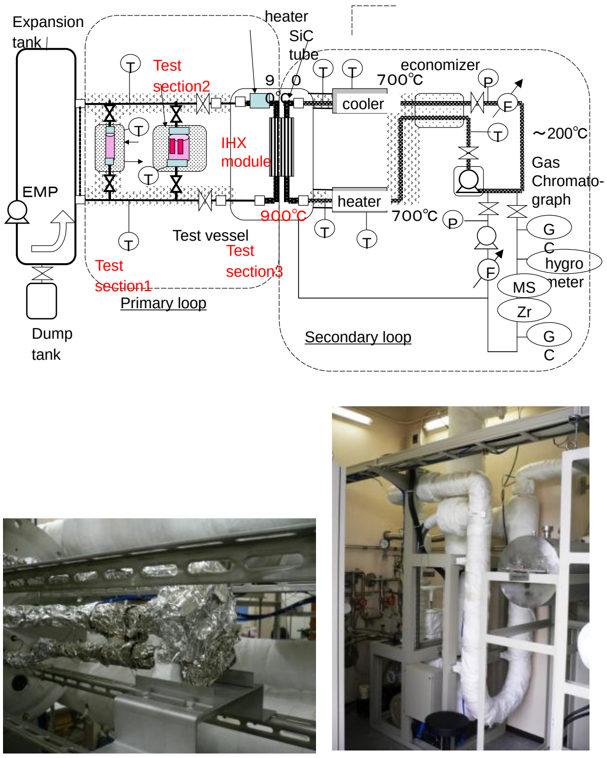

Fig.2 Lead Lithium loop in Kyoto university.

Verification of Tritium Breeding Ratio not only from neutronics aspects but realistic mass balance in the integrated fuel loop is one of the major issues to launch DEMO project with confidence. Recovery and economy of tritium fuel must be evaluated with ITER under limited condition, but other neutron sources are desired for the development of blanket concepts. Combination with tritium recovery process and estimation of the inactive inventory in blanket materials should be estimated. Figure 3 shows the flow of tritium in the biomass-fusion reactor system with LiPb. In any kinds of fusion plant, its environmental release comes from tritium transfer and permeation in normal operation. To control the tritium in the plant, as well as the emission to the environment and dose to the public will be one of the critical development paths for fusion energy.

The blanket technology determines the feature of the entire fusion plant, because both power and tritium, that are the major concern to the public for the energy source, comes from blanket. And as shown in the above case, biomass-fusion concept provides fuels instead of electricity as the fusion energy product, with smaller plant size compared with electricity generation, and show some advantageous feature of low system pressure and small tritium emission. However its key technologies require engineering verification in the integrated experiments. There should be many more potentially attractive blanket concepts, but all of them require integrated test facility to identify technical issues for realistic design. Basic studies on the blanket technology will also need such kinds of facility beyond the material development phase. Neither Broader Approach nor ITER/TBM provides this kind of research activities. The research plan proposed by Sagara in this symposium would be expected to be one of the possible first steps for the next generation reactor technology study toward fusion energy.

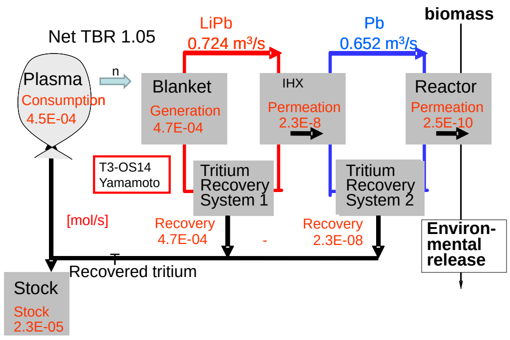

Fig.3 tritium flow in the biomass-fusion hybrid plant with LiPb blanket.