Plasma Fueling Technologies

For a sustained fusion reaction, plasma fuel must be continuously fed into the magnetic confinement chamber to replace the plasma fuel consumed by the fusion reaction. Since the confinement chamber operates within a vacuum, the original approach to plasma fueling consisted of injecting small puffs of fuel gases into the vacuum surrounding the confined plasma and allowing the materials to drift into the reaction zone. But, as the machines were scaled up, larger and denser plasmas turned out to be more difficult to fuel by gas injection from the edge because the gas could not work its way into the center of the plasma. This problem has been solved by development of a new approach based on propelling a frozen pellet of deuterium deep into the plasma. The fuel is propelled with sufficient force to penetrate the hot plasma fuel core and then melt, thereby releasing its positive ions and converting to plasma.

Building on this concept, the "pellet gun" was developed. Firing its pellets of frozen deuterium and tritium deep into the center of reactor grade plasmas, the pellet gun now provides the balanced refueling capability necessary in fusion reactors. It is a simple efficient method that is compatible with all heating methods.

Through use of the pellet gun, plasma fuels of record density have been attained, a key factor in attaining an N-tau of 100 trillion on the Alcator C fusion device. So successful is this method that it is now the principal refueling technique being applied on the TFTR and the Joint European Tokamak.

Materials Technologies

Materials technology requires selecting, testing, and evaluating candidate materials for components of experimental systems and providing the scientific and engineering data base needed to do the same for commercial reactors. Materials research has led to significant advances in the identification and development of materials for service in the fusion environment. This has expanded the range of designs possible for a commercial power producing fusion

Technology for National Defense

High technology developed for magnetic fusion energy has become increasingly important for the United States National defense program. This is especially true for the so-called directed energy weapons systems. A vital segment of the technology base supporting development of neutral particle beams, electron beams, microwave beams, and free electron lasers is the product of early magnetic fusion energy research.

The technology developed for the neutral beam injectors which heat fusion plasmas to millions of degrees has been transferred to the Strategic Defense Initiative (SDI) Program where it is being modified to meet unique defense applications. The neutral beams used in the MFE program are attractive because of the extremely high beam powers which have been attained.

Both the technology and feasibility of producing powerful sharply focused beams of electrons were first demonstrated in association with an early fusion experiment called the Astron Project. It included a high current electron accelerator termed a linac, capable of injecting a tightly collimated beam of very high energy electrons into a long cylindrical vacuum vessel. The project also developed advanced techniques for manipulating such beams.

In the early 1970's, experiments to study the propagation of these beams through gases were begun with the linac. This use of the Astron accelerator continued after the termination of the Astron experiment in 1973. Over time, the linac evolved into the Advanced Test Accelerator, the major National facility for research in electron beam weapon feasibility. The accelerator is also being used for experiments on high power microwave and laser weapons.

Microwave tubes similar to those used in plasma radiofrequency heating have been developed by the same companies for use in various military applications. Building on developments from the gyrotron program, gyroklystrons and gyro-traveling wave tubes have been produced. These oscillators and amplifiers offer advantages such as higher efficiency, compactness, high power and high frequency. For radar use, the higher frequency gives higher resolution of targets, and the higher power results in increased radar range and resistance to jamming. These characteristics are very attractive for strategic defense systems.

Another new technology is being developed using the induction linear accelerator in the Advanced Test Accelerator. The accelerator produces pulses of electrons which are passed through a magnetic "wiggler structure" to produce a laser with extremely high power levels. This so-called free electron laser is being developed by the SDI Office and is a front runner in the current directed energy weapons research program. The free electron laser is also an important potential new heat source for plasma heating.