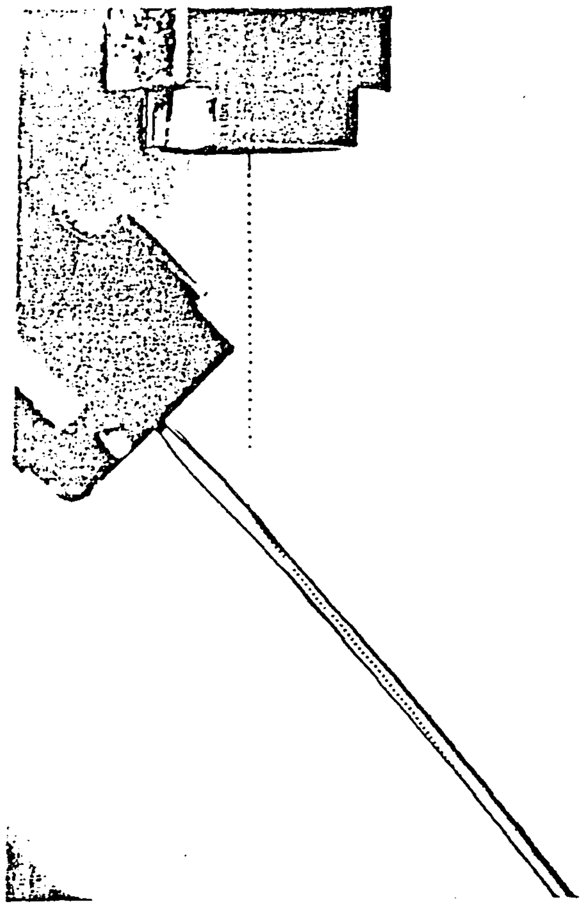

Diameter of micro spheres 0.2 mm

Production rate 6000 spheres/s

Fig. 2

Production of Fine Fraction Micro Spheres Using a Vibrating Drop Generator and Gelation in a Silicon Oil Jet

STATUS OF FAST BREEDER REACTOR DEVELOPMENT IN THE UNITED STATES OF AMERICA

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INTRODUCTION

The Federal Government has recognized that assuring adequate supplies of economical electricity is important both domestically and to the world community and that many traditional means for producing electrical energy cannot be counted on to meet the growing need for electricity. Remaining sites for large hydropower plants are severely limited. Oil and natural gas, attractive as peaking power options, cannot be regarded as economic fuels for major new baseload electric power stations.

Other potential sources for producing electricity--fusion, solar photovoltaics, wind, biomass, geothermal--are being developed, but at this point do not offer a high confidence in their ability to generate large amounts of economical electricity. Each suffers from at least one of three basic limitations: 1) the technology for large-scale electric power is not developed; 2) the technology does not yet appear to be economically competitive; and 3) the resource may be promising in individual regions of the country, but has a limited national capability.

The United States is left, then, with only two energy sources for large-scale electric power expansion: coal and nuclear energy. Because uranium is a limited resource, nuclear power cannot be considered a long-term contributor to our electricity supply without the breeder reactor. Since the breeder utilizes the large fraction of uranium that cannot be used in current generation light water reactors, it ensures that nuclear power can be a reliable source of electricity for thousands of years, independent of the price and supply of uranium. The breeder provides insurance against future shortages of economic electric capacity.

The goal of the United States Liquid Metal Fast Breeder Reactor (LMFBR) program is to develop the technology to the point that the private sector can deploy a safe, economic breeder reactor.

The LMFBR will provide virtually inexhaustible supplies of electrical energy for the long term and will provide additional confidence to LWR nuclear deployment in the near term. The LMFBR program consists of a streamlined research and development effort focussing on those actions needed to enable private sector financing of industrial deployment including plant demonstration and technology efforts in reactor fuels, components, materials, physics, and safety.

Operating experience with breeder reactors in the United states and abroad leaves no doubt as to their technical feasibility. What remains is a demonstration of the requisite technology to enable commercial deployment by the private sector at an acceptable degree of risk. In essence, the LMFBR is a complex undertaking requiring years of intensive work. This size of the undertaking is currently beyond the investment and time horizon of any domestic business venture.

The Federal role in breeder reactors is to conduct the necessary research, development and demonstration so that the potential economic, environmental, and safety benefits of the breeder can be utilized by private industry at a risk level that is consistent with normal business practices and to provide a positive policy climate for the establishment of the necessary institutional and regulatory framework for the development and deployment of commercial size breeder plants by the private sector. The ultimate responsibility for commercialization will rest with private industry.

