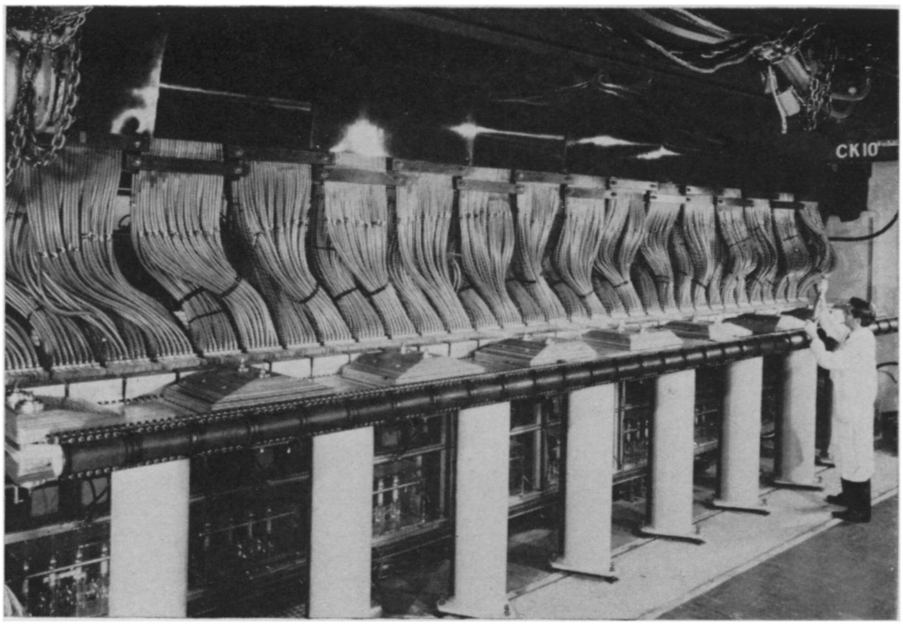
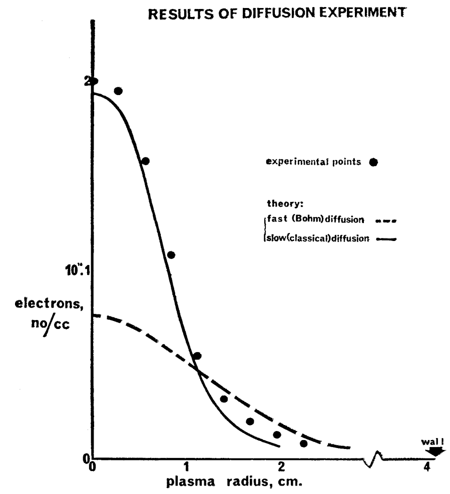


Photos: Culham Laboratory

The eight-meter plasma confinement device at the Culham Laboratory.



Density profile at 20 microseconds

Culham's results match theory.

CONTROLLED FUSION

Plasma confinement improved

While nuclear engineers are harnessing the nuclear energy of uranium fission, they have had little success so far in controlling the even more impressive thermonuclear power of fusion: the basic process of the hydrogen bomb.

The difficulties and frustrations in fusion research come from the otherworldly temperatures needed to stimulate fusion, and the need to keep the fusion material—at those temperatures an electrically charged gas or plasma—confined long enough so that fusions can happen.

The confinement problem has been a major stumbling block. Now, experiments in both Germany and England have shown that in some cases the plasma behaves in a way that they had hoped for but never before seen. A major step toward confinement, the experiments give fusion workers a direction in which to work.

The energy from both fission and fusion comes from the fact that for some elements, the nucleus is not the same weight as the sum of its parts. The nucleus of a heavy atom—uranium, thorium or plutonium, for example—is heavier than the total number of protons and neutrons that make it up.

The extra mass represents the energy contributed by the forces that hold the nucleus together, and it is this binding energy, or part of it, that is set loose in the fission process.

At the low end of the weight scale, where helium, lithium or barium are found, the complexities of the nuclear binding force make nuclei that are actually lighter than the sum of their parts. Instead of giving up energy when they come apart, these nuclei give it up when they come together.

Everything in nature tends to move toward lower energy states; this should make fusion a downhill slide. However, the attractive force that pulls the parts of the nucleus together is of very short range—about the dimensions of a large nucleus. Beyond such distances, electrical forces dominate the situation, and nuclei repel each other since they are always positively charged.

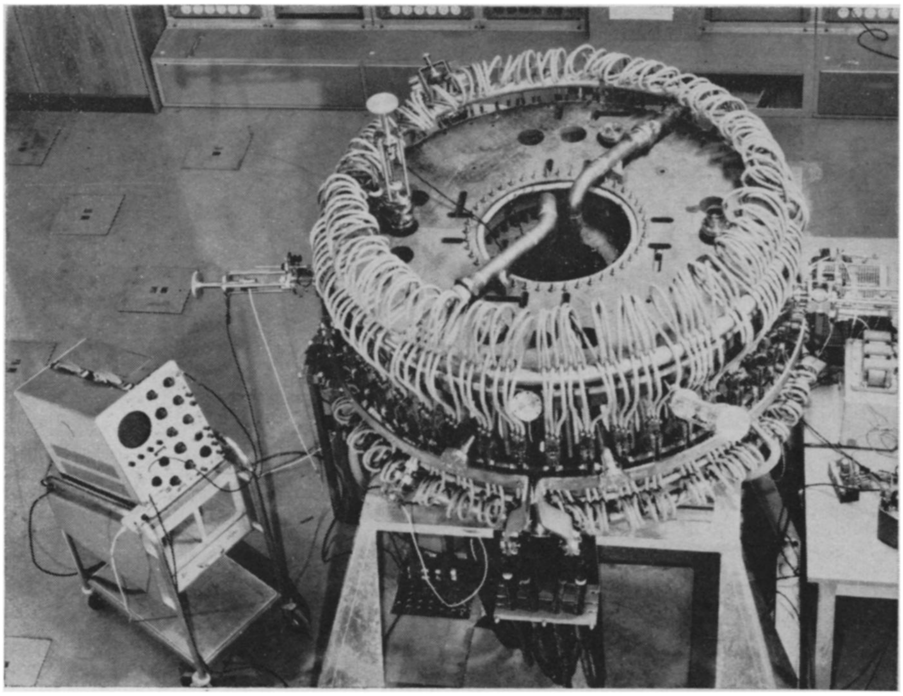
The problem is to overcome the electric forces and get two small nuclei close enough together for the nuclear force to take over and fuse them into a bigger one. This requires high temperatures—on the order of hundreds of millions of degrees.

