EXPERIMENTAL BREEDER REACTOR NUMBER I, EBR-I CRITICALITY ACCIDENT

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INTRODUCTION

The Experimental Breeder Reactor, EBR-I was the first reactor built at the Idado National Engineering Laboratory, INEL. It began operation in 1951 and produced the first usable electricity from nuclear heat on December 20, 1951. It achieved full-power operation the next day.

In 1953, the reactor confirmed that a nuclear reactor designed to operate in the fast neutron range is capable of breeding more fuel than its operation consumes.

The reactor, which used enriched uranium as fuel, was un-moderated. It used a sodium-potassium alloy eutectic (NaK) that was liquid at room temperature as coolant. NaK tended to burn when it came into contact with air. The pipes containing the NaK and the pumps moving it would have to work perfectly for a long time. In case the pipes did fail, the atmosphere into which the NaK leaked should not contain air.

The EBR initially used traditional impeller pumps, but they were later replaced by electromagnetic pump as well. These had no moving parts, were completely sealed, and were made entirely of metal.

A blanket of U^{238} around the core provided the "fertile" material in which breeding took place. The liquid-metal coolant permitted the neutron energies to be kept high, thus promoting fissionable-material breeding. The coolant also enabled high-temperature and low-pressure operation, both conducive to efficient power production.

President Lyndon B. Johnson dedicated EBR-I as a National Historic Landmark on August 26, 1966 and it was opened to the public for visits and tours.

Figure 1. Exterior of Experimental Breeder Reactor, EBR-1 plant.

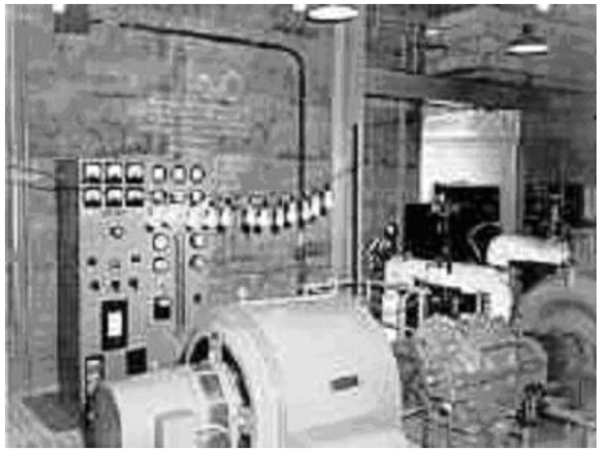

Figure 2. String of light bulbs was first nuclear-generated electricity from EBR-I on December 20, 1951.

ACCIDENT AT EBR-I

To facilitate the design of EBR-II and the Fermi fast reactors, Argonne National Laboratory turned EBR-I to the task of exploring excursions and the reactor's inherent shut-down potential. It appeared that under certain conditions, the reactivity in the core increased when the temperatures went up. This is undesirable since a negative temperature coefficient of reactivity is a desirable safety feature.

Attempts were made to increase the EBR-I fuel to a temperature of 500 degrees C, to see if it would lose reactivity. To get the fuel that hot, the drastic step of shutting off the flow of coolant had to be taken.

The safety systems that would automatically scram the reactor before it reached the test temperature were also purposely disconnected. It was known that this could cause a meltdown if a scram of the reactor was not timed perfectly.

On November 29, 1955, the EBR-I reactor was ready for the test. The plan was to scram the reactor when the power level reached 1,500 kilowatts or when the doubling of the fission rate occurred at a one-second interval. When this moment arrived, an assistant misunderstood the operator's instruction and scrammed the reactor with a slow moving control rod, not the indicated faster one. The operator quickly reached over and pushed the proper button, but the lapse had cost two seconds.

Fifteen minutes later, radioactivity within the control room set off the alarms and everyone evacuated the building. Half of the football-sized core had melted.

The event produced no sound, no steam, no smoke, and no explosion. The scientists found in this event lessons to learn and saw an opportunity of perhaps making lemonade out of a lemon: to learn how to handle a damaged core safely and efficiently.

AFTERMATH OF ACCIDENT

The Atomic Energy Commission, AEC Headquarters decided not to inform the general public about the incident. The news leaked out in April 1956, covered by the nuclear and national presses. The editor of Nucleonics warned the AEC that nuclear accidents were public business. He said: “Apart from the bad effect that secrecy would have on attitudes toward nuclear safety, such withholding of news is wrong in principle. It is beyond the authority of AEC to withhold information not affecting the national security. And because AEC operates in so much secrecy, public confidence in it will surely be undermined.”

