DOUBLE YOUR PLEASURE DOUBLE YOUR FUN

Doublet, a plasma with an unusual two-lobed cross section, performs well in fusion experiments

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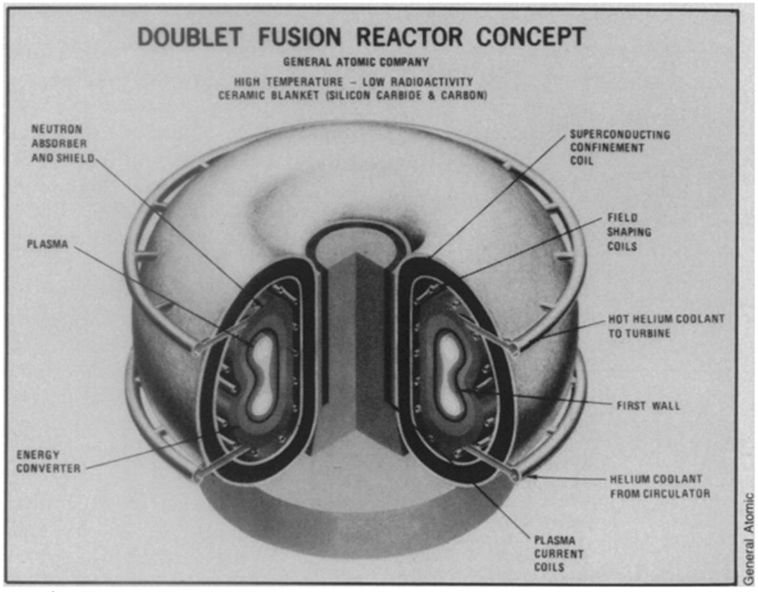

A fusion reactor based on the doublet concept might look like this.

"Doublet" is not a garment worn by Shakespearean actors with hosen, breeches and cracowes as they tread the boards of the Folger stage—at least not among those concerned with experiments in controlled thermonuclear fusion. It is instead the name of a rather singular experiment in the general class of those attempting to confine a plasma in a toroidal or doughnut shape. The intent of all such experiments, of course, is to find ways to confine a plasma, a fuel in which the atomic nuclei have been separated from the electrons that normally orbit them and make it dense enough and hot enough for fusions to occur among the nuclei, releasing useful energy.

Among the general class of toroidal experiments doublet gets its name from the unusual cross section of its plasma, which takes the form of a double circle or figure 8. The usual toroidal experiments, most of which are called tokamaks, use plasmas with simple circular or elliptical cross sections. According to Teruo Tamano of General Atomic Co. in San Diego, where the doublet experiments have been concentrated, the doublet shape yields important advantages in confinement, stability and density of the plasma—factors important to any hope of obtaining useful energy from controlled fusion—compared to plasmas of other cross sections. The hope is that future work will see more improvement. Tamano described the results of the latest doublet experiment, known as Doublet IIA, at the recent meeting of the Plasma Physics Division of the American Physical Society in San Francisco.

The doublet plasma showed a stable confinement up to a time of 25 nanoseconds. More important perhaps than the time itself is that no major disruptions were recorded in the doublet-shaped plasma even though electric heating currents up to 300 kiloamperes were run through it, and the confining magnetic field reached 8 kilogauss. High values of both these factors can sometimes contribute to plasma disruption. In all, Tamano calls the experiment a demonstration of equilibrium, stability and good confinement.

Probably the most significant datum concerns the product of confinement time and plasma density, the so-called Lawson criterion, which is often used as a basis of comparison to rate different experiments' approaches to the state that could actually yield an energy gain. The Lawson criterion for the doublet plasma was seven times that for a circular plasma with all other factors equal. It was also three times that for an elliptical cross section.

The doublet apparatus is designed so that it can compare plasmas of the three different shapes within itself. Tamano says the changes from elliptic to circular to doublet can be made in the same day. The vacuum chamber in which this is done is a toroid with an oblong cross section: The radius of the doughnut itself is 66 centimeters; the cross section is 35 centimeters wide by a meter high. An array of complicated diagnostic equipment monitors the shape and characteristics of the plasma. The doublet shape is produced by manipulation of the magnetic field. The experimenters excite certain coils to generate a magnetic field that pinches in the middle of the plasma and forces it to compensate by developing lobes above and below the middle.

The doublet configuration is especially stable against internal disruptions that can arise from interactions between the charged particles of the plasma and the balance of the magnetic fields inside the plasma and outside. Tamano attributes this to the shape, which results in a distribution of magnetic field modes inside and outside the plasma in such a way that the plasma has a hard time coupling the inside and outside modes to each other and opening a channel for escape. Also the doublet can contain a more dense plasma than other shapes because of its high volume-to-surface ratio, which makes the balance of surface-tension forces and disruptive outward pressure more favorable.

"Things look very good," says Tamano. The outstanding question is how dense a doublet plasma can be made, or to put it in the usual plasma physicist's terms, how large a beta can be gotten. Beta is the term that measures the ratio of the outward pressure of the plasma (which depends on its density) to the inward pressure of the confining magnetic field. Ideally, beta values as close to one as possible would represent the energetically most efficient operation of a fusion experiment.

Tamano reminds us that beta values for the usual toroidal (tokamak) experiments have generally remained low (although there is now talk of high betas in ordinary tokamaks—more in a later article). This is a trade-off against temperature. Fairly high temperatures can be obtained by ohmic heating—running an electric current through the plasma itself and letting its own electrical resistance heat it. But for that to work, the plasma density has to be kept fairly low, and typical betas for circular-cross-section plasmas run to about 0.5 percent. At present the doublet's beta runs to 1.0 percent.

Both of these are far away from a percentage in the 80s or 90s, say, and the next effort will concentrate on using a method of auxiliary heating, radiofrequency waves, which do not suffer the density limitation of ohmic heating. The idea is to see just how high the beta for a stable doublet plasma can be pushed by this means. □