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IRRADIATION TESTING FACILITIES: NEEDS, LIMITATIONS AND AVAILABILITY^(a)

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IRRADIATION TESTING FACILITIES: NEEDS, LIMITATIONS AND AVAILABILITY

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The needs for fast reactor irradiation testing facilities are reviewed and the availability of testing reactors to meet the needs are discussed. Limitations of available facilities are identified and space requirements are compared with availability. The need for continued and improved availability of EBR-II for near term fast reactor fuels and materials testing is emphasized and alternate testing facilities such as Fermi are briefly reviewed. The overall testing capabilities of the Fast Flux Test Facility are discussed.

Meaningful irradiation testing results are clearly an essential requirement for the successful development of the LMFBF. The establishment of a technology that permits the long term reliable operation of fuel cladding and structural materials at temperatures in excess of half their melting points in high energy irradiation fields to fluences significantly greater than those experienced to date should not be expected to be a straight forward development and testing task. Further, the behavior of fuel materials at the levels of burnup and temperatures required for economic power generation are subject to significant uncertainty. The characteristics and consequences of failure of fuels and materials in the high temperature sodium coolant, with its affinity for impurities and certain fission products, are poorly understood. The list of questions which must be answered to permit successful design and operation of an economic and reliable fast breeder reactor whether cooled by sodium or other fluids, is long and challenging.

With respect to the needs for irradiation testing facilities to provide means for developing answers to the many technical questions, it must first be stated that, in general, fast reactors are needed to test fast reactor fuels and materials. The current abundance of thermal test reactors can be used for some purposes such as screening tests of potential fuel materials, examining questions such as does fuel A swell more than fuel B, other things being equal. Such tests can also be used in a semi-quantitative way to cross compare results of the limited fast reactor irradiations with the much larger number of thermal flux irradiations of many of the fuels and materials of interest to fast reactors. In addition, some use is being made of thermal test reactors because of the closer approximation to fast reactor fuel column lengths which can be tested, compared with the available US fast testing facility, EBR-II. Also, some thought is being given to use of thermal test reactors as nuclear heat sources for investigation of things such as fuel rod failure and fission product release characteristics using specially designed integral sodium loops. By and large however, thermal test reactors are of interest for fast reactor testing because of their availability rather than because of known applicability of results.

The only operating US sodium cooled fast reactor, EBR-II, must clearly be the primary test facility for LMFBF irradiation testing for the immediate future. Use of this facility has grown in an exponential manner since 1965 when the first

few experimental assemblies were installed. Today, the available irradiation space in EBR-II, at least in the higher flux positions, is essentially occupied to the extent of operational capability. At the present time, there are approximately 34 experiment containing assemblies being irradiated in the EBR-II. The makeup of these experimental assemblies range from full experimental fuel loadings in encapsulated 19 pin arrays, to 19 and 37 pin configurations containing materials specimens with relatively little fuel content. The number and composition of these experimental assemblies is such that the available reactivity is the primary restraint on further experimental irradiation test insertions in high flux locations.

A significant factor limiting the output of experimental results from EBR-II irradiations has been the operational availability of the facility. As a result of a variety of EBR-II operating problems, and a conservative operation philosophy, the effective plant factor has been limited to 30% in 1966 and only 20% in 1967. The operating problems encountered have included nuclear performance anomalies, difficulties in detection and isolation of failures in experimental and driver fuel pins and a larger number of non-reactor related systems difficulties. Plans for improvement in the overall plant factor of EBR-II are being developed in recognition of the need to provide greater on-stream time but these improvements can be expected to require as much as three to five years to develop an effective plant factor in the range of 40 to 60%. The low operational plant factor of EBR-II is a significant factor in the rate of progress of LMFBFR irradiation testing as evidenced by the observation that 24 of the 34 experimental assemblies inserted into the reactor in the past three years are still under irradiation. It is also true that many of these tests have high exposure objectives which require long irradiation times.

Projections of EBR-II irradiation test space needs to support LMFBFR development programs, including FFTF, over the next one to two years clearly indicate that the available space in the higher flux positions falls substantially short of the indicated needs. Current planning by EBR-II users calls for a minimum of twelve additional subassemblies over roughly the next year with some planning indicating that this estimate may be low by as much as a factor of two under certain conditions. While minor improvement in accommodating the backlog and planned experimental irradiations will result from the planned increase in EBR-II power to 50 MW, the increase in space with flux of interest for fuel irradiation is still small, rather like the visible part of the proverbial iceberg. It appears most likely that some form of priority system will be necessary until the EBR-II plant factor significantly improves and until unencapsulated experimental fuel irradiations become accepted practice.

