CONF-850410--15

CONF-850410--15

DE85 004039

SAFETY IMPLICATIONS FROM 20 YEARS OF OPERATING EXPERIENCE AT EBR-II

by

J. I. SACKETT and H. W. BUSCHMAN
ARGONNE NATIONAL LABORATORY
IDAHO FALLS, IDAHO 83401

Summary of a paper
to be presented
at the

INTERNATIONAL TOPICAL MEETING ON

FAST REACTOR SAFETY

KNOXVILLE, TENNESSEE

April 21-25, 1985

SAFETY IMPLICATIONS FROM 20 YEARS OF OPERATING EXPERIENCE AT EBR-II

J. I. Sackett and H. W. Buschman
Argonne National Laboratory
Idaho Falls, Idaho 83401

EBR-II recently passed a major milestone in its operating history, 20 years of operation on August 13, 1984. The plant has gone through three major program phases during this time and is now entering a fourth. Those are: 1) demonstration of the feasibility of a complete LMFBR power plant, including on-site reprocessing of metal fuel, 2) irradiation testing of fuels and materials to support core and fuel design for CRBR and FFTF, 3) operational-safety testing to establish and demonstrate the inherent safety of LMFBRs and now, 4) the integration of this technology into demonstration of the integral fast reactor (IFR) concept. As EBR-II has progressed through these phases, much has been learned that is relevant to fast-reactor safety.

Probably the most important lesson is that LMFBRs have inherent characteristics that can contribute strongly to safety if design advantage is taken of them[1]. As has been established in the course of operation, good design advantage was indeed taken of these characteristics for EBR-II. This has allowed EBR-II to greatly simplify the reactor shutdown system, removing 29 trips with a corresponding improvement in plant factor and simplifying both operation and maintenance.[2] These characteristics have also allowed EBR-II to accommodate aggressive shutdown-heat-removal-testing, culminating in loss-of-flow-without-scram tests planned for 1985 and 1986.[3] One result of this work is that we are now in a position to further simplify the plant by eliminating requirements for several engineered safety features, possibly including the auxiliary pump in the primary system. The auxiliary pump was intended to augment natural convective flow for core cooling under a variety of transient conditions. The results of improved analytic modeling and whole plant tests has provided confidence that the pump is not required for safety.

The primary heat-transport-system is in fact designed to remove decay heat without requiring electric power. The secondary sodium system is not required for heat removal and is, therefore, not "safety grade." The secondary sodium is drained upon loss of water in the steam drum or a leak in the steam-generators. Perhaps the best operational demonstration of the benefit to safety of these features was a fire in the emergency power electrical switchgear in March 1981 that, through a complicated series of events, caused the plant to lose both normal and emergency ac power. Reactor safety was not a concern, however, because decay heat was rejected reliably by natural convective flow. The major operational concern was to establish power to the feedwater pump before the steam drum was boiled dry and it would be necessary to dump the secondary sodium to the storage tank (to avoid thermal stress in the steam system).

Another important contribution to safety has been demonstration of the benign nature of fuel-clad breach and the safe continued operation of breached oxide and metal fuel.[4] This test program is continuing, exploring the behavior of breached fuel under increasingly severe conditions, including over-power transients in EBR-II. As a secondary result of this testing, much has been learned about the impact and control of fission products released to the cover gas and the primary sodium. Both because of the primary-system design (a pool system with a large sodium inventory to better accommodate contamination) and the development of effective cleanup systems for fission products, it is being demonstrated that EBR-II and other LMFBRs can safely accommodate breached fuel.

An important aspect of the EBR-II operating history has been the continued development of metal fuel, which is the EBR-II driver fuel.[5] Besides greatly improving its operating capability, much has been learned about its inherently safe characteristics. The two most important are: 1) the development (at relatively low burnup) of interconnected porosity in the fuel which then allows fission gas to be released, limiting further fuel swelling and resulting in a mechanically weak fuel-matrix that can be easily constrained by the cladding and, 2) the relatively low temperature-rise radially across the fuel, resulting in low fuel-centerline temperatures. This low fuel-centerline temperature limits the positive reactivity feedback from doppler as the fuel centerline temperature decreases on a loss of flow. It is this characteristic that offers significant potential for designing plants that can survive loss-of-flow without scram.

Other important factors include strong negative reactivity feedback from structural components in the core, large thermal capacity from the primary sodium inventory and relatively "slow" pump coast-down on loss-of-power. Each of these characteristics exists in the EBR-II plant and has been explored extensively by both analysis and tests.

Another finding of major importance, but one which has been difficult to describe and distill in a way to be of real use to designers, is operability. The operability of EBR-II has been constantly improved throughout its history, as indicated by improvements in plant factor. Improved operability is also of major significance to safety, reducing the number of operating or maintenance errors that could lead to accidents. The key design ingredients for inherent operability are:

1) A relatively simple plant design

2) A relatively small number of active components (especially valves and pumps)

3) A relatively small number of instruments for control or protection.

4) A clean, uncluttered presentation to the operator of information he needs to control and maintain the plant.

In a word, design complexity is the enemy of operability. Unfortunately, the desire to emphasize redundancy and diversity can work strongly against operability and, in some cases, safety. At EBR-II, much has been done to simplify the plant by removing unnecessary systems. This can be done if the basic plant is itself inherently safe. Also, much work is now underway to improve the way information from plant instrumentation is used for control or protection, reducing the complexity of what is presented to the operators. (This has been emphasized as a result of problems encountered in fuel handling at EBR-II.) Third, many control functions are being automated, again to streamline and simplify both operation and maintenance. For example, EBR-II reactor power and shaped power transients can now be controlled by computer, the EBR-II automatic control rod drive system. To be automated next is reactor startup.

Increasingly, computers will be utilized at EBR-II (and other plants) to simplify the tasks of operation and maintenance; their reliability and usefulness must be demonstrated. Continued EBR-II operation is expected to contribute to this area as well.

In summary, the EBR-II operating experience has gone a long way toward demonstrating that LMFBRs can be designed to be both inherently safe and easy to operate and maintain.

REFERENCES

1. Sackett, J. I., Singer, R. M., Amorosi, A., "Design Features to Maximize Simplicity, Operability and Inherent Safety of LMFBRs," Trans. ANS, Vol. 38, June 1982

2. Sackett, J. I., "Safety Philosophy in Upgrading the EBR-II Protection System," proceedings of the International Meeting on Fast Reactor Safety and Related Physics, Chicago, November, 1976

3. Singer, R. M., et al., "Decay Heat Removal and Dynamic Plant Testing at EBR-II," Second Specialists' Meeting on Decay Heat Removal and Natural Convection in LMFBR, BNL, Upton, New York, April 17-19, 1985

4. Lambert, J. D. B., et al., "Performance of Breached LMFBR Fuel Pins During Continued Operation," BNES Conference on Nuclear Fuel Performance, March 25-29, 1985 (submitted)

5. L. C. Walters, B. R. Seidel, J. H. Kittel, "Performance of Metallic Fuels and Blankets in Liquid-Metal Fast Breeder Reactors," Nuclear Technology, Vol. 65, May 1984