Ultrasafe Reactors, Anyone?

The U.S. industry shrugs off proposals for creating a "second nuclear era" based on fail-safe designs

If the U.S. nuclear industry is to climb out of its doldrums and begin building reactors again, it may have to move to a new generation of safer, more efficient plants, according to several analysts. Concepts for ultrasafe reactors are now being studied by government and independent groups. But American reactor manufacturers are not enthusiastic. They regard the fail-safe designs as exotic and too expensive to be of practical value.

The chief apostle for rethinking plant design is Alvin Weinberg, director of the Institute for Energy Analysis at Oak Ridge, Tennessee. He argues that ultrasafe reactors could be the basis of a "second nuclear era" in the 1990's and beyond.

Weinberg, a controversial insider of the nuclear brotherhood, leads a review group looking into the possibilities for improving U.S. reactors, with support from the Andrew W. Mellon Foundation of Pittsburgh. The second nuclear era, as he sees it, might arrive 10 years from now, if the demand for nuclear electricity reappears.

Not one new plant has been ordered in the United States since 1978. During the present hiatus, Weinberg says, it would be smart to come up with designs that are virtually free of risk. If some certifiably safe models are developed and offered to utilities as standardized designs, public agencies might allow them to be licensed and built more rapidly. It now takes about 12 years to license and build a plant in the United States, as opposed to about 6 years in Japan, according to the Atomic Industrial Forum. Weinberg's goal is to remove some of the institutional barriers by offering risk-free designs.

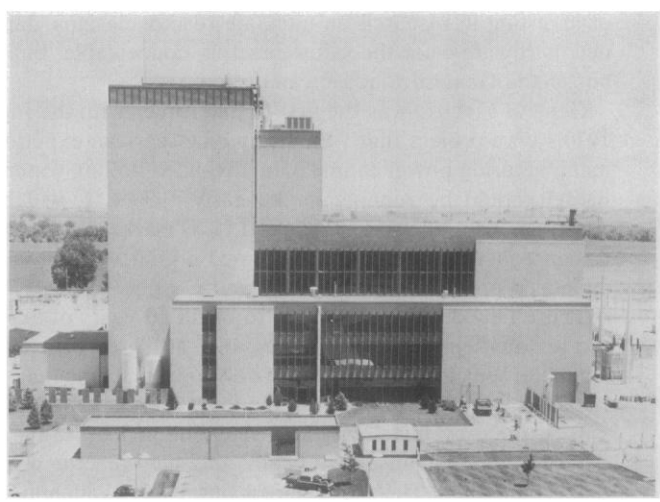
Several problems have flattened the domestic nuclear industry in the 1980's. The most important is economic. Demand for electricity has grown very slowly in the last 5 years, and, in fact, it declined in 1982, leaving utilities with excess electric capacity. Many companies that might have built new plants have turned away from nuclear power because of its high initial cost. Nuclear plants outdo their competitors on fuel efficiency, a factor that comes into play late in a plant's life. This fuel advantage has been wiped out recently by the relentlessly inflationary demands of plant construction, by new licensing requirements, and by high interest rates. Thus, Weinberg's research is an effort to find a straightforward technical fix for a complex tangle of economic and risk-reduction problems.

Like Weinberg's group at Oak Ridge, the Office of Technology Assessment (OTA), a congressionally sponsored outfit, also has begun looking into ways to improve reactors. The OTA is making a broad review of the industry's chances for adaptation and survival as part of a project requested by nuclear power advocates Senator James McClure (R–Idaho) and Representative Marilyn Bouquard (D–Tenn.).

The harshest comment came from a federal research manager with 20 years' experience in analyzing fission reactor designs. He asked to speak off the record. Few would voice the opinion he gave, he said, but many in the nuclear field share it. In his opinion, Weinberg's project is "very, very dangerous" because it will lead the public to ask "Why do we need to start all over with X billion dollars worth of research unless you guys think something is wrong with the reactors we have?" There is nothing wrong with existing reactors, he insisted, and he described the second nuclear era studies as "a welfare program for otherwise unemployed nuclear engineers." He said that the Clinch River breeder project is the same kind of thing. Only half-joking, he said the second nuclear era scheme may be an insurance policy for the beneficiaries of the Clinch River program, a means of staying employed if Clinch River is killed.

