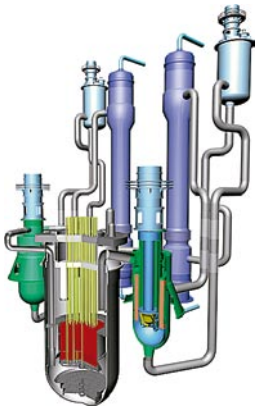

Mitsubishi Activities for FBR Commercialization Development

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The fast breeder reactor (FBR) cycle enabling the effective use of uranium as a semi-permanent resource was selected as an "essential national technology" and has been developed as a national project in which MHI has positively participated. In October, 2006, its proposed sodium-cooled loop-type large-scale FBR was adopted as a principal concept of commercial reactors. In April 2007, MHI was selected as the core company to carry out the development of FBRs on the strength of its past achievements. In response, MHI established Mitsubishi FBR Systems, Inc. (MFBR) to promote the development of FBRs. As the core company, we are determined to continue carrying forward the intensive development of FBRs at an accelerated rate toward the planned start-up of the demonstration reactor in 2025 to ensure early commercialization of FBRs.

1. Introduction

Through the effective utilization of uranium, the FBR cycle has the potential to generate ten times the energy of other energy sources (**Fig. 1**) and is expected to be a semi-permanent resource.[1] In addition, CO_2 production can be reduced down to approx. 1/100th that of fossil fuels, greatly contributing to the measures against global warming. Up to the present, the FBR research and development have been conducted as a national project centered on the Japan Atomic Energy Agency (JAEA), and in March, 2006, the technology was selected as an Essential National Technology[2] by the Council for Science and Technology Policy, stating that the "FBR cycle technology that can greatly contribute to the stable supply of energy for the nation to the benefit of its industrial development as well as improvements in peoples' lives, and, accordingly its development will need large-scale and long-term support by the state." Furthermore, in response to the basic policies for FBR development, compiled by the Atomic Energy Commission of Japan,[1] the concrete objectives of the realization of a demonstration reactor (start-up of operation) by around 2025 followed by the introduction of FBRs on a commercial basis not later than 2050[3] was settled. MHI has also positively participated in this national project from the initial stage as a manufacturer of nuclear plants and has accumulated and improved related technology in the areas of design, manufacture and inspection, responding appropriately to the service conditions peculiar to a sodium-cooled reactor.

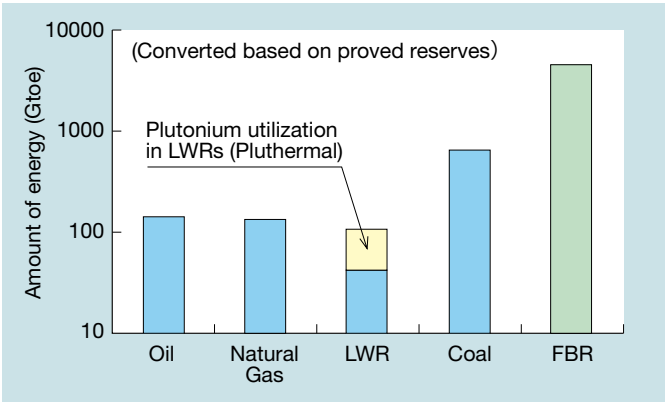

Fig. 1 Potential Productivity of Principal Energy Sources

2. MHI activities for FBR development

The development of FBRs in Japan has been conducted in a staged manner including the experimental fast reactor "Joyo" and the prototype fast breeder reactor "Monju". A plant verification test is underway at "Monju" toward the restart of operations. MHI has taken part in the upgrade work for the "Joyo" MK-III project (improvement of secondary equipment in relation to power upgrading) and the improvement of "Monju" to prevent sodium leaks, in addition to the commitment to the plant engineering, design, manufacture and on-site work for the maintenance and replacement of these main components, and thus has significantly enhanced not only the overall plant technology related to the design, manufacture and on-site work but also the maintenance and repair technology associated with the sodium-related components and piping systems.

