fore their first full-term pregnancy (SN:11/9/85,p.293). But the studies were too small to provide definitive answers; and because most were conducted in the early 1970s, they could not analyze the pill's long-term effects. The new study took up those questions.

"For the first time," says Richard Sattin of the Centers for Disease Control (CDC) in Atlanta, who led a large team of investigators, "we had enough numbers so that we could look at subgroups of women and patterns of [birth control pill] use." The study, conducted by the CDC and the National Institute of Child Health and Human Development in Bethesda, Md., compared the oral contraceptive use of 4,711 women with newly diagnosed breast cancer with that of 4,676 controls.

Use of the pill for 15 or more years had no effect on a woman's risk of developing breast cancer, according to the researchers; nor did it matter how long it had been since the last use of the pill. Neither a family history of breast cancer nor a personal history of benign breast disease made women more vulnerable to pill-related breast cancer; nor did use of the pill before a full-term pregnancy. And there was no evidence that use of any particular type of pill increased the risk of breast cancer.

There is concern that those women who use oral contraceptives when they are very young (mid-teens), while their breasts are developing rapidly, may be more vulnerable to breast cancer. But since few women in that age group took the pill when it was first introduced in the early 1960s, Sattin says, the study couldn't draw any conclusions about the long-term effects of such use. "The evidence for young women will still take quite a while," Sattin says. "There's a lot of conflicting evidence about that."

Indeed, the very long-term effects of pill use by women of any age may not be known for another decade. Samuel Shapiro of the Boston University School of Medicine points out in an accompanying editorial that there are no data on what happens more than 15 years after women stop taking the pill. And as women begin to pass that mark, he adds, they will also be entering the age range in which the incidence of breast cancer climbs steeply.

Other questions that remain open include the effects of new formulations of birth control pills and the effects of patterns of pill use outside the United States. Shapiro adds that the study addresses only the question of breast cancer, and not other possible side effects of the pill, which include an increased risk of heart attack. However, he writes, "From a public health viewpoint, as best we can judge on the present evidence, that cost [of oral contraceptives] is acceptable, at least in the United States."

— L. Davis

Hanford reactor's safety is questioned

Since the catastrophic Chernobyl reactor accident in April (SN:5/3/86,p.276), at least six studies have been commissioned or undertaken to assess the safety of a U.S. defense reactor at the Hanford site near Richland, Wash., which bears some Chernobyl-like attributes. Three of these assessments have already been published. The most recent, released last week by the U.S. General Accounting Office (GAO), found that many systems and components in the 23-year-old "N-Reactor" — one of two reactors at the Hanford site — are deteriorating to a point where they could jeopardize safety. GAO estimates that correcting those deficiencies and replacing aging parts could cost the federal government as much as $1.2 billion.

Still another report, due out soon, will acknowledge there are still many uncertainties as to whether the plant's design features are potentially serious liabilities in a core-melt accident, according to Robert Barber, director of nuclear safety for the Department of Energy (DOE). Such an accident occurred both at Pennsylvania's Three Mile Island #2 nuclear plant and at Chernobyl. Though two earlier DOE studies found no major safety problems, Barber told SCIENCE NEWS, neither appraisal evaluated N-Reactor's design in great detail or considered how the plant might respond in a severe core-melt accident.

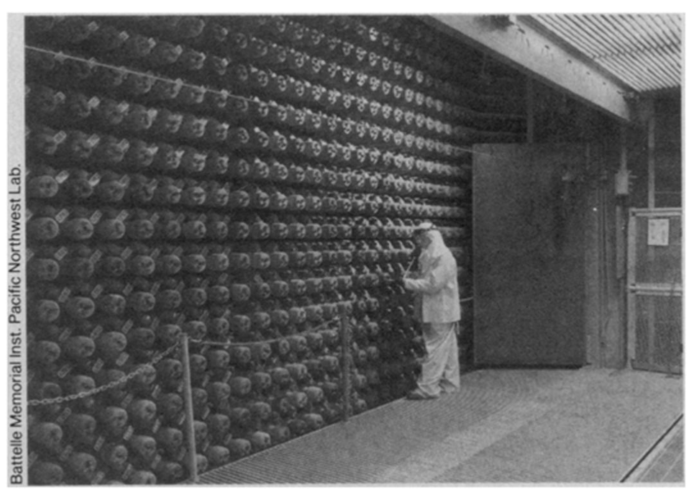
The N-Reactor's lack of a domed containment building to trap radioactive materials emitted during a serious accident is one of the design features it shares with the Chernobyl plant. According to Rep. James Weaver (D-Ore.), a recently disclosed report written a number of years ago by the Atomic Energy Commission, DOE's predecessor agency, says the plant's builder chose the filtered "confinement" system — instead of a more substantial "containment" building — "because of its lower cost." Weaver notes that a federal advisory committee on reactor safeguards reported at about the same time, however, that "Several of its features raise questions as to the possibility of larger releases from a severe accident than are believed credible for commercial power reactors."

One of those questionable features is the confinement system's reliance on aerosol filters to limit radioactive releases, according to Washington, D.C.-based reactor-safety analyst Susan J. Niemczyk.

Until about 10 years ago, she says, severe-accident models tended to ignore the quantity of radioactive aerosols that might be released, but recent studies have shown that a pressurized-water reactor, like N-Reactor, might generate tons. Meanwhile, experience has shown in reactor cleanup systems where filters are used that significant filter clogging can occur after just a few dozen pounds of aerosols enter, she adds. With the N-Reactor's system of four filters, "it probably wouldn't take a whole lot of aerosols [during a severe accident] before you'd risk clogging the filters, failing them and then begin pumping [radioactive particles] directly into the environment," she says.

Niemczyk also believes that computer codes recently developed to better gauge a commercial reactor's potential radioactive emissions during a severe accident (SN:4/20/85,p.250) "would not be appropriate for analyzing the Hanford N-Reactor because of the completely different configuration [from other U.S. reactors] of its core." Like the Chernobyl plant, the Hanford reactor core is made up of more than 1,000 separate fuel tubes — each in its own miniature reactor vessel — instead of a single huge reactor vessel surrounding all of the fuel rods together. Without updated codes, she says, "it's not obvious how [DOE] assessed the Hanford reactor's safety."

DOE's Barber acknowledges that the already-published DOE reports fall short on this count, but adds that in the soon-to-be-released report, "Our reviewers



Worker removes cap from one of N-Reactor's 1,003 fuel-holding process tubes in preparation for refueling. Unlike the Chernobyl plant, which also has many individual process tubes housed in a graphite moderator, N-Reactor's monthly refueling is conducted when the plant is shut down.

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*