Analysis found that under the influence of the extraordinary heat, the fuel elements had bowed and expanded, causing the obstruction of the coolant flow in the coolingchannels. The heat had been greater on one side of the elements than the other, and since the fuel was clamped at both ends, it bent toward the higher heat, a simple mechanical event. In the future, this could be easily prevented by allowing expansion of the ends of the fuel elements.

EBR-I received a new core in 1957 employing zirconium spacers and other features to hold the fuel rigid. EBR-I continued to serve for experiments.

In 1962 Argonne National Laboratory (ANL) installed what would be EBR-I’s last core, this one with plutonium fuel. Experiments continued until ANL shut down the reactor in 1964, ready to move on with EBR-II, the next evolutionary step in the march toward commercial-sized fast breeders.

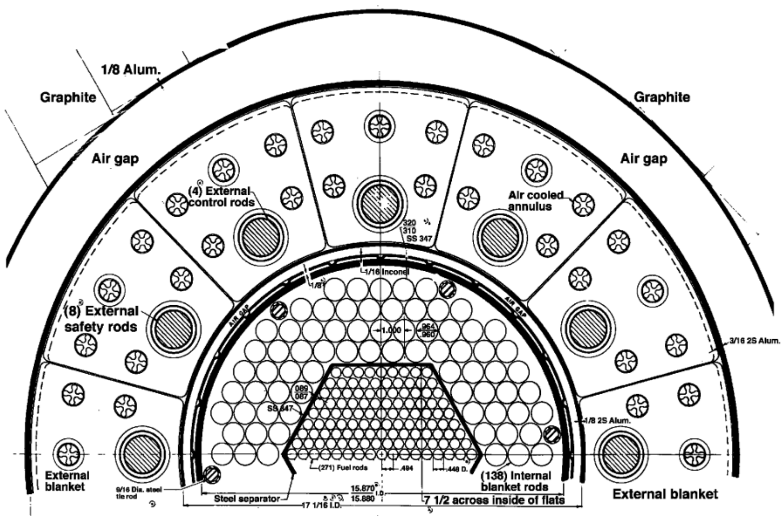

Figure 3: Experimental Breeder Reactor 1, EBR-I mark 1 and mark 2 core configuration.

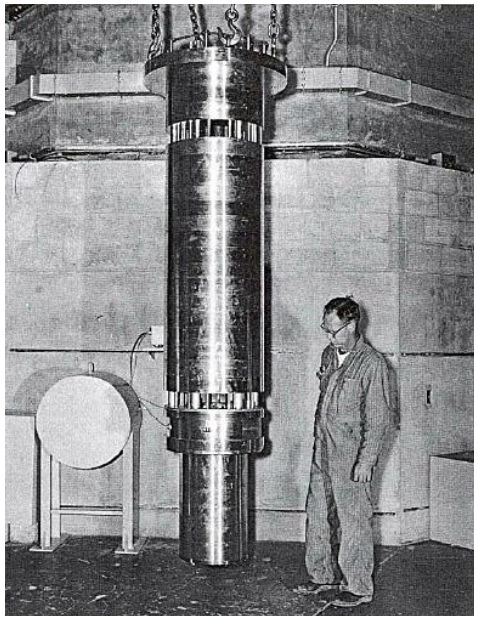

Figure 4. EBR-I core.

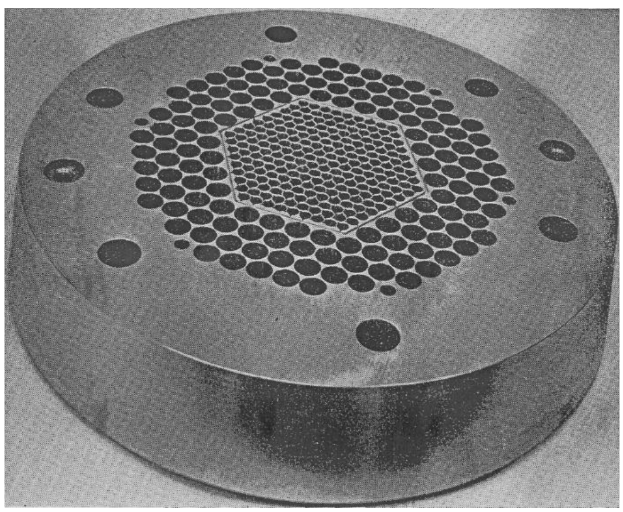

Figure 5. Upper plate of EBR-I.