In addition, MHI has participated in the design and development of the technology for the demonstration reactor promoted by electric utilities as a reactor to succeed "Monju". MHI also took part in the Feasibility Study on Commercialized Fast Reactor Cycle Systems (FS) (from 2001

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to 2005) implemented by power utilities, and manufacturers, under the leadership of JAEA for the purpose of presenting both the concept of an economically competitive reactor and the R&D process to attain the desired result, and thus validated the concept through element tests and conceptual design study.[4] As a result, the concept proposed by MHI was designated as the reactor to be primarily developed (principal concept) in October, 2006.[5]

At the start of the FBR Cycle R&D Project, the Government decided a policy to concentrate the responsibilities and engineering functions to a sole core company, so that FBR development activities could be effectively carried out under a clear chain of responsibility to promote the development of the principal concept, and in February, 2007, JAEA called for applications for a core company to engage in the engineering activities for Fast Breeder Reactor development,[6] for which MHI applied and was successfully awarded in April of the same year.[7] Further MHI established Mitsubishi FBR Systems, Inc. (MFBR) and has been committed to promoting the study and R&D of the conceptual design of commercial and demonstration FBRs in cooperation with JAEA.

3. Outline of Sodium-Cooled Loop Type Large-Scale FBR Plant

Since a commercial FBR is required to have economic efficiency equivalent to a conventional LWR, MHI proposed the innovative concept of a sodium-cooled loop type large-scale reactor in which innovative technology is incorporated for enhanced safety and reliability besides being economical (**Fig. 2**). The present concept aims not only to increase the output power but also to reduce the amount of construction materials as much as possible through the reduction in the number of loops, the adoption of high-chromium steel with low expansion coefficient and high-temperature strength,

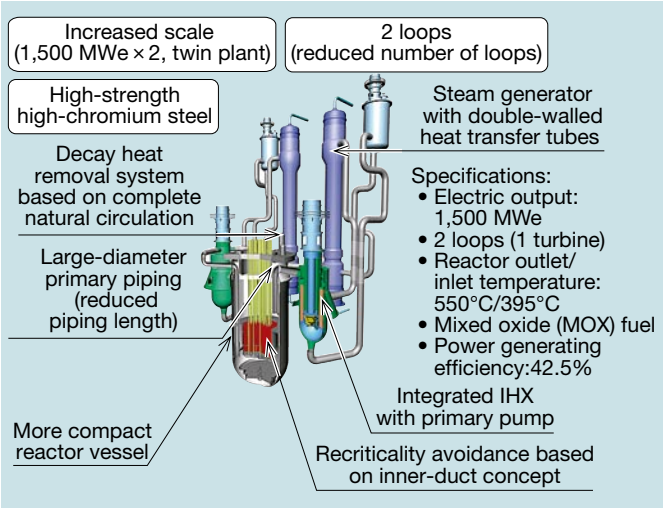

Fig. 2 Sodium-Cooled Loop Type Large-Scale FBR[4]

shortening the piping length by connection of outlet/inlet piping to the upper part of the reactor vessel, as well as the integration of a pump into IHX (integrated IHX with primary pump) (**Fig. 2**), thereby demonstrating the concept has significant potential for economy. [4,5]

4. Conceptual road map toward a commercial FBR

In order to introduce commercially-based FBRs by 2050, the construction of a demonstration reactor is indispensable to implement step by step development based on the element study and simulation tests on an engineering scale in parallel with the design tasks. To address this construction project, MHI believes it necessary to adopt a two-stage development strategy, i.e. the Development Test Reactor to demonstrate the concept of a commercial reactor with leading innovative technology (500-600 MWe: to be operated by about 2025)

