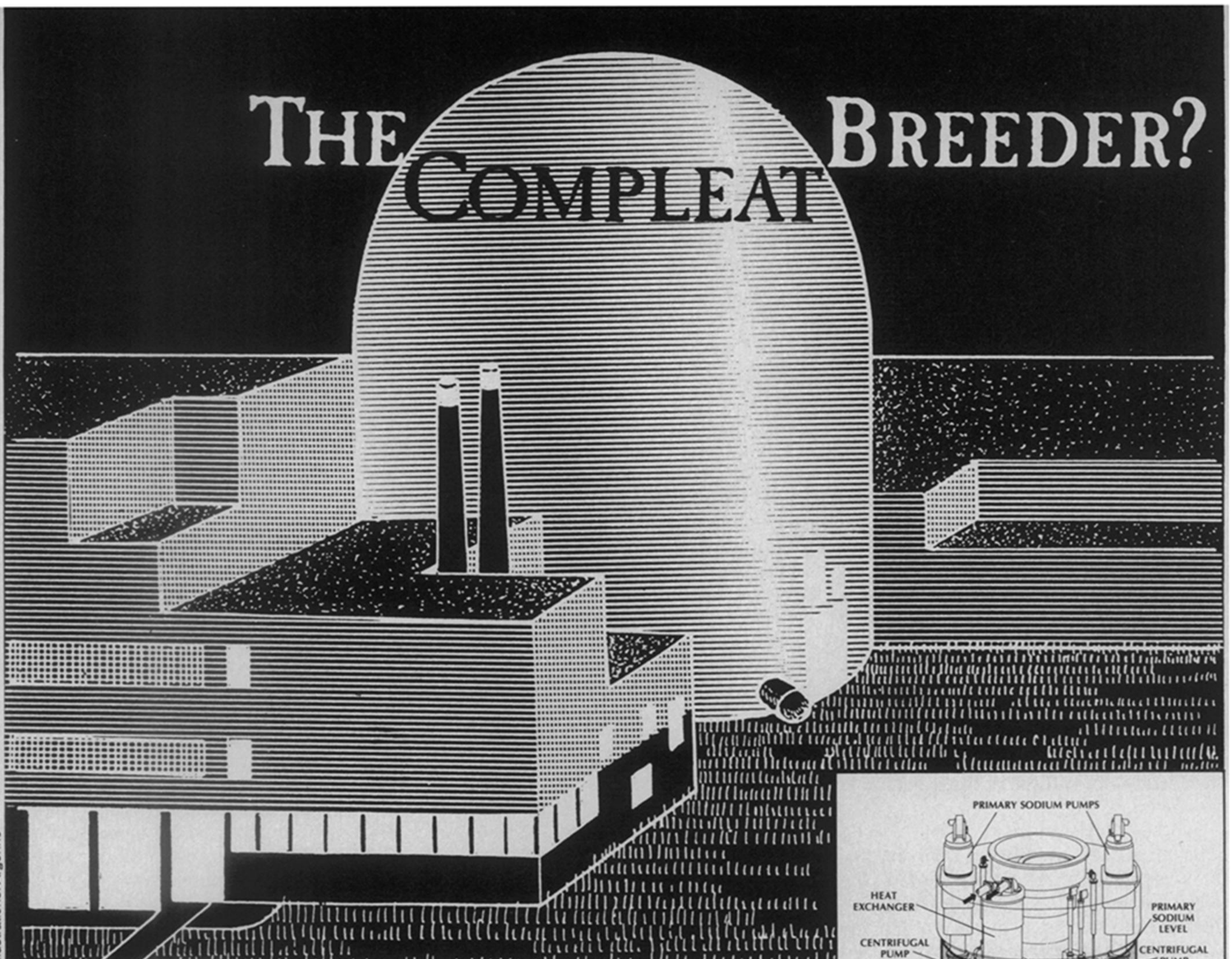
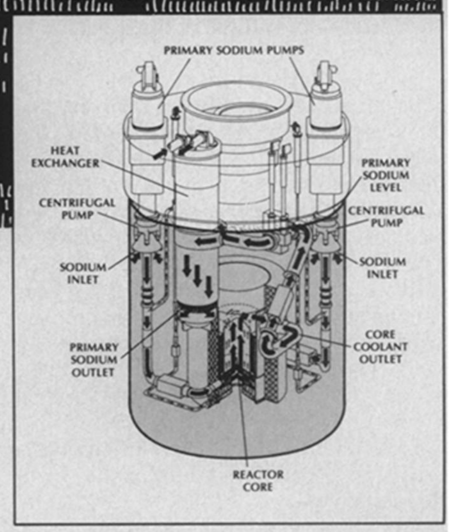
THE COMPLEAT BREEDER?