Safety at a price

General Atomic's High Temperature Gas Cooled Reactors may be safer than light water reactors, but they may cost more and have not been tested on a large scale.



The nuclear industry is involved in both OTA and Weinberg's projects, and, of course, it conducts research on its own. But industry engineers speak disparagingly of outside work as "paper studies" of little practical value. Spokesmen at both Westinghouse and General Electric seem to regard Weinberg's effort as an academic project. A Westinghouse official said that designs that have not been reduced to practice, like some in Weinberg's review, must be regarded as riskier than those that have been tested by years of use. The industry's recommendation for improving reactor safety is simple: follow Japan's example and build new plants using the best available designs (see box).

Weinberg is aware that his work is controversial. Even the suggestion that the hiatus in new plant orders may last a decade is anathema. At a recent news conference, Weinberg described himself as the "in-house antinuke," a disingenuous remark, for he was appearing that day to promote the breeder reactor. But his words reflected the tension that exists between the commercial sector and outside reformers, even when the outsiders are nuclear boosters like Weinberg. The industry is very uncomfortable with the unstated premise of the second nuclear era studies: that present reactors may not be safe enough.

Weinberg and his colleagues began their study by looking at the accident risk estimates for present-day reactors to see how they ranked. According to a paper by one of Weinberg's co-workers, A. P. Fraas,* they discovered a great variation in the estimated risk that a plant might have a severe core-damaging accident. Some plants appeared to be 100 times more likely than others to have such an accident. It is possible to lower the risks by adding new safety components. But this is costly, Fraas says, and sometimes makes the system more difficult to manage. The most ambitious improvements of this kind mentioned by Fraas would only reduce risks by a factor of 20 to 50.

With tinkering of this sort, older plants might be made as safe as a new reactor about to be built by Britain. The latter is a pressurized water reactor, Britain's first, called Sizewell-B. For an additional capital cost of about 25 percent, this plant has been reworked to be 100 times safer than its American prototype.

Thus, there are limits to what can be done to improve existing designs. The results are not all that impressive, Fraas writes, for the systems become very complex, and the risk assessments are still open to wide interpretation. In short, even if one spends a lot of money to make existing designs safer, the risks may still appear too large.

All of the risk estimates described thus far apply to pressurized or boiling water reactors, which dominate the American market. Weinberg's group and the OTA are looking at three other types as well, two of which have a fairly good record of performance thus far. One is the heavy water or deuterium reactor made by Canada, known as the CANDU. Although no statistical risk estimates have been calculated for the CANDU, Fraas writes that it is "extremely unlikely" to have a severe core damage accident, because the excess heat would probably be carried away from the core quite efficiently by metal pipes. However, it is possible that a CANDU might release radiation during an accident, just as is true of other plants. The cost of building a CANDU in the United States might be one-third higher than that of a comparable light water reactor, Fraas estimates.

The other type of reactor mentioned is the High Temperature Gas Cooled Reactor (HTGR), designed by General Atomic of San Diego. Although it has not been built in dimensions as large as those used for light water and CANDU plants, smaller versions have been operating successfully for some time. One advantage of the HTGR is that it has a capacity to absorb excess heat in an accident. According to Fraas, if the coolant is lost and no remedial steps are taken, heat will not begin to damage the HTGR core until 10 hours have passed. In the pressurized water reactor, the type at Three Mile Island, damage begins to occur after 45 seconds.

The disadvantages of the HTGR are that it has not been tested on a large scale and, according to Fraas, it may cost 20 percent more than a comparable light water reactor.

One other model is being examined—an entirely new Swedish design that is meant to be intrinsically safe. As Weinberg says of this reactor, "You have to violate the laws of nature in order to have meltdown." Its name is apt, American reactor designers say. It is called PIUS, for Process Inherent Ultimately Safe Reactor. The Swedish designer, K. Hannerz, began work on this concept in 1979 just after Sweden's decision to adopt a moratorium on nuclear plant construction. His goal was to create a system that would be so patently safe that even the most conservative critics would not be afraid to permit its construction.

PIUS is a pressurized water reactor that has been entirely immersed in an underground swimming pool and shielded by thick prestressed concrete walls. Its aboveground appearance would be

New U.S. (Japanese) Reactors

There is a striking contrast between the way Japan and America are planning for the future of nuclear power. While the United States is thinking of investing in research on ultrasafe reactor designs, Japan is investing in new hardware—not the safest reactors conceivable, but the best Westinghouse and General Electric can design.