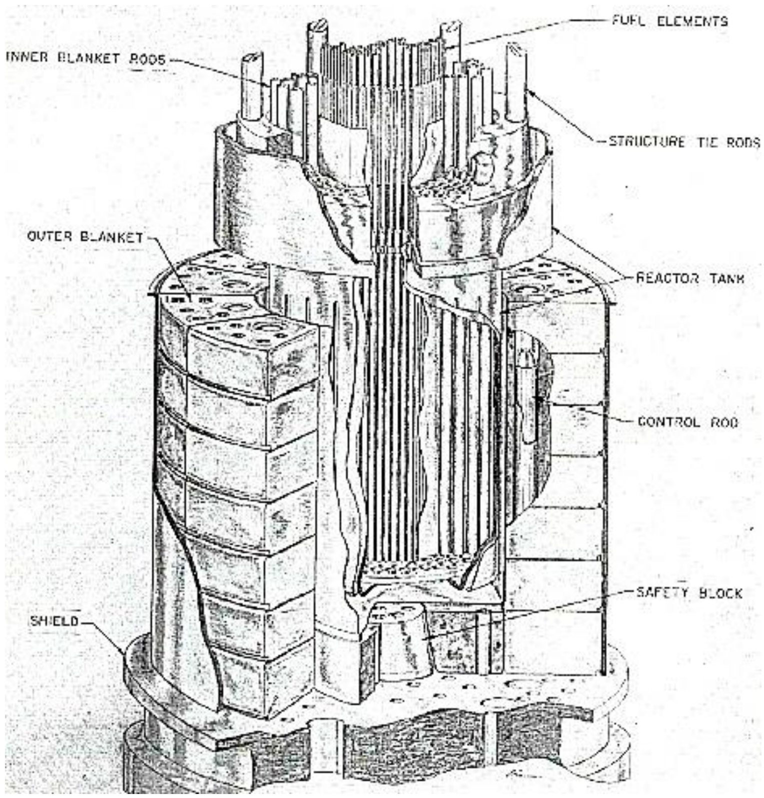

Figure 6. EBR-I core perspective.

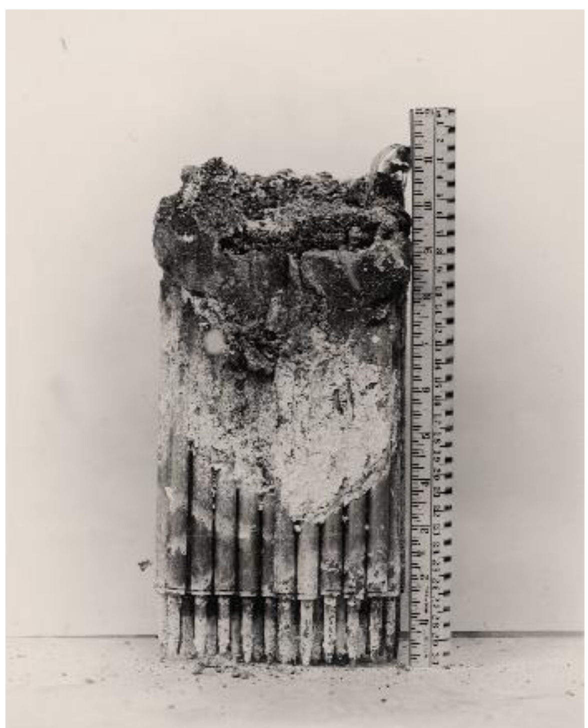

Figure 7. Damaged core of EBR-1 reactor from 1955 core meltdown.

