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THE INTEGRAL FAST REACTOR (IFR) CONCEPT

by

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In addition to maintaining the viability of its present commercial nuclear technology, a principal challenge in the U.S. in the 1990s and beyond will be to regain and maintain a position among the world leadership in advanced reactor research and development. In this paper we'll discuss factors which we believe should today provide the rationale and focus for advanced reactor R&D, and we will then review the status of the major U.S. effort, the Integral Fast Reactor (IFR) program.

The challenges presented to advanced reactor development are increasing throughout the world. The global issue, and therefore a challenge for every national nuclear program, is how could nuclear power make a significant contribution to growing environmental problems associated with fossil fuel combustion. Although the data on atmospheric warming and associated climate changes are not fully conclusive, enough is known to begin to influence nuclear R&D programs, which of course by their nature are long-range in their potential impact.

The magnitude of the climate-change issue has major implications for nuclear technology. Replacing even half of the present fossil fuel combustion would require about 1500 full size reactor plants, roughly a four-fold increase from the number in operation today. This in itself is a formidable problem, but more importantly, if LWRs were utilized, this quantity of reactors would use up the world's natural uranium resources in two to three decades (OECD reasonably assured and estimated additional resources, plus perhaps even a portion of the speculative resource category). To impact the atmospheric warming issue, some form of the breeder reactor is essential, for only then can a large-scale nuclear power option be maintained for many hundreds of years. Breeding is not needed today, and probably not in a decade or two either. However, it is certain that it will be needed, if nuclear is to contribute significantly toward the future energy demands. Whether a breeder is deployed by itself or in tandem with one or more types of converters, its absence would relegate nuclear technology to an inconsequential role in meeting future environmental challenges.

In addition to the global environmental issue, two other major factors challenge nuclear R&D, especially in the U.S. Public perception of the safety of present reactors is one of these factors. It is of course not obvious that new reactor technology will overcome problems of safety perception. Still, as difficult as the issue is, public perception of safety is a major challenge of the 1990s and beyond, and orientation of nuclear R&D program to address this issue is needed. Technology can make some difference, and greater reliance on passive or inherent features, and less reliance on engineered safety systems and the operating staff, might bring significant benefits.

The third major factor challenging the U.S. R&D program is nuclear waste disposal. We believe that there is much to be gained in reducing the isolation period required for nuclear waste through separation and recycling of the long-lived radionuclides, the actinides. By recycling most or all of the actinides, the isolation period could be reduced to hundreds of years instead of a million years. Acceptance of this sort of isolation period should be more easily gained, given our ability to construct all sorts of structures that last several hundred years.

We believe these three factors provide the rationale and should influence the details of nuclear R&D for the coming decades. Nuclear technology that provides an opportunity for large-scale, long-term impact (i.e., some form of breeder) must be included. Technologies that enhance the inherent or passive safety characteristics of the plant should be sought, and we should challenge R&D programs to provide a technological improvement in nuclear waste.

At Argonne National Laboratory, R&D associated with the IFR concept has been conducted since 1984. We believe the IFR has at least the potential to make contributions to all three of the problem areas cited. In some cases, the features have already been proven or demonstrated, while in others we are still in a development mode. Before we review how the IFR is fairing against our three criteria, we first review the main elements of the concept, and where the R&D now stands.

The IFR is a sodium-cooled fast reactor, with metal-alloy fuel rather than the usual mixed-oxide. A unique and radically new form of reprocessing called pyroprocessing is being developed, the key step being electrorefining, where uranium and uranium-plutonium are electrolytically separated from fission products in a relatively small vessel (diameter ~1m) at 500°C. The whole fuel cycle involves a small number of steps (e.g., element removal from assemblies, element chopping, electrorefining, cathode processing, injection casting of reprocessed metal fuel rods, processing the resultant cast rods to length, loading into new cladding, and reassembly), leading to a compact fuel cycle facility, which appears might be economic even at a size sufficient to serve only a single plant. At a single plant size, it might be located *integrally* with the reactor.

One of the first priorities was to obtain irradiation data on the specific IFR alloys, uranium-10w/o zirconium and uranium-plutonium-10w/o zirconium. This has come along very well, and as of March 1989, IFR fuel had achieved 18.5% burnup in EBR-II, far exceeding the design goal of 10% for the initial experimental assemblies. Based on this level of burnup and the substantial number of fuel elements irradiated in EBR-II, the basic metal fuel is fully demonstrated. Important results were also obtained from in-reactor tests of fuel pins tested beyond cladding breach, showing the benign behavior of breached pins. The initial breach of the fuel pin did not degrade with further irradiation even after 223 days of operation beyond breach.

The demonstration of the key IFR processing step, electrorefining, has moved up from laboratory scale to engineering scale. Ten-kilogram amounts of uranium have been electrotransported routinely. The next step is the plant-scale demonstration in the refurbished EBR-II Fuel Cycle Facility (now called the Hot Fuel Examination Facility South or HFEF/S) with actual irradiated fuel from EBR-II. Rapid progress has been made during the past year in making the necessary preparation for facility modifications. All major process equipment systems are in the final phase of design or are actually in the prototype fabrication stage. We expect to complete the facility modifications and the equipment installation and qualification by September 1990.

The inherent passive safety potential of the IFR concept was demonstrated through the two landmark tests conducted in EBR-II in April 1986; a loss-of-flow without scram test and a loss-of-heat-sink without scram test, both from the full power operating condition. Even under these very severe accident conditions, the reactor shut itself down without intervention of operators or reliance on engineered safety systems. The IFR inherent safety characteristics are due to the unique combination of nuclear properties associated with metallic fuel and high boiling temperature of liquid metal sodium.

With this overall status of the IFR R&D program in mind, how does the concept compare with the three critical criteria outlined earlier? As far as breeding is concerned, whenever it is needed, the metal fuel of the IFR with its resulting hard neutron spectrum, gives rise to the best achievable breeding performance. Alternatively, until plutonium is needed, by selective loading of blankets the reactor can be operated in a self-sustaining mode.

Studies have shown that the passive safety characteristics that have been demonstrated in EBR-II can also accrue to larger reactors that embody the IFR characteristics of metal fuel and the pool primary system arrangement. Thus two of the three classical ATWS events in fast reactors, loss-of-flow and loss-of-heat-sink without scram, are of no real consequence. Moreover the third accident, a transient overpower initiated by a control rod runout, appears to be much reduced in magnitude in the metal-fueled IFR with its lower burnup reactivity swing during its cycle and the associated reduced control rod worths that is brought about by the higher core conversion ratio that metal fuel affords.

Finally, in the waste area, IFR pyroprocessing has two distinct advantages for separating actinides from the waste stream. First of all, most of the actinides accompany the uranium/plutonium product stream in the IFR process, and the remaining actinides can then be separated from the waste streams more easily than in the PUREX process. The hardened IFR neutron spectrum is better for actinide burning than that of any other reactor type. Thus the potential of the IFR concept to make actinide recycling practical is very promising. This area of actinide separation and recycling is the newest and least proven of the key IFR features, and is the subject of some emphasis in the current R&D program.

In conclusion, Argonne's entire reactor development program is today oriented around the IFR. We expect to begin the fuel cycle demonstration late next year, whereupon the EBR-II facilities will provide a small but complete prototype of the IFR concept.