During the past year major progress occurred across the spectrum of United States Department of Energy (USDOE) programs for development of the fast breeder reactor.

The Fast Flux Test Facility (FFTF) completed its first cycle of sustained operations and will shortly complete a second cycle of operation. The FFTF is the world's largest and most heavily instrumented reactor for testing core components. Over seventy full-size core components are currently undergoing irradiation and over half of the design fuel burnup of 80,000 MWd/MTm has been attained.

The Clinch River Breeder Reactor Plant (CRBRP), which is an intermediate step before building a large-scale plant, is moving toward the construction stage. The plant design, which is the forefront of technological advance, is approximately 90% complete. More than 70 percent of the major equipment and components have been delivered or are on order. The licensing process, resumed in September 1981, is proceeding exceptionally well. Last August the Nuclear Regulatory Commission (NRC) granted the USDOE request to begin site preparation and in September 1982 work was initiated. Overall, CRBRP licensing is moving at a faster pace than that of any light water reactor over the past five years.

Agreement was reached in 1982 between the USDOE and the Electric Power Research Institute (EPRI) to cooperate on the large scale prototype breeder effort. A Consolidated Management Office was established to include representatives from the utility industry, reactor manufacturers, and architect engineers. Plans are underway to incorporate cooperative agreements with foreign interests.

Significant base technology advances were primarily related to FFTF continuous operation. Better physics prediction techniques have been developed, improved knowledge of fuel bundle thermal/hydraulics behavior has been obtained, and a fully-instrumented materials test is providing unique data on in-reactor stress-rupture properties of US and foreign alloys.

Construction was completed or is underway on three facilities related to the FFTF. A Fuel Storage Facility will permit storage of several years of FFTF fuel until it can be processed or placed in long-term storage. A Maintenance and Storage Facility will be capable of repairing large components. The Fuels and Materials Examination Facility will house the FFTF and CRBRP Secure Automated Fuel (SAF) fabrication line.

The United States Department of Energy continues to be actively involved in international exchanges of breeder reactor technology. This is facilitated through bilateral agreements with other countries engaged in breeder reactor development, as well as through international agencies such as IAEA and OECD.

PLANT PROJECTS

Current USDOE plant projects include the Experimental Breeder Reactor-II (EBR-II), the Fast Flux Facility (FFTF), the Clinch River Breeder Reactor Plant (CRBRP), and the Large Scale Prototype Breeder (LSPB). Plant status ranges from successful operation at EBR-II and FFTF, to initial stages of construction and continued phases of licensing for CRBRP, to advanced conceptual design and institutional planning for the LSPB. Both EBR-II and FFTF were the sole responsibility of the USDOE. The CRBRP is a joint undertaking of the USDOE and 753 electric systems from the public, private, municipal, and cooperative sectors of the utility system. The LSPB entails a cooperative undertaking between the USDOE and the Electric Power Research Institute (EPRI) with the projected future inclusion and financial contributions of electric utilities, private industry, and foreign participants. Prime responsibility for constructing and operating this project rests with private industry.

Experimental Breeder Reactor-II (EBR-II)

The EBR-II is a 62.5 MWt/20 MWe pool-type LMFBR, located at the Idaho National Engineering Laboratory (INEL). The plant is in its twentieth year of operation, having achieved wet criticality in November 1963. This plant has been the work horse of the USDOE fuels, absorber, materials, and safety irradiation programs, routinely achieving plant capacity factors of over 70% throughout the past seven years. The double-tube-wall steam generators have operated throughout the plant life with no major repairs.

The EBR-II testing program is currently emphasizing operational reliability testing. This program covers sustained operation of breached fuel elements, transient overpower and undercooled testing of intact and breached fuel, and shutdown heat removal testing.

Fast Flux Test Facility (FFTF) Project

The FFTF Project comprises the reactor and supporting facilities located at the Hanford Engineering Development Laboratories (HEDL). The FFTF recently completed its first 100 day cycle of sustained operation and is nearing conclusion of the second cycle. By March 1, 1983, the FFTF had achieved over 150 equivalent full powerdays (EFPD) of operation with a peak fuel burnup of approximately 37,000 MWd/MTm. It recently operated for two months at full power without interruption.