General Electric was the first to join forces with the Japanese in the mid-1970's on a project that would rely on American experience and Japanese manufacturing power to make an advanced boiling water reactor. The first model should be running in the early 1990's. It will be built in Japan. Westinghouse, likewise finding the U.S. market inhospitable, took its best design concepts to Japan and formed a joint venture in 1981 to create an advanced pressurized water reactor.

These new designs are meant to distill 20 years of experience, including the lessons learned from the accident at Three Mile Island in 1979. For example, Westinghouse hopes to develop a machine that will reduce worker radiation exposure to one-fifth the level seen at similar U.S. reactors. This will be done by installing extra shielding and by using robot fuel loading devices. Westinghouse also claims this new reactor will be more efficient than comparable U.S. models, raising plant availability from the current U.S. average of around 75 percent to an expected 90 percent.

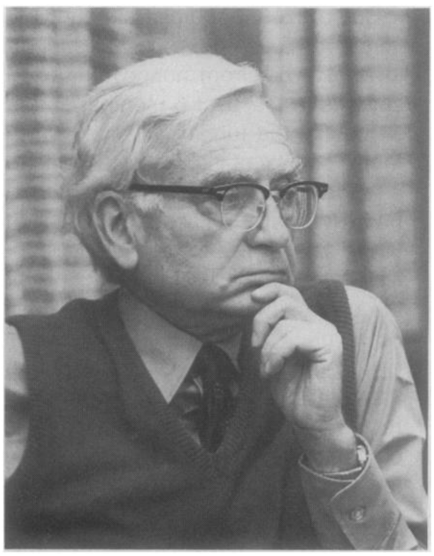
Thus, the world's most efficient and safest light water reactors are to be built by Mitsubishi, Hitachi, and Toshiba, under license from U.S. companies. Later, if there is a demand for them in the United States, similar models may be built by domestic companies. But at the moment, American utilities are patching up old reactors, not ordering new ones.

Even though American companies will play a key role in developing these advanced reactors, they will not by any means control the technology. As partners, the Japanese will have a say in how the design data are used. And as builders, they will acquire some valuable expertise in manufacturing and operating the first plants. With its excellent reputation for industrial quality control, Japan could become a major builder and exporter of high-quality reactors.

Although Japan has no plans at the moment to export these new machines, it could always do what France has done. After a period of tutelage under a Westinghouse license, France declared its independence and became one of the company's chief competitors abroad. If Japan leaps into the export business, its first market is likely to be China.—**E.M.**

* "Survey and Assessment of the Technological Options Available to the Nuclear Industry in the 1980 to 2000 Period" (Institute for Energy Analysis, Oak Ridge, Tennessee, November 1982).

something like a missile silo. Because the entire machine sits in a pool of borated water, the cooling system cannot fail. If the primary system breaks down, the fuel core is flooded with the surrounding borated water without human or mechanical intervention. According to Weinberg, the reactor is supposed to be able to cool itself by natural heat convection for at least a week without any mechanical help. "That's long enough to get a fire hose in, if you need it," he says. One last point in PIUS' favor: unlike other reactors, it appears to be invulnerable to sabotage.



Alvin Weinberg

Ultrasafe reactors could be the basis of a "second nuclear era."

PIUS has some obvious problems. Nothing like it has been built, and so it is not clear whether it will work. Its cost is not known but is likely to be higher than that of conventional reactors. Because its concrete shell is buried in the ground, a Westinghouse engineer says, PIUS may be more vulnerable to seismic shock. It may be difficult to develop waterproof control systems. Maintenance may be awkward. Despite these weaknesses, PIUS may have its value, particularly if its inherent safety makes it easier to license.

The fundamental flaw in all of these designs is that they seem to cost at least 20 percent more to build than existing types. Thus, even allowing for improvements in fuel efficiency, these new concepts are in many ways less attractive economically. This means that the era of ultrasafe nuclear plants may not come to pass unless an important precondition is met: the economy will have to be far healthier than it is today, and demand for electric power will have to be growing strongly.—**ELIOT MARSHALL**

Who's Who in Biology

When Edwin Whitehead selected the Massachusetts Institute of Technology (MIT) as the site for the Whitehead Institute for Biomedical Research, he evidently chose wisely. MIT faculty members in biochemistry, cellular/molecular biology, and microbiology have been rated by their peers as the most prestigious in their disciplines. The Whitehead Institute, whose researchers were initially drawn from MIT's existing faculty, thus tapped into the top rank of American biological research.