Illustrations: Argonne

Against backdrop of conceptualized IFR plant is cutaway (inset) of the breeder's core. Tinted area, region submerged in pool of liquid sodium, includes most support systems. Today most reactors use extensive networks of pipes to route coolant from the core to the heat exchangers located outside of the core-containment building, and back. Submerging equipment like the circulation pumps and primary heat exchangers in the pool allows a more compact design, reducing the piping necessary. Moreover, pipe quality becomes less critical when the primary coolant — which becomes radioactive — risks leaking only into the pool, not into the populated regions of the power plant.

By JANET RALOFF

When the Clinch River Breeder Reactor (CRBR) project died last year (SN: 11/19/83, p. 329), many assumed the U.S. breeder development program died along with it. But, as illustrated by a new program at Argonne National Laboratory outside Chicago, breeder reactor development in the United States is still very much alive. According to its designers, the new Argonne reactor shows the potential for being safer, less costly and more resistant to fuel theft by terrorists than virtually any other reactor on the drawing board. They named it the *integral* fast reactor (IFR) to denote that it would contain all the components necessary for power production, fuel reprocessing and waste treatment in one facility.

By definition, a breeder reactor is one that creates more fuel than it consumes. It does this by transforming nonfissile uranium-238 — the most prevalent natural form of uranium — into fissionable plutonium. And that explains its conceptual allure: These power plants could greatly extend the world's nonrenewable fission energy resources, and with them the useful life of the nuclear energy option.

The breeder concept is credited to Walter Zinn, Argonne's first director. Under Zinn, Argonne built the first experimental breeder reactor, EBR-1, on its Idaho Falls, Idaho, site. EBR-1 went into operation in December 1951, becoming the first nuclear reactor of any kind to produce electricity.

The new IFR is essentially a redesigned version of EBR-2, an experimental power plant that has been operating at Idaho Falls for more than 20 years. However, work on refining the complete IFR concept began only in the fall of 1983. Why? "It's a sore point," admits Charles Till, Argonne's associate laboratory director for reactor research and development, "but the main line of breeder development was the CRBR line." And beginning in the mid 1960s, that line departed substantially from the one evolving at Argonne. "My own guess," Till says, "is that had CRBR gone ahead, designs like this IFR, even though they show considerable promise, would not have been looked at." But with CRBR's demise, the nuclear research community was willing to take a fresh approach.

The Department of Energy (DOE) offered further evidence of that when it recently initiated a competition among three established nuclear contractors — General Electric Co., Westinghouse Electric Corp. and the Atomics International Division of Rockwell International Corp. — for the design of a small, safe breeder. "The idea [behind this competition] was to innovate — to let your mind flow freely and not to let it get stuck on the Clinch River configuration," notes John Graham, who until last April had been a breeder reactor designer with Westinghouse. (Westinghouse lost out during the first elimination round of DOE's competition.) The DOE-funded Argonne project is currently independent of this competition. At some later date, however, IFR may have to compete on its merits against the top contender emerging from this industrial design program. It's also possible, as Ben Blumberg at GE's breeder design program in Sunnyvale, Calif., points out, that some of IFR's more attractive safety features could be integrated into outside programs, such as his own, if they prove less costly.

Like CRBR, Argonne's IFR would be cooled with liquid sodium. Unlike CRBR or commercial U.S. reactors, IFR's core and most of its support systems would be submerged in a pool of the coolant. Another big difference between IFR and either CRBR or commercial U.S. reactors is the fuel type. IFR's would be metal, most likely an alloy of uranium, plutonium and zirconium. The fuels in commercial power reactors today, though termed "ceramics," are really metallic oxides such as uranium dioxide. In recent decades, ceramics have come to dominate the nuclear fuel market because of their ability to withstand high radiation without damage and to permit operation of the reactor at higher—and presumably more efficient—temperatures than pure uranium or many uranium alloys. But the Argonne team believes that its fuel's lower operating temperature is more than compensated by its contribution to design safety.

Uranium deposited on negative electrode at end of electrorefining phase of fuel reprocessing. Colorless chlorides of lithium and potassium comprise 97 percent of crystal; remaining 3 percent uranium chloride imparts amethyst hue. Electrorefining is the only IFR technology not yet proven on demonstration scale.

For instance, the high thermal conductivity of this metallic fuel and the thermal inertia of the big pool of cold sodium "gives a reactor response that is very stable to all kinds of upsets," says Till. "Our calculations indicate that basically no matter what happens in the non-nuclear part of the steam [-producing] part of the plant, the reactor will simply shut itself down [whenever a problem develops]." Natural convective cooling removes heat from the fuel. And there is little chance that the fuel would ever overheat to the point of melting, Till says, because its high thermal conductivity prevents it from retaining heat.