The FFTF is a 400-megawatt (thermal) sodium-cooled fast reactor specifically designed for development and testing of fast breeder reactor fuels, materials, and components. The reactor is a loop-type plant, with three heat transport system loops. The plant has neither steam generators, nor blanket assemblies for fissile breeding, consistent with its role as a test reactor. The outer three rows of core assemblies are stainless steel radial reflector assemblies which serve to enhance the neutron flux in the core interior.

The FFTF is equipped with a great deal of instrumentation. Each core assembly is provided with instruments for measurement of sodium flow rates and outlet sodium temperature. Three instrument trees, one servicing each of the three core sectors, provide this outlet instrumentation for all fuel assemblies, control and safety assemblies, and for selected reflector assemblies. In addition, eight of the 73 core positions are equipped for full in-core instrumentation. Two of these eight positions are available for closed-loop facilities having independent sodium loops, intermediate heat exchangers, pumps and dump heat exchangers. The other six fully-instrumented positions are open to reactor primary coolant.

Fuel assembly loading began in November 1979, initial criticality was achieved in February 1980, full power was first reached in December 1980, and sustained (first cycle) operation began in April 1982. After an interruption caused by a primary sodium pump problem, first cycle operation was completed in November 1982. Second cycle operation began in January 1983. A major project goal for

1983 is to complete two full operating cycles. This would result in achieving goal burnup of 80,000 MWd/MTm for the first core fuel by the end of 1983.

Clinch River Breeder Reactor Plant (CRBRP) Project

Site work for the CRBRP began in September 1982 and is progressing rapidly. In November 1982 the NRC issued the CRBRP Final Environmental Statement Supplement which recommended issuance of a Construction permit.

The overall objective of the CRBRP project is to design, construct, and test the nation's first intermediate scale LMFBR powerplant and operate the plant as part of a utility system. The CRBRP will provide important information regarding the safety, environmental acceptability, and economic potential of LMFBR's as an essentially inexhaustible, domestic energy source.

Design of the Clinch River Breeder Reactor Plant, a 975 MWt/375 MWe LMFBR, is now over 90% complete. The CRBRP is a three-loop plant which will operate at a vessel outlet sodium temperature of 995°F (535°C). The plant incorporates a "hockey stick" steam generator design, with identical evaporator and superheater modules. Each loop includes two evaporators and one superheater. The steam generator module is a 757-tube counterflow heat exchanger with a dry weight of about 106 tons. The fuel material is mixed uranium-plutonium oxide, and the blanket material is depleted uranium oxide. It is presently planned to operate with a heterogeneous core configuration which consists of a single fuel enrichment zone interspersed with inner blanket assemblies. This fuel and blanket array is surrounded peripherally by radial blanket assemblies. Upper and lower axial blankets are fourteen inches (35.6 cm) in length. Fifteen control rod assemblies (nine primary and six secondary) are employed. An equilibrium-cycle breeding ratio in the range 1.22 - 1.29 is expected with the heterogeneous core configuration.

The cumulative value of CRBRP equipment delivered through the end of 1982 is $359 million including such major components as the reactor vessel, guard vessel, primary control rod drive mechanism, intermediate heat exchangers and check valves. Testing is underway on the prototype sodium pump and performance testing begun on the steam generator. The total value of components on order at the end of 1982 was about $740 million, representing about 75% of the major nuclear components. Total project expenditures were almost $1.4 billion at the end of 1982. About $2.2 billion will be required to complete the plant by October 1989.

With the full support of the Administration for completion of the project, the Agency has instituted the necessary actions to permit completion of the CRBRP at the earliest possible date. The full licensing review by NRC has been reactivated, the CRBRP management structure has been reorganized and strengthened, and CRBRP contractual arrangements are being streamlined and made more cost-effective.

The final supplement to the Final Environmental Statement was issued by the NRC on November 3, 1982. Environmental hearings by the Atomic Safety and Licensing Board (ASLB) were concluded in January 1983 and on February 28, 1983 the ASLB issued a partial initial decision recommending a Limited Work Authorization. The NRC Safety Evaluation Report was issued on March 11, 1983. This will allow hearings to begin in early summer 1983 and permission to begin safety-related construction in November 1983.

Large Scale Prototype Breeder (LSPB)

The LSPB program is a joint effort of the US Government and industry to establish institutional and financial arrangements, and to develop implementation plans for proceeding with the design, construction, and operation of a commercial size breeder under a cooperative arrangement that is expected to include electric utilities, private industry, and foreign government participation.