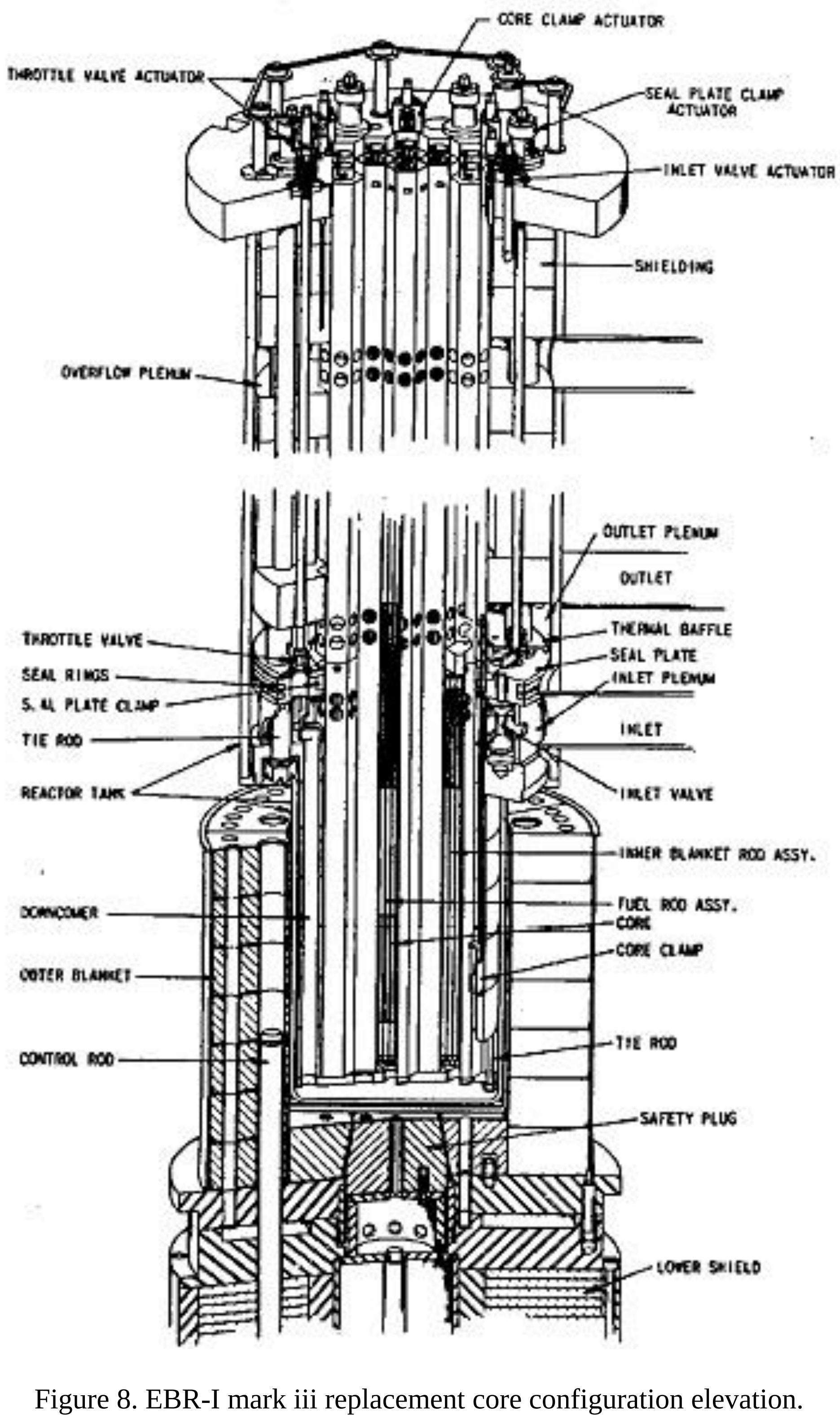

Figure 8. EBR-I mark iii replacement core configuration elevation.

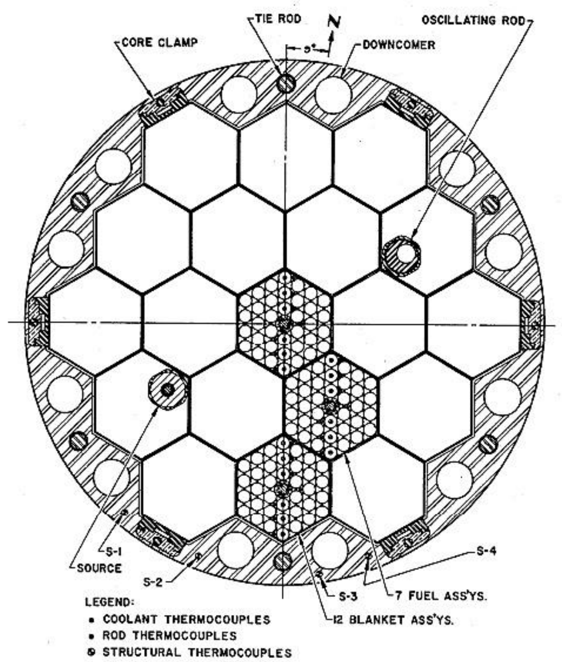

Figure 9. EBR – I mark iii core configuration at midsection.

Figure 10. EBR-II plant succeeded the EBR-I reactor.

