have raised some of the same questions" as Niemczyk has.

In contrast to these design and analytical questions, the new GAO report focuses on more obvious problems that signal age — valves that are becoming worn, graphite that is becoming misshapen, unreliable mechanical systems. In fact, it was largely his concern about having to fix these nuts-and-bolts types of safety-related problems that prompted Sen. Mark Hatfield (R-Ore.) last week to say, "I am convinced that the N-Reactor should be shut down by 1995 for economic if not safety reasons." Toward that goal, on Aug. 7 he marshaled legislation through his subcommittee on energy and water that would strike $21 million from DOE's 1987 budget — money DOE had earmarked for beginning renovations to extend the life of the reactor well into the next century. The legislation also instructs DOE to consider closing the plant.

N-Reactor's main function is to produce plutonium for nuclear weapons. Because plutonium is being stockpiled, Weaver says the plant is not needed.

DOE disagrees. Not only does the reactor produce electricity at a cost that is below the national average, says DOE spokesperson Jack Vandenberg, but also "we feel it is needed to produce plutonium. However, since supplies of plutonium are a classified matter, we cannot discuss that in any detail." *— J. Raloff*

Galaxies cluster around cosmic strings

How the galaxies formed is one of the most serious questions in cosmology and astrophysics. Most theories assume that the universe started out smooth and undifferentiated, but for galaxies to have formed, there had to be some kind of flaw in the smoothness, around which matter could gather. One very new suggestion is that these were topological flaws in space-time itself, the so-called cosmic strings. Now a calculation shows that cosmic strings will cluster hierarchically, and this clustering closely resembles the distribution of galaxies seen in what astronomers call Abell clusters. Neil Turok of Imperial College in London described this development in Berkeley, Calif., at the recent Twenty-Third International Conference on High-Energy Physics.

Physicists today treat space-time as if it were a material substance. It is stretchable, compressible and twistable. It can also undergo phase transitions, analogous to freezing or boiling, in which its basic structure changes radically. Cosmic strings are a relic of such a phase change. Phase changes usually take some time to complete themselves; in the same pot there will be both liquid water and bubbles of steam for several minutes. In the case of the universe, scientists are dealing with eons of time. The supposed phase change mostly occurred eons ago, but a few small relics of the previous structure of space-time may still persist.

These topological flaws appear as "strings," which may be either open-ended and infinitely long or closed loops. It is the closed loops that are of interest in the business of nucleating galaxies. As time goes on, they shrink and disappear, giving up the energy they possess as gravitational radiation, but while they last, they exert strong gravitational forces. Responding to these forces, matter will gather around the string loops, and so the evolution of galaxies could begin. Ultimately the string disappears, but the galaxy persists.

In the beginning, string loops come in various sizes. Now, Turok says, interested physicists have calculated that large loops will attract smaller ones to form clusters around them. These loop clusters look geometrically like the clusters of galaxies, particularly the Abell clusters, which are small and dense as galaxy clusters go. Usually they contain more than 50 galaxies in a space no larger than 1.5 megaparsecs (slightly less than 5 million light-years).

Rival theories of galaxy formation have trouble with Abell clusters, Turok says. One of the most common of such theories proposes that the universe wasn't entirely smooth at the beginning, that there were small primordial clumps, density fluctuations, scattered randomly about. There is no explanation why these clumps were there; they are simply primordial. Galaxies could gather around such clumps, and such theories may even have an explanation for the larger galaxy clusters.

But according to Turok, while this theory does not predict the formation of Abell clusters, cosmic string theory does. The clustering of small loops around larger ones mimics the structure of Abell clusters, and it even reproduces the correlation function that describes the sizes of galaxies in the Abell clusters. The correlation function says that the radius of a galaxy in an Abell cluster is inversely related to the mean distance between galaxies in the area where it is. The theoretical calculation of the development of clusters of cosmic strings predicts a similar correlation function. As Turok puts it, "The correlation of Abell clusters fits the prediction from the numerical simulation of the formation of strings."

— D. E. Thomsen

A plasma 10 times as hot as the sun

"Tokamak" is a word composed of the first syllables of the Russian words for "toroidal magnetic chamber." A Russian invention, the tokamak has been voted by many physicists most likely to succeed in achieving controlled thermonuclear fusion. In the toroidal chamber, magnetic fields confine a plasma — an ionized gas — while its temperature and density are raised to the point where nuclei in it should fuse and produce energy. In experiments conducted during July, one of the world's biggest tokamaks achieved a plasma temperature of 200 million kelvin (200 MK).

This temperature, achieved by the Tokamak Fusion Test Reactor (TFTR) at the Princeton (N.J.) Plasma Physics Laboratory, is the highest ever reached in a laboratory. It is 10 times the temperature in the center of the sun, but more important, it is more than enough for break-even, the point where fusions produce as much energy as has to be expended to ignite them.

Besides temperature, break-even requires another criterion: the product of plasma density and confinement time, usually called the Lawson criterion. In April, TFTR experiments at lower temperatures produced a Lawson criterion of 1.5×10^{14} seconds per cubic centimeter, which is close to the goal for a practical reactor and five to seven times what is needed for break-even. However, the 200-MK experiments had a Lawson criterion of 10^{13}, two or three times too small for break-even.

The next step is to put the high values together and get break-even. Donald Grove, TFTR project manager, says they expect to achieve that in 1987 using the hydrogen isotope deuterium, with which they have been working so far. Then they intend to introduce another hydrogen isotope, tritium. Deuterium-tritium fusion, which most controlled fusion experiments today are trying to achieve, produces energetic neutrons, from which energy can easily be harvested and converted to useful things like steam or electric power. They hope for deuterium-tritium break-even in 1989.

One reason tokamaks are expected to succeed is that they should help confine themselves by producing a "bootstrap current," a current flowing through the plasma around the torus. This current will generate a magnetic field that will help the external magnets confine the plasma. In these experiments, Grove says, a current not due to external driving seemed to arise in the plasma. The physicists concluded that this was probably the bootstrap current, Grove says, although supporting evidence for that conclusion so far is nil. *— D. E. Thomsen*