An agreement between the Department of Energy and the Electric Power Research Institute (EPRI) to cooperate on the large scale prototype breeder effort was executed in August 1982. EPRI established a Consolidated Management Office

(CoMO) which began operation in October 1982 to execute its responsibilities under the terms of the DOE-EPRI agreement. CoMO staff include representatives of the utility industry, reactor manufacturers and architect engineers. The private sector is contributing $10 million to this effort over the next two years; DOE has budgeted $15 million for FY 1983 and is requesting $15 million in FY 1984.

FY 1983 CoMO efforts are directed at : 1) establishing specifications for the LSPB that reflect requirements of the utility industry and design commonality, where possible, with foreign participants; 2) incorporating appropriate design changes into the previously established large plant advanced conceptual design to provide inherent safety, competitive economics, and low technical risks; 3) advancement of design with emphasis on capital cost reduction; 4) establishment of plant schedule and cost estimates; 5) continued evaluation of potential sites; and 6) initiation of environmental and safety documentation.

Current planning is for the major financial contribution toward the cost of the LSPB to be provided by private industry with efforts made to secure financial and technological cooperation with foreign nations.

BREEDER TECHNOLOGY

This program provides the technology base to enable the plant projects to proceed in a cost-effective manner, enabling the private sector to proceed with industrialization and deployment of the LMFBR. The mission of the LMFBR base program is to develop the requisite technology to the point where the private sector is able to support construction and operation of inherently safe, economically competitive liquid metal fast breeder reactor plants for supplying electricity to the grid. This program is subdivided into five general categories: Engineered Systems and Components, Materials and Structures, Fuels and Core Design, Physics, and Safety.

Engineered Systems and Components

The objective of the Engineered Systems and Components program is to support the development and proof testing of key, high risk, high payoff components and systems which are needed for competitive LMFBR plants to meet the plant performance requirements, to improve reliability, to enhance plant and system simplicity and inherent safety, and to reduce capital and operating costs. The strategy is to perform sufficient R&D to generate the technology needed to support reliable and economic component design, fabrication, and operation; and to verify adequacy by testing critical features, small models, and engineered development units. Principal emphasis has been placed on the development of large steam generators and sodium pumps.

Steam generation development activities include the design, fabrication and testing of two different once-through steam generator designs for future large-plant applications: a single-wall, helically coiled tube concept and a double-wall, straight tube concept. Design of the 70 MW helical coil model was completed and a test unit will be delivered to the test site in mid 1983. The preliminary design was completed on a 70 MW straight-tube model, detailed design is underway, and fabrication is proceeding on the test unit. Testing will be conducted in the ETEC Sodium Components Test Installation (SCTI) in the 1984-1985 period. In addition, the prototype 117-MWt "hockey stick" CRBRP steam generator began testing in the SCTI in 1982. The steam generator effort also includes a series of large sodium-water reactor tests, completed in 1982, to simulate the effects on an LMFBR steam generator in the unlikely event of the complete rupture of a steam/water tube surrounded by sodium.

The development of large (85,000 gpm) primary-system and intermediate-system sodium pumps is proceeding. The reference primary pump model tests have been completed, and fabrication is progressing toward a delivery to ETEC in late 1983.

Other development activities underway to support component technology development includes flow induced vibration analysis including small scale IHX flow tests, flow distribution testing and analysis, mixing and stratification testing and analysis, subcomponent development and testing, fabrication process development, inspection development, maintenance equipment, and procedure development.

The efforts in the Materials and Structures area are needed to: 1) assist projects in the resolution of problems typically experienced during plant design, construction, licensing and operation; 2) satisfy R&D needs identified by plant projects; and 3) establish and document the technology base required for LMFBR Industrialization. The program addresses these needs by: 1) providing the technology required to assure that LMFBR components and systems will be free from structural failures during their design lifetime; and 2) developing materials, design methods and criteria, materials property data, and procedures that will assure economic and safe components and systems while providing designers with sufficient flexibility in component and systems design to facilitate optimization.

Program elements include high temperature structural design, seismic design, mechanical properties design data, fabrication, nondestructive examination, tribology, advanced alloys, and coolant technology.

