History of Liquid Metal Reactors in the United States 2

Today, U.S. commercial nuclear power reactors are based on a design known as the light-water reactor (LWR). In this design, uranium oxide-based nuclear fuel is used once and then prepared for disposal. Although not commercialized in this country, other reactor designs continue to be explored and developed. One such design is a liquid metal reactor (LMR). This design uses metal fuel that is reprocessed after each use cycle and then fed back into the reactor as new fuel. Reprocessing is a chemical and physical process whereby new fuel is separated from the waste products. The LMR reactor was origin all y developed as a "breeder reactor" to produce excess plutonium during its operation. Breeder operation implies that the reactor and fuel reprocessing system can produce more nuclear fuel than the reactor consumes.

The liquid metal reactor concept has been under development in the United States since the 1950s. The first nuclear reactor ever to produce electricity y, the experimental breeder reactor (EBR-I) at Argonne West in Idaho that began operation in 1951, was such a system (3, 15). The Clinch River Breeder Demonstration reactor was an LMR breeder design intended to demonstrate the concept on a large scale. It was designed to use a nuclear fuel reprocessing technology known as PUREX[1] for converting its spent fuel into new nuclear fuel. The Clinch River project was terminated by Congress in 1983 because of concerns about its risks in terms of

[1] The PUREX process was originally developed in the 1940s to separate plutonium for weapons production. The process in which spent fuel is dissolved, and plutonium and other materials are separated from wastes, can also be used to produce plutonium for nuclear fuel.

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Argonne National Laboratory West. A *number of nuclear test facilities are located at this site, including the EBR II nuclear reactor (the domed structure in the center), and its fuel recycling facility (in front and to the right of the EBR //)*

nuclear weapons proliferation, its effects on the environment, and its economics compared with competing reactor designs.

The current advanced liquid metal reactor/integral fast reactor (ALMR/IFR) concept, begun in 1984, grew out of these earlier programs. In the last decade, this development program worked with an experimental LMR breeder reactor EBR-11 at Argonne West to conduct safety tests, including simulated accidents involving loss of coolant flow; to test experimental ALMR/IFR nuclear fuels; and to develop a new type of nuclear fuel reprocessing known as pyroprocessing.

Reprocessing of spent nuclear fuel to recover plutonium and other nuclear materials for making new fuel is inherent to breeder reactors. Breeder reactor operation uses some form of spent fuel reprocessing to separate new nuclear fuel from waste nuclear fission products. Various nuclear fuel reprocessing technologies have been developed. PUREX reprocessing was pursued in the first decades of breeder power reactor development. PUREX reprocessing of commercial nuclear reactor spent fuel produces a "civilian" grade of plutonium that can nevertheless be used to make nuclear bombs.[2] During the 1970s the United States abandoned commercial PUREX plutonium reprocessing plans after a long debate over the merits and risks of developing a commercial plutonium-based nuclear power industry. The debate centered on several issues, including the environmental risks associated with the proposed nuclear fuel reprocessing cycles and expansion of the industry; the economics of plutonium reprocessing and fuel recycle; and the potential impacts of an expanded plutonium economy on international security with respect to nuclear weapons proliferation. The debate became part of the 1976 presidential campaign agenda, and in April 1977 the Carter Administration called for an indefinite deferral of U.S. programs aimed at commercialization of the plutonium fuel cycle, including spent fuel reprocessing (8, 9).

THE PRESENT ALMR/IFR CONCEPT

Researchers at Argonne National Laboratory and General Electric (GE), who together are developing the present ALMR/IFR concept, have attempted to address the earlier objections to LMR breeder reactor reprocessing systems. Some potential advantages claimed for the present ALMR/IFR concept include the ability to:

- supply a significant portion of future worldwide energy needs, through wide deployment eventually as a plutonium breeder reactor fuel reprocessing system;
- eliminate U.S. and Russian surplus military plutonium while producing electricity;
- provide superior nuclear proliferation resistance and acceptable nuclear material safeguards, compared with the standard plutonium fuel reprocessing and separation technology (PUREX), thereby allowing export (with safeguards) to other nations:

[2] Civilian and military forms of plutonium differ merely in the concentration of the plutonium isotope plutonium-239. Military-grade material has more than 90 percent plutonium-239 and civilian grade less than 90 percent. Many consider this difference to have little significance in terms of making a nuclear bomb.