There is a second, apparently fail-safe aspect to this configuration. If the worst imaginable chain of events occurred — leading to the risk of melting fuel — one would like the system to automatically remove the fuel from the reactor core, thereby quenching the heat-producing nuclear chain reaction. On the basis of both the theoretical characteristics of the fuel/fuel-holding materials and actual observation of these materials under temperature-spiking experiments, Till says, it appears that at near-melt temperatures, the fuel will in fact pop up and out of the core.

Each fuel element is fitted loosely inside a cylindrical rod, called the clad. The clad is much taller than the fuel element, leaving ample room for the fuel to swell and for fission-product waste gases to collect as the fuel "burns up." However, to carry the heat of the fuel to the wall of the clad, which makes contact with the coolant in the pool, a little extra liquid sodium is slipped inside the clad. Since sodium boils at 900°C — more than 200 degrees below the melting point of the fuel—by the time the fuel melts there should be enough vapor pressure from the sodium to help hoist sufficient swollen fuel up the cladding and out of the core. Till points out that this fission-quenching fuel pop-up actually occurred during one metallic fuel experiment in EBR-1.

Finally, IFR would incorporate the automatic reprocessing of fuel (separation of wastes from reusable fuel) with the fabrication of both new fuel and glass-encapsulated nuclear wastes. Already five complete reactor-core loadings of EBR-2's fuel, roughly 35,000 fuel pins, have been reprocessed using a relatively new pyrometallurgical technique, and all "by remote control—there was no human contact with the fuel material," Till says.

As an added safety feature, IFR's design calls for an operating reactor to manufacture all its replacement fuel on-site by breeding plutonium from uranium-238 brought to the plant with the first reactor-core loading of nuclear fuel. Till says that rates of plutonium production can be controlled so that no excess accumulates, beyond what can be handled by the automatic reprocessing. "Thus," he says, "IFR should eliminate any concerns about public safety associated with cross-country transport of fissionable or radioactive materials, now necessary to reprocess fuel from power reactors." In addition, Till says, the reprocessing technique "virtually eliminates the possibility of stealing or diverting nuclear materials because the material is at all times far too radioactive for handling without highly specialized equipment."

There are still some uncertainties in IFR's design that must be tested. For example, the alloy now believed to represent the best IFR-fuel candidate has not yet been tested in EBR-2, although that is scheduled to occur soon. Similarly, IFR's two-step reprocessing technique has only undergone rigorous testing with EBR-2's

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fuel, although recent bench-scale reprocessing tests with the new alloy have been successful. If all goes well, a decision could be made within two years to put EBR-2 into full operation as a prototype IFR.

While no one downplays the importance of reactor safety, many experts believe the real make-or-break issue for the commercial viability of breeders in the United States—and the basis for most public and industry opposition to breeders—will continue to be one of cost.

What might a commercial version of this reactor cost? "You should be able to design this to be very competitive with the best of the light-water reactors" now in operation — that is, with those that were not plagued by cost overruns, licensing delays or massive retrofitting of new safety features, Till told SCIENCE NEWS.

According to Graham, however, if there is any potential weakness to Argonne's IFR program it is likely to be the national laboratory's focus on safety—at the expense of minimizing cost. "For a lot of years the [national] labs have tended to design Rolls Royces rather than Chevrolets," he says. Graham suspects Argonne's candidate reactor may be "overdesigned to produce safety, whereas I think the GE and Atomics International designs will probably emphasize the cost element." (In interviews with SCIENCE NEWS, representatives of the breeder efforts at both GE and Rockwell International confirmed that one of the primary goals driving their programs was indeed that of trying to keep costs down.) That is not to suggest that the contractors will ignore safety, Graham adds, but rather that they're approaching the design of safety with more attention to cost-effectiveness.

Clark Gibbs agrees. As director of the Advanced Nuclear Generation department of the Electric Power Research Institute in Naperville, Ill., Gibbs believes that in trying to make the breeder reactor attractive to both the public and the electric utilities, "our biggest problem is the capital cost of the plant. So in that regard, this [IFR] effort is not directed toward addressing the major problem."

But Till argues that safety cannot be separated from the issue of a power plant's potential cost. If the public or the Nuclear Regulatory Commission has any question about the inherent safety of a plant's design, expensive licensing delays will begin popping up, as will requirements that engineers go back and augment the original plant design with additional safety features — factors responsible for driving capital costs "out of sight," according to Till.

"It is our hope with this machine," he says, "that the case for safety can be made sufficiently simply and transparently that those risks of additional costs can be made minimal." □