Fuels and Core Design

Objectives of the Fuels Programs are to: 1) confirm performance of the current breeder fuel; 2) develop and prove the companion fuel blanket and absorber core component systems under prototypic conditions that demonstrate licensable, viable LMFBR core sytems; 3) support the CRBRP core requirements; 4) to extend the lifetime (3 years) of core components to be economically competitive; 5) develop, establish and demonstrate an integrated fuel supply for FFTF and CRBRP; and 6) transfer the developed technology to industry. Activities have accelerated since initiation of FFTF Operation. There are more than 50 full-scale test assemblies in the FFTF core. The test program includes 8 standard driver fuel assemblies which are earmarked for special examination upon discharge after one, two, three or four full cycles of reactor operation (an FFTF cycle is 100 to 112 equivalent full-power days). An additional six standard driver fuel assemblies are designated for operation to cladding breach or assembly deformation limits. A further ten assemblies include fuel pin spacer variables, four of which are grid-spaced tests; five assemblies have reference fuel pins and advanced alloy ducts; and four oxide fuel assemblies have advanced alloy cladding and ducts. Also included are oxide radial blanket and inner blanket assemblies; advanced absorber assemblies; two safety-related fuel assemblies with annular axial blanket pellets; and a reference driver fuel assembly fitted with an outlet radionuclide trap.

Other tests undergoing FFTF irradiation include reference absorber assemblies (in control rod positions), four structural materials surveillance assemblies (in reflector positions), and four fully-instrumented test assemblies. Two instrumented fuels test assemblies contain thermocouples which measure both axial and radial temperature distributions in full 217-pin reference driver fuel assemblies. An instrumented absorber test provides both temperature and pressure measurements for full and partial-length absorber stacks similating various control rod axial positions. These three assemblies provided valuable assembly thermal-hydraulics data during full-power and natural circulation testing. An additional fully-instrumented Materials Open Test Assembly (MOTA), dedicated to testing cladding, duct, and reactor structural materials began irradiation during FFTF Cycle 2 operation. This test is currently providing unique data on in-reactor stress-rupture properties of several alloys.

By March 1, 1983, the FFTF had achieved over 150 equivalent full power days (EFPD) of operation with a peak fuel burnup of approximately 37,000 MWd/MTm. The average and peak burn-up goals are 45,000 MWd/MTm and 80,000 MWd/MTm respectively. Four fuel tests and one absorber test have been removed from the core and two of the fuel tests have been examined. No evidence of possible performance problems were detected during the examinations. No cladding breaches have occurred in any driver assemblies or tests using reference fuel pins; however, early fission gas release occurred in a special test pin. The assembly containing the breached pin was rapidly identified using tag gas analysis techniques and removed from the core.

Steady-state irradiations including run-beyond-cladding breach (RBCB) of both oxide and carbide fuel pins continue in EBR-II emphasizing performance testing of pins incorporating advanced cladding alloys. A number of non-fueled tests with advanced alloys are continuing, some having reached three-year fluence values.

The requisite technology for fabrication of plutonium-bearing fuel elements, in a manner consistent with the needs of the nuclear industry and the general public for the next several decades is being developed. This technology development activity known as Secure Automated Fabrication (SAF) will provide fabrication methods which offer high productivity while affording maximum protection to operating personnel. The technology also reduces to the lowest practicable limits the potential for escape of plutonium from a fabrication facility. The concept involves full automation of unit processes, from initial powder preparation to the final step in fuel pin fabrication. Process control will be provided by a centralized computer linked to distributed local control systems.

Process integration of SAF technology is underway. This demonstration is being conducted with fuel material containing no plutonium. Installation of a complete SAF line in the Fuels and Materials Examination Facility (FMEF) will begin in 1984, with completion scheduled for late 1985. Plutonium will be introduced into the line in the 1986-1987 timeframe. The SAF line will have a fuel pin production capacity of six metric tons (U + Pu) per year. This capacity will be sufficient to fulfill the fuel supply requirements for both FTR and CRBRP. Subsequent fuel pin inspection and fuel assembly operations are also being automated to meet the same criteria as the SAF line in reducing personnel exposure, improving productivity, and enhancing quality.

Low level waste processing and wet scrap recycle capabilities are being developed in conjunction with the SAF technology. This will provide well over 99% plutonium recovery and a large reduction in the volume of waste arising from fabrication operations.

Physics

The purpose of the physics program is to prove and reduce to practice LMFBR data bases and analytical design capabilities needed for FFTF operation, CRBRP licensing, startup and efficient performance, and confident design of a near-competitive plant. Key elements maintained in the program are acquisition, testing and implementation of detailed nuclear data and analytical design capabilities, measurements and analyses of physics parameters in critical assemblies, and analyses of advanced core and shield design options. Selected priority efforts provide direct support of specific CRBRP licensing matters and studies of FFTF operating data, and contribute capabilities needed by industry for predicting the design and safety of future LMFBR plants.