- reprocess its own spent nuclear fuel. and that from other types of nuclear reactors, into new fuel, possibly extending the cupacity or acceptability of geologic repositories and easing relevant repository licensing and safety concerns by eliminat ing some of the long-l ived radionucli des: and
- operate more safely than existing LWR systems due to fundamental physical and design differences.

These claims have not been fully demonstrated or proven at the current stage of development of this technology. However, they are used to justify continuing development because, if they were demonstratrated, they would offer considerable benefits.

Goals of the ALMR/IFR Program

The emphasis of the ALM R/IFR and its predecessor research and developmen(programs has been adjusted in response to certain domestic and international political developments. As originally conceived of four decades ago. LMR technology meant a plutonium breeder nuclear reactor (producing more plutonium fuel than it consumed) using PUREX nuclear fuel reprocessing for the production of electricity. After the United States abandoned the commercial izat ion of breeder reactors and PUREX reprocessing in the 1970s because of concerns about plutonium proliferation, environmental impacts, and costs, ALMR/IFR developers conceived of a new fuel reprocessing technology claimed to involve less proliferation risk than the earlier PUREX technology. Nevertheless, electricity production remained the primary goal for justifying the program. During the last 5 years, however. the ALMR/IFR concept began to be promoted more as a method to reprocess and transform spent nuclear fuel from commercial LWRs so as to make it more acceptable for disposal in geologic repositories, such as the still incomplete Yucca Mountain repository in Nevada.[3] After 1991, when arms reduction agreements between the United States and the former Soviet Union appeared likely to produce significant quantities of surplus military plutonium, developers of the ALMR/IFR concept emphasized its potential to eliminate this plutonium by consuming it as a nuclear fuel to make electricity.

Most recently, ALMR/IFR developers have again refocused on the potential of the technology to eliminate plutonium (and other actinides) in spent nuclear fuel by reprocessing it into new ALMR/IFR fuel (and waste fission products). However, this time the rationale is not so much that it would help the geologic repository program, but rather that as long as plutonium exists even in spent nuclear fuel, it remains a potential nuclear weapons proliferation risk. The ALMW/IFR concept, developers argue, might eliminate that risk. The technology was renamed the “ALMR actinide recycle system” to reflect this change of emphasis.

One proposal for the ALMR/IFR specifically examined in the recent Office of Technology Assessment (OTA) report *Dismantling the Bomb and Managing the Nuclear Materials was* its use for the disposition of surplus military plutonium. Its designers have promoted it as a means to transform surplus weapons plutonium into fission products that could never be turned back into a nuclear bomb. The OTA report concluded that although the ALMR/IFR system was designed as a plutonium producing breeder reactor it could be operated as a net plutonium consumer. However, some limitations of the ALMR/IFR concept for

[3] Geologic repositories are deep, excavated underground vaults constructed for the purpose of permanently containing nuclear wastes. The Yucca Mountain site in Nevada is being evaluated by the Department of Energy for its suitability as a geologic repository for spent nuclear fuel from commercial reactors. In December 1987, Congress amended the Nuclear Waste Policy Act of 1982 mandating that Yucca Mountain be the only site evaluated for a national nuclear waste repository. Public opposition, management problems, technical uncertainties, and regulatory difficulties have delayed the evaluation process. The date at which a geologic repository may be completed and licensed to accept high-level waste remains uncertain.

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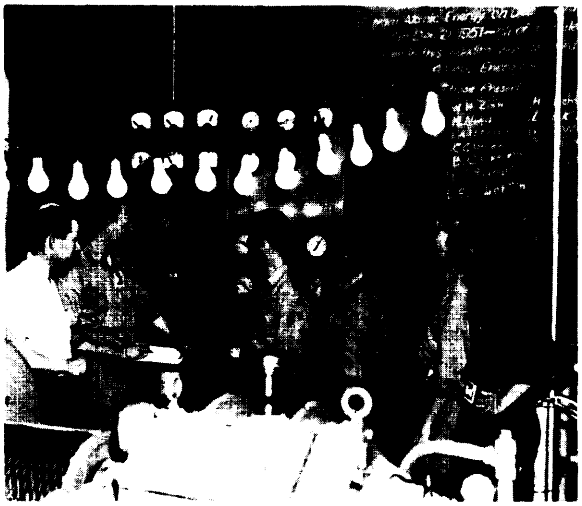

