§2. Historical Study of Fusion Research Based on Experimental Devices

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We studied the historical evolution of fusion research in Japan based on the documents and materials on experimental devices. We summarized the results in the following providing the names of main devices.

Fusion researches in Japan began around 1956 with the pinch experiment at Osaka University, the torus experiment at Nagoya University, and Scylla type experiment at ETL, Tokyo. Until 1958, the high-temperature-plasma devices based on the three confinement approaches - pinch, mirror and stellarator concepts - were built to confirm and extend the works published so far in the world. The major efforts in the early experiments were focused on production of high-quality plasma and reliable control of the devices by the improvement of device and by the development of technologies. Each experiment encountered technical difficulties and was also experiencing various problems such as arcing, electric breakdown and lack of reproducibility. In order to understand the plasma behavior in a magnetic field, small-scale experiments were carried out for studying wave excitation, diffusion and radiation in the cold plasma produced in the glass discharge tube. Experiments for fundamental plasma physics were done prior to developing the technology for high temperature plasma production.

During 1965 to 1970, by advances in technologies of the fusion plasma devices and in plasma experiments, the production of high-quality plasma became feasible and Joule-heated plasma studies were progressed. Since experimental confirmation of usefulness of minimum B and average minimum B for confinement as well as improvement of the confinement time in T-3 tokamak, laboratories in the world began to build tokamaks. A new generation of torus experiments started such as toroidal hexapole device, JFT-1, at JAERI and JIPP-I stellarator at IPP, Nagoya University.

1970~1975: The success of plasma heating in ATC Tokamak enhanced interest in instabilities and heating of plasma. The toroidal device experiments were advanced to JFT-2, JIPPT-II stellarator/tokamak and Heliotron C, which provided auxiliary heating by RF and NBI. Small tokamaks (TNT, TORIUT at the University of Tokyo, Asperator at Tohoku University, and NOVA at Kyoto University) were built not only for heating enhancement but also for physics studies of plasma heating as well as plasma instabilities. Turbulent heating was investigated as an alternative in OT-1 Tokmak at Osaka University. In fundamental experiments which were upgraded in the capability and in the size, the studies of propagation and absorption of various waves, and of wave–plasma interaction were conducted to understand plasma heating mechanisms by using the wave of LHH, ICRH, and ECRH. More precise experimental studies were carried out by developing the diagnostic technology to interpret the experimental data and theory. Alternative concepts, RFP, FRP and CCT configurations and other tours experiments, were proposed and the studies in these devices were initiated in CCT, STP, and NBT-1 at IPP, Nagoya University and in TPE-1 at ETL.

1976~1980: The experiments of NBI and RF heating were carried out successfully in JFT-2, JFT-2a, JIPP T-II and Heliotron D. Studies of high-beta plasma production were carried out in small Tokamaks (TNT and TORIUT at the University of Tokyo, HYBTOK at Nagoya University, WT-1 at Kyoto University, and Asperator T-4 at Tohoku University) with high power heating and with non-circular cross-section plasma. Alternative concept experiments were enhanced and RFP (TPE-1 at ETL, and STP), FRC (OCT at Osaka University) were actively investigated. Open System was studied for plugging plasma by RF in RFC-XX at IPP, Nagoya University and for minimum B plug with Yin-Yan coil in GAMMA 6 at Tsukuba University and for the confinement of high temperature plasma by the injection of plasma and high energy ion in PIIAC at Osaka University. In order to support large fusion oriented plasma experiments, physical and technological studies were continued in the small devices. Development of the device for high power heating by NBI and by RF, and of the important components such as high power ion source and Gyrotron was carried out. Large Tokamak JT-60 with the poloidal divertor was constructed providing high power NBI development. The fusion program in Japan was directed from fundamental research related to plasma physics to the high temperature fusion plasma researches and the fusion engineering researches.

1981~1985: After H-mode was found, researches on Tokamak were promoted. Small tokamak studies at Universities progressed to the high power heating and the current drive thanks to developing RF heating device. Studies of the alternative for high-beta plasma confinement were continued on STP-3M, TPE-2, OCT and TS-3 Spheromak. Their studies were focused on production of the good magnetic field configuration for stabilities and of the high temperature plasma. The studies on mirror systems were progressed to hot plasma confinement on RFC-XX and on TANDM mirror GAMMA 10. Heliotron devices were upgraded to Heliotron E and JT-60 experiment was started. TRIAM at Kyushu University was constructed for the steady operation of Tokamak with toroidal current drive.

After 1986: Large device experiment was accelerated to get the data of confinement scaling for the design and discussion of next stage fusion machines. LHD project started in 1985 based on the physics and technology database established so far.

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