MAGNETO HYDRODYNAMIC (MHD) PUMPS

Hendrik Lorentz equation is used to introduce the principle of operation of an MHD liquid metal pump eliminating moving parts. Like in an electromagnetic gun, the electric current path is I = ev and the magnetic flux is B. The current passes through the rails and the armature, which is a plasma. According to Lorentz law of magneto hydro magnetics, a resultant force F is generated that is perpendicular to both the current path and the magnetic flux. According to Lorentz equation:

$$\begin{aligned}\bar{F} &= e\bar{E} + \frac{1}{c} e\bar{v} \times \bar{B} \\ &= e\bar{E} + \frac{1}{c} \bar{I} \times \bar{B}\end{aligned} \tag{1}$$

where c is the speed of light.

In the absence of an electric field E:

$$\begin{aligned}\bar{F} &= \frac{1}{c} e\bar{v} \times \bar{B} \\ &= \frac{1}{c} \bar{I} \times \bar{B}\end{aligned} \tag{2}$$

The force uses the generated plasma to accelerate a projectile. The rails are constrained by the barrel, and the armature is allowed to move and accelerate the projectile. An arc discharge across the base of a projectile can act as an armature if it is confined behind the base of the projectile. Confinement of the plasma can be achieved if two rails are used above and below the projectile, and with insulating rail spacers to the right and left hand sides. In a solid armature were used, the projectile must maintain contact while sliding along the rails. With such type of device velocities of 2 km/sec can be attained. Higher velocities reaching 11 km/sec can be achieved with plasma arc armatures, eliminating the contact. This velocity is about 10 times the speed of a rifle bullet or 30 times the speed of sound. Problems of erosion of the gun barrel would have to be surmounted.

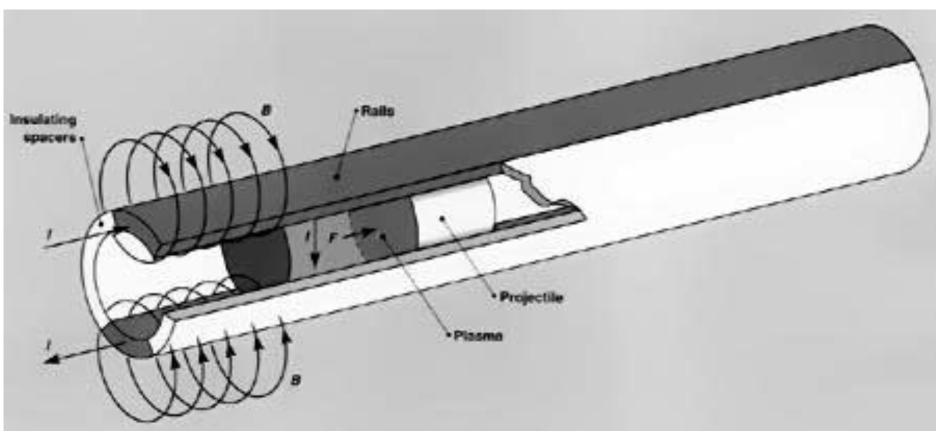

Figure 11. Principle of operation of a rail gun.

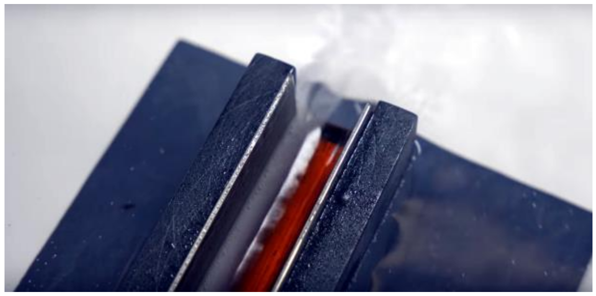

Figure 12. Ionized water propelled by a MHD pump. It may silently propel a naval vessel silently without moving parts as in the “caterpillar drive” in the movie: “The Hunt for Red October.” An impediment is the generation of bubbles of hydrogen caused by the electrolysis of the water.

Figure 13. Liquid metal MHD pump. Perpendicular electric and magnetic fields generate the force moving the liquid metal which is a eutectic liquid metal alloy at room temperature composed of of Pb, Bi, tin and indium.

REFERENCE

1. George Voelz, “The SL-1 Reactor,” Chapter 15, in: Suzan M. Stacy, ed. “Proving the Principle - A History of the Idaho National Engineering and Environmental Laboratory, 1949-1999, DOE/ID-10799, 2000.