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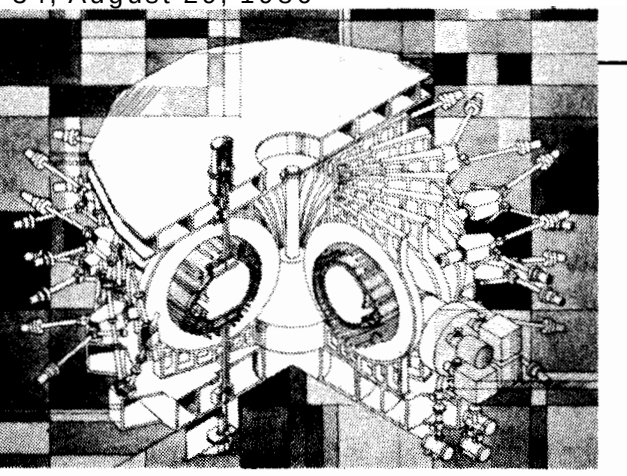
The status of the tokamak projects



The JT-60, a large tokamak designed by the Japanese Atomic Energy Research Institute.

The **TFTR,** built and operated at Princeton University for the Department of Energy, in mid-July achieved a new temperature record of 200 million degrees Celsius, 10 times hotter than the center of the Sun and the highest temperature ever recorded in a laboratory. "This marks a major milestone in progress toward the development of fusion energy," according to Energy Secretary John S. Herrington. "The temperature achieved is in the range required for a fusion reactor. These promising results bring us closer to the goal of fusion energy," he said.

JET is the Joint European Torus, a project of the European Community. It is by far the world's biggest tokamak in terms of the volume of plasma contained—and volume is important (see line 14 on Table 1). JET and the TFTR are the only tokamaks equipped to handle tritium—the deuterium-tritium combination is 200 times more reactive than deuterium-deuterium. Neither has yet achieved results adequate for introducing tritium.

JT-60 is the big Japanese tokamak, operational only since April 1985. The early results shown here are based on incomplete instrumentation and are only indicative, according to Dr. Curt Bolton of the Department of Energy Office of Fusion Energy. Neutral beam heating began this month, and its substantial contribution should be reflected in early results, Bolton says.

MIT's **Alcator C**, operated under contract with the Department of Energy, was designed to achieve break-even with a small, compact machine using very strong magnetic fields (Table 1 lines 2, 3 and 10). Alcator C will cease operating in November 1986, but may be reincarnated at Lawrence Livermore National Laboratory. The successor machine at MIT, the **Alcator C-Mod,** will have new toroidal and poloidal magnets and a new vacuum chamber. It has been designed to maintain a high Lawson product ($n\tau$) while achieving high temperatures with radio frequency heating. It is projected to achieve 5 kiloelectron volts while $n\tau = 1\text{-}2 \times 10^{14}$, according to Dr. Ron Parker of MIT's Plasma Fusion Center. That would still be below the threshold for full ignition. But C-Mod would serve as a half-scale prototype of the projected Compact Ignition Tokamak (CIT), having the same magnetic field as the eventual CIT, according to Parker.

Doublet III is GA Technologies' experiment in confinement quality (Table 1 line 8). It has already been succeeded by Doublet III-D (first plasma, February 1986), but it is too early for significant results. High betas (β), or the ratio of the outward pressure of the plasma to the field strength required to confine it, are expected this winter, once neutral beam heating is in place, says Dr. James Luxon, technical coordinator for the Doublet.

ISX-B, the Oak Ridge National Laboratory experiment in confinement efficiency, was shut down in 1984. Because of stingy funding, there is no successor tokamak planned. The lab is building a stellarator, the Advanced Toroidal Facility (ATF), that is expected to achieve high β at high temperatures in steady state operation, according to Dr. Michael Saltmarsh, head of the ORNL Confinement Projects Section. It will operate with plasma in March 1987, "but we will not have a clear picture of what it will do for about a year," Saltmarsh says.

ORNL's continuing major contribution to tokamak research is its development of neutral beam and pellet injection equipment—technologies as complex as the tokamak proper. The TFTR uses pellet injection built at ORNL, and Princeton's PBX device uses four ORNL neutral beam injectors.

The **Soviets** are still a major contributor to tokamak development—an approach they invented—while not at its forefront. Their current machine, the **T-10**, is roughly comparable to the Princeton Large Torus (PLT), a leading machine of the late 1970s. Work done with the T-10 on electron cyclotron heating (a form of radio frequency heating) has been unique.

The next Soviet tokamak is to be the T-15, according to Bolton at the Department of Energy. The T-15, he says, is the rough equivalent of the TFTR or JT-60, and construction is under way. "Two years ago, it was to come up in 1986; obviously, there have been delays," Bolton says.

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