With improved availability, EBR-II will make a more rapid contribution to the development of LMFBFR irradiation testing results. However, this facility like any irradiation testing facility, has some limitations, partially inherent, which limit the direct applicability of results and restrict experimental flexibility. A primary limitation is the maximum flux level, approximately 2 to 3×10^{15} nv. Because the available flux is substantially below the design levels for FFTF and interests for LMFBRS, long irradiation times are required to achieve materials irradiation fluences which are representative of the expected design condition. While fuel burnup rates can be adjusted to more nearly represent prototypic conditions by the addition of U-235 enrichment, such a change results in a non-prototypic relationship between fuel burnup and cladding fluence, complicating the evaluation of test results. Near prototypic fuel pin irradiations with respect to length are not possible because of the relatively short core, 14 inches, compared with LMFBFR and FFTF design core lengths ranging from two feet to over four feet. This parameter has assumed greater importance in recent months with the recognition that radial fuel swelling may be affected by fuel column length.

The inability to provide instrumentation for irradiation tests in EBR-II is a limitation which complicates interpretation of test results. In addition to the

well recognized importance of characterized operating temperatures on cladding and structural materials with regard to effects of temperature on mechanical properties, there is recent evidence that irradiation damage effects in cladding materials may be particularly sensitive to narrow ranges of temperature. Thus, the need for quite precise knowledge of cladding temperature assumes new importance.

An additional limitation of EBR-II is the necessity to conduct all tests in the primary coolant, with primary coolant chemistry and, subject to some adjustment, primary coolant temperature. Thus, tests which might evaluate effects of coolant chemistry, particularly oxygen, on cladding mass transfer and mechanical properties are precluded, except at the EBR-II operating coolant purity levels. While some effort has been devoted to investigation of possible limited closed loop capability in EBR-II, the availability of such a capability, which might also permit somewhat more risky tests, appears to be several years away.

Some of the limitations of the EBR-II would be eased with the availability of the Enrico Fermi reactor for fuels and materials testing. The core height and potential flux are substantially more representative of LMFBR requirements, but the same limitations apply with respect to instrumentation capability and closed loops. There is also some probability that the SEFOR reactor might be convertible for irradiation testing some time in the early 1970's, after the currently planned physics studies have been completed. The capabilities of a modified SEFOR would not however be expected to be a major contribution to fuels and materials testing as a consequence of the relatively low power and flux but it is not known if a detailed assessment of potential testing capabilities has been made.

The Fast Flux Test Facility is being designed as the primary fuels and materials testing facility for the AEC's LMFBR development program, under the management of the Pacific Northwest Laboratory. This major testing reactor will provide a flexible capability for testing of fast reactor fuels and materials under well characterized and controlled conditions. The facility includes several sodium cooled, independent closed loops with a heat dissipation capability of up to 6 MW with bulk sodium temperatures up to 1200°F. These closed loops will provide controlled coolant chemistry with individual coolant purification systems as well provide for instrumentation of experiment test conditions including temperature, flow, and other specialized instrumentation. Tests can be conducted in these closed loops to failure, a feature of major importance since characterized test failures frequently contribute the greatest yield of meaningful testing information. Substantial test space is provided within the driver core region which will operate initially with an outlet temperature of 900°F with similar instrumentation capability to the closed loops. Reflector region test space is also provided. With a core height near three feet closely prototypic fuel pin cluster tests can be performed. In recognition of the limitations arising from significant departures in available neutron flux from LMFBR design values, the FFTF will provide an initial fast flux capability approaching 10^{16} nv. Additional planned FFTF features include facilities for short term, cyclic and limited transient testing, a closely coupled inert gas atmosphere non-destructive examination facility and a nuclear proof test facility. The FFTF is planned to be complete in 1973, making it available for use in proof testing of fuel for LMFBR demonstration plants, and in the confirmation of design margins for fuels for those plants. A major additional use of the FFTF will be in the development of improved fuels and materials for commercial LMFBRs, both in exploring the capabilities and behavior of candidate fuels and materials systems under prototypic conditions and in fuel system proof testing.