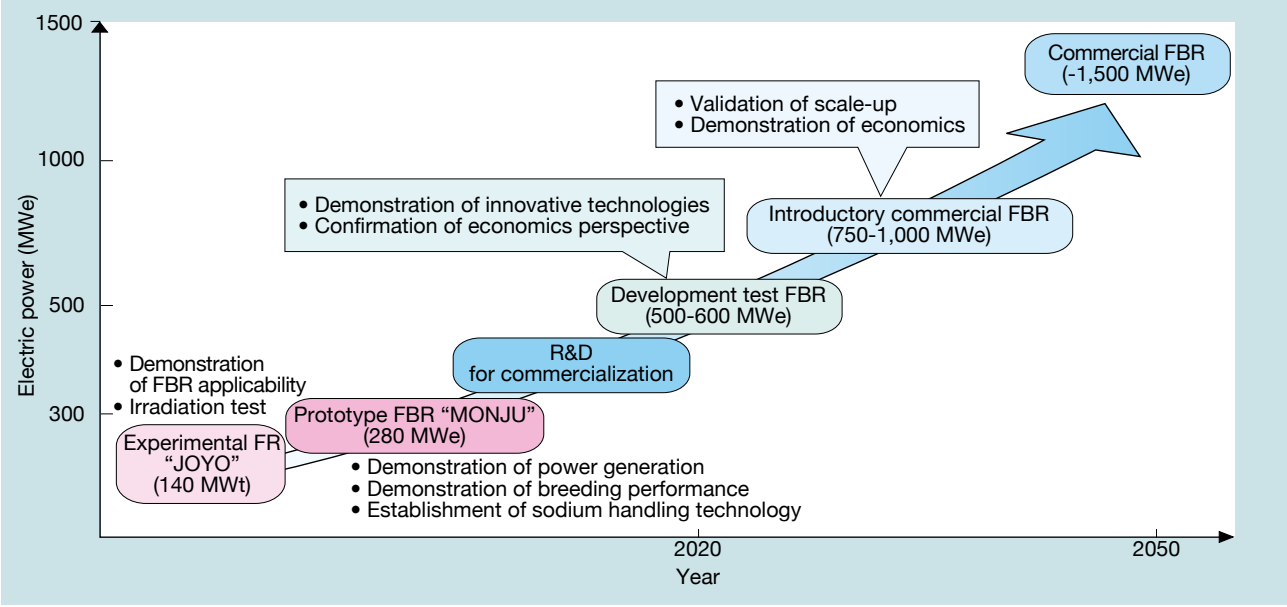

Fig. 3 Conceptual Road Map for the Development of Commercial FBR[8]

followed by the Introductory Commercial Reactor to validate the increased scale and achievement objectives (economic efficiency including cycle incidents) (750-1,000 MWe: to be operated in about 2035) (**Fig. 3**).[8] Incidentally, it will be essential to be prepared for long-term maintenance and handing down technical competence along with the cultivation of human resources toward the production of FBRs around 2050, and therefore, the present two-step strategy is a meaningful methodology for development.

5. Efforts associated with international standardization

In recent years, not just in Japan but worldwide, the necessity for the development of FBRs is becoming more recognized, reflecting the concepts of the effective utilization of uranium resources as well as the reduction in radioactive waste.

In the Generation IV Reactor Project, an international project in which 10 countries and the EU are taking part, the FBR cycle has been nominated as a major candidate for the future. A demonstration reactor, BN-800 (800 MWe), in Russia, a prototype reactor (500 MWe) in India, and an experimental reactor (25 MWe) in China are under construction aiming at commercial operation around 2030 pursuant to their respective national policies for the development of the FBR cycle.[9]

On the other hand, in the U.S.A., the Global Nuclear Energy Partnership (GNEP) program was presented by the Department of Energy (DOE) in 2006 to express the necessity for fast reactors (advanced recycling reactors).[10] The DOE invited package proposals for advanced recycling reactors to form the technical core of the program along with the Consolidated Fuel Treatment Center for reprocessing spent nuclear fuels in order to bring about the GNEP program.[11] MHI made a proposal for GNEP program in cooperation with AREVA and Japan Nuclear Fuel Ltd., and it was successfully awarded. MHI aims at the standardization of the sodium-cooled loop type large-scale FBR, the principal concept originating in Japan, to become the leader of the design and development of advanced recycling reactors, and is currently investigating the advanced recycling reactor in this line.

It is anticipated that from now on FBR development will be promoted as an international collaborative research and development theme and MHI will further increase its share of international cooperation under the guidance of the government, JAEA and power utilities.

6. Conclusion

MHI has participated in the national project since its initial stage recognizing the importance of FBR cycle and has cultivated technology across the broad range of FBR plants through its experiences with "Joyo" and "Monju", the design study of demonstration reactors, and so on. MHI proposed a sodium-cooled, loop-type, large-scale FBR to be selected as a principal concept of commercial FBR on the basis of this technology, and in 2007 was selected as the core company to engage in engineering activities for fast breeder reactor development by the government. Furthermore, MHI has established a new company MFBR to push forward this project.

To promote FBR development, it is essential to establish the basic specifications for the demonstration reactor, a road map toward construction, and select a site, at an early stage in addition to the early resumption of "Monju". MHI is determined to promote a commercial FBR, establish the technology on a industrial level, and contribute to the progress of society, while being committed to furthering the maintenance and handing down of technology in parallel with the development and reinforcement of human resources to meet the urgent needs of the times in cooperation with the JAEA.

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