Such heating ionizes a neutral gas into a charged plasma and imparts high enough velocities to the particles for them to overcome the electric forces, and if they can be confined in a narrow space for a long enough time, a useful number of fusions can occur. Researchers try to hold a plasma inside a vacuum chamber with magnetic fields that have a tendency to squeeze it into a cylinder.

But the attempt to hold a plasma like this is bedeviled by many troubles. If an open-ended cylinder is used, the plasma is likely to blow out the ends. One can get rid of the ends by using toroidal shapes—donuts or twisted donuts. But plasmas are still subject to various instabilities, unwanted turbulences that, once they get started, blow the plasma apart. And plasmas are always subject to diffusion, a steady sideways motion of particles which take some of them to the wall of the chamber where they are absorbed or neutralized.

It is on the diffusion front that the German and English results represent a major step toward the goal of controlled fusion.

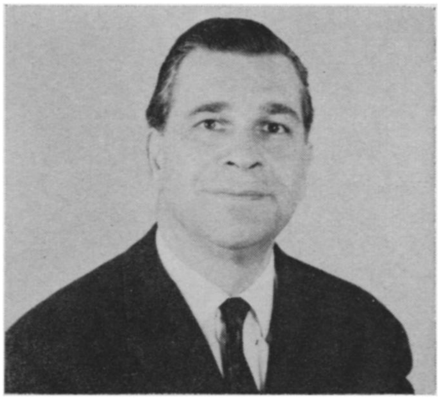
At the Max-Planck-Institut für Plasmaphysik at Garching near Munich, Drs. Gerhart von Gierke, Günter Grieger, Karl Ulrich von Hagenow, Erhard Berkl, Dieter Eckhartt, Einar



Photos: Max-Planck-Institut fur Plasmaphysik

Wendelstein II, Garchings toroidal device that gave classical diffusion.

Grieger: Ask not why it conforms.



Dr. Gerhart v. Gierke leads the group.

The march toward fusion goes a step at a time. but there is now renewed hope of getting there

Hinnov and Wolfgang Ohlendorf have achieved what is called classical diffusion in a barium plasma in a toroidal device, Wendelstein Stellarator W II.

Classical diffusion is so called because it is calculated according to a relatively simple classical theory of the motion of charged bodies in magnetic fields. It predicts a relatively slow diffusion rate that gets slower very rapidly as the magnetic field increases. The observation of classical diffusion is itself an important step; in all toroid devices up to now physicists have observed what they call Bohm diffusion—a much faster rate that does not improve very much with increasing magnetic field.

Theorists are just beginning to explain why Bohm diffusion happens where it does. Meanwhile experimenters are heartened to find that classical diffusion, which is better understood, can happen, and that therefore the classical theory, which heretofore has been far from experimental results, is of some practical use. Why this particular toroid did it is not currently at issue. "It should never be necessary," says Dr. Grieger, "to ask why an experiment conforms with theories. Ask rather why one does not conform."

As the next step, says Dr. Grieger, "We must find another mechanism to generate plasma. [Our present one] isn't going to work at the very high temperatures [several hundred million degrees C.] that we need to get fusions with sufficient frequency."

The English experiment was done at the Culham Laboratory by Drs. Hugh A. B. Bodin, John McCartan and Gerd H. Wolf, and Ian Pasco and Alan Newton. They used an open-ended device eight meters long, in which they managed to keep the plasma confined for long enough—between 10 and 30 microseconds—to make meaningful measurements of the diffusion across the tube. Their measurements also fitted the classical prediction best.

There has never been evidence of nonclassical diffusion in plasmas held in straight devices. But plasma in such devices usually blows out the ends too fast for measurement of diffusions. Now, in the British work, there is evidence for classical diffusion in straight devices.

The British results are increasing expectations for a major element in the U.S. controlled fusion program: Scyllac, a 15-meter straight plasma device planned for Los Alamos. Money for Scyllac, though authorized earlier, has just been released. Atomic Energy Commission spokesmen deny that the release is connected with the British result—authorized money, they say, can sometimes be held up pending detailed review of a project.

But AEC scientists concerned with Scyllac are encouraged by the British result. The showing that classical diffusion can exist in a straight device gives them a greater hope of achieving it with Scyllac. Since Scyllac will be nearly twice as long as the Culham device, it should be able to hold the plasma within its magnetic bottle for a longer time.

Meanwhile at Princeton University physicists are trying to achieve classical diffusion in toroidal devices. So far, says Dr. Shoichi Yoshikawa, they have achieved rates up to 20 times more favorable than Bohm diffusion, but they have not yet reached as low as classical diffusion.

Toroids are favored by many, including the Culham people, for easier long-term holding of the plasma. Scyllac, says Dr. Bernard J. Eastlund of the AEC, is designed so that it can be converted to a torus after straight-tube experiments are over.