Electricity was first generated with the EBR 1 (Experimental Breeder Reactor 1) in 1951 Research with this system was in part the basis of the EBR II and the current ALMR/IFR design.

plutonium disposal noted in the OTA report include the following:[4]

- It would require many cycles of plutonium reprocessing over many decades to completely fission and destroy a significant portion of surplus military plutonium, compared with other possibly more rapid disposal methods such as vitrification.[5]
- The plutonium reprocessing required for complete destruction of surplus military plutonium is a <u>transformation</u> and not a disposal method. It would change one type of waste (plutonium) into another type of waste (highly radioactive fission products) that would still require treatment and disposal in facilities that are not yet available in the United States (a problem in fact with any radioactive waste disposal concept).
- The licensing and change in national policy involved in the act of deploying plutonium-fueled nuclear power reactors with plutonium reprocessing could be expected to be difficult in the United States, which abandoned this technology in the mid-1970s because of economic and proliferation concerns.
- It would not be economical to develop such a reactor system solely for disposal of surplus military plutonium. Selection of this option could make sense only as part of a larger national decision to turn to a plutonium breeding/reprocessing nuclear energy program.
- Developers of the ALMR/IFR concept envision many facilities operating as breeder reactors deployed in the21 st century as the next generation of U.S. nuclear power reactors. In this scenario, the amount of plutonium available from dismantled nuclear warheads would be relatively minor compared with the amount of plutonium that would be cycled through these reactors.

Selective emphasis on a single capability or function of the ALMR/IFR concept, while ignoring its other features, has made it difficult for those not intimately involved to evaluate, criticize, or even understand the program. Therefore, for the purpose of the present study, the ALMR/IFR system is looked at from the broadest perspective. It is evaluated as a system containing a nuclear reactor capable of operating as a plutonium breeder, a nuclear fuel reprocessing and fabrication (pyroprocessing) system, a nuclear waste handling system, and a system for reprocessing existing spent fuel from conventional U.S. commercial LWR into new ALMR/IFR nuclear fuel.

In addition, the present study looks at the timeliness of the ALMR/IFR technology. That is, given the early development status of the program,

[4] For a more complete explanation of these Findings, see U.S. Congress, Office of Technology Assessment, *Dismantling the Bomb and Managing the Nuclear Materials* (Washington, DC. U .S. Government Printing Office, 1993). Some of the advantages claimed by the developers are listed on the following pages.

[5] ALMR/IFR promoters point out that the technology could provide more rapid disposition by using the fuel made from weapons plutonium for a very short period and removing it for storage and subsequent complete burning in the future. The short fuel use would "spike'" the material by making it radioactive, although less radioactive than the fully used up fuel. This strategy would also be appl icable to <u>any</u> reactor-based disposition; for example, after conversion to MOX (mixed uranium and plutonium oxide) the fuel could be used briefly in already available conventional reactors to achieve the "spiked" fuel effect.

what long-range problems in energy production or waste handling might it be appropriate for the ALMR/IFR technology to address?

Previous Analyses of the ALMR/IFR Concept

A number of studies have examined the use of nuclear reactors, including the ALMR/IFR, to dispose of plutonium from dismantled U.S. and former Soviet Union nuclear weapons or from spent nuclear fuel. These studies were carried out by the Office of Technology Assessment, the National Research Council Committee on International Security and Arms Control, the General Accounting Office, the RAND Corporation, and the Department of Energy (27, 37, 46, 48, 50), Although each study approached the issue from a unique perspective, they reached many similar conclusions.

All concluded that long-term plutonium disposition will be lengthy, complex, and costly. In addition, short-term plutonium storage will be required regardless of the ultimate disposition option selected. The most available long-term options are either conversion to mixed-oxide fuel for use in existing, proven, light-water reactor designs without nuclear fuel reprocessing, or disposal as waste, for example through vitrification. Any disposition option will stretch over decades and is likely to involve costs rather than net economic benefits. Although all options involve some unresolved issues and risks of uncertain magnitude, these studies concluded that the development of advanced reactors for plutonium disposition would involve the highest costs and greatest uncertainties.