MIT's stellar rating in these disciplines can be detected from a careful reading of the latest volume of assessments of graduate programs in the United States, published by the National Academy of Sciences.* Like previous volumes in this series (*Science*, 8 October, p. 140, and 3 December, p. 980), this one, which covers the biological sciences, is a near-impenetrable document that lists an array of data on each program. The data include the number of faculty members in each program, the size of the university library, and the proportion of faculty receiving federal funds.

Although the study deliberately avoids ranking programs, it does include the results of a survey in which 1848 academic biologists were asked to rate programs in terms of the quality of their faculty and their effectiveness in educating graduate students. The survey proved controversial. Only 56 percent of those surveyed agreed to participate, and "some faculty members included in the sample made known to the committee their strong objections to the reputational survey," the report states. Similar surveys in the past have been criticized for confusing prestige for quality.

Respondents were asked to rate faculty members in each program on a scale of 0 (not sufficient for doctoral education) to 5 (distinguished). The following are the top-rated programs, with their overall scores. Some universities have more than one program in each discipline; in those cases, the program is identified.

Biochemistry: MIT, 5.0; Harvard, 4.9; Stanford, 4.9; University of California (UC) at Berkeley, 4.6; Rockefeller, 4.6; Wisconsin at Madison (biochemistry), 4.6; Yale, 4.5; UC San Francisco, 4.4; Harvard Medical School, 4.4; Cornell, 4.3; Brandeis, 4.2; UC San Diego (chemistry), 4.2; UC Los Angeles, 4.1; Pennsylvania, 4.0.

Botany: Texas at Austin, 4.5; UC Davis (botany), 4.5; UC Davis (plant physiology), 4.5; UC Davis (plant pathology), 4.3; Wisconsin at Madison (plant pathology), 4.3; UC Berkeley (botany), 4.3; UC Berkeley (plant physiology), 4.2; Cornell, 4.2; Michigan, 4.2; Yale, 4.1; Duke, 4.0.

Cellular/Molecular Biology: MIT, 4.9; Caltech, 4.8; Rockefeller, 4.8; Yale, 4.7; Wisconsin at Madison, 4.6; Harvard, 4.3; UC San Diego, 4.3; UC Berkeley, 4.2; Columbia, 4.1; Colorado, 4.1; Stanford, 4.0; Washington at Seattle, 4.0.

Microbiology: MIT, 4.9; Rockefeller, 4.8; Washington at Seattle, 4.3; Johns Hopkins, 4.3; UC San Diego, 4.3; Chicago (virology), 4.2; Pennsylvania (immunology), 4.2; Duke, 4.2; UC Los Angeles, 4.1; UC Davis, 4.0; Columbia, 4.0; Illinois, 4.0; New York University, 4.0; Pennsylvania (microbiology), 4.0; Stanford, 4.0.

Physiology: UC San Francisco, 4.5; UC Los Angeles, 4.3; Pennsylvania, 4.3; Rockefeller, 4.3; Washington at Seattle, 4.3; Yale, 4.3; Harvard, 4.1; Michigan, 4.1; Columbia, 4.0; Washington University at Saint Louis, 4.0.

Zoology: Harvard, 4.7; UC Berkeley, 4.4; Washington at Seattle, 4.3; Yale, 4.2; UC Los Angeles, 4.1; Duke, 4.1; Stanford, 4.0; Texas at Austin, 4.0; Wisconsin at Madison, 4.0.

The last major survey of faculty reputations was conducted by the American Council on Education in the late 1960's. In general, relative standings did not change much between the two surveys, although a few institutions—such as MIT and UC San Francisco—appear to have gained in prestige.—**COLIN NORMAN**

**An Assessment of Research-Doctorate Programs in the United States: Biological Sciences* (National Academy of Sciences, 2101 Constitution Avenue, NW, Washington, D.C., 1983). The survey was sponsored by the American Council of Learned Societies, the American Council on Education, the National Research Council, and the Social Science Research Council.