As both the CRBR and LSPB have adopted heterogeneous core designs, considerable effort has been focused on zero-power experiments which mock-up heterogeneous core configurations. Particular attention has been given to acquisition of data for sodium void worth, fission rate distributions, criticality, control rod worth, and the ^{238}U capture-to-^{239}Pu fission rate ratio. The latter has tended to be overpredicted in typical LMFBR spectra. Recent progress in resolving this discrepancy includes the intercalibration of radio-metric and mass spectrometric measurement techniques, and the adoption of ENDF/B-V nuclear data in many recent analyses. These efforts have resulted in improvements in predictions.

The FFTF completed approximately 134 EFPD with the completion of the first cycle of FFTF operations. Initial results indicate that reactivity loss due to burnup is slightly greater than expected. Fuel discharged after Cycle 1 will be examined and burnup samples analyzed for comparison with calculations. Additional operational information concerning neutron source buildup and decay in Pu-enriched fuel has been obtained, and a broad base of FFTF dynamic response data has been accumulated using a technique of repeated small binary control rod oscillations covering a wide band of frequencies.

The physics program at the FFTF encompasses integral measurements of core neutron and gamma ray fluxes in support of the fuels and materials irradiation test program. Through the use of a special, cooled thimble, measurements were made at the center of the core using laboratory-quality detector systems to measure the neutron and gamma ray spectra, absolute fission rate distributions of a number of isotopes, and gamma ray dose rate profiles at very low power levels. An important initial application of this data was the determination of fuel pin power levels required to produce incipient fuel melting in fresh mixed oxide experimental fuel pins. Reaction rate measurements were also made throughout the shield, providing a basis for evaluating the lifetime of reactor components and for validating the analytical techniques employed for shield design.

 The buildup of corrosion products in the FFTF heat transport system is being monitored for evaluation of predictive methods, for establishing feasibility of maintenance techniques, and for future evaluation of methods of reducing dose rates associated with equipment in the heat transport system.

Safety

The safety program supports the licensability and industrialization of the LMFBR by performance of work to assure and demonstrate the public safety of large breeder reactors. It beneficially influences LMFBR design by identifying and exploiting inherent plant characteristics to enhance safety, reduce complexity, and reduce capital cost. Action will be taken in parallel with these activities to develop plant safety design criteria and a licensing approach which will reflect the renewed emphasis on inherency, improved safety, and reduced cost.

The program for development of fast reactor safety technology is organized according to five program elements. These elements include core safety considerations, categorized as four lines of assurance (LOA), and plant safety considerations. The four LOA's (LOA-1: prevent accidents; LOA-2: limit core damage; LOA-3: maintain containment integrity; LOA-4: attenuate radiological consequences) emphasize prevention of severe accidents (LOA-1 and -2) as well as mitigation of accident consequences (LOA-3 and -4).

The objective of LOA-1 is to demonstrate that LMFBR's can be designed, constructed and operated in such a manner as to present an extremely low probability of accident initiation. An important new element of the LOA-1 program is to better understand the constructive role of computers in operational safety activities. Recent accomplishments include the completion of the Master Information Data Acquisition System (MIDAS), now in operation at FFTF, and the development of a computerized procedures generation system.

The second line of assurance, LOA-2, provides a demonstration that the inherent response of the reactor system will limit core damage if accident initiation cannot be prevented. Such initiation could occur if the Reactivity Shutdown System (RSS) and/or Shutdown Heat Removal System (SHRS) fail to function, or if local faults are permitted to propagate beyond Design Basis limits. Activities in LOA-2 focus on 1) providing the RSS faults can be accommodated through the operation of a self-actuated shutdown system; 2) demonstrating inherent or degraded-mode SHRS operation, so that SHRS faults can be accommodated; and 3) showing that local faults which propagate beyond design basis limits can be accommodated without initiation of bulk sodium boiling. Recent progress in the latter area includes completing a series of PINEX experiments in which annular fuel pins were subjected to transient overpower conditions and molten fuel was observed to axially relocate in the central annulus--resulting in a negative reactivity feedback. A computer model has been completed, based on this data, to investigate the visibility of such fuel motion phenomena in terminating a certain class of accidents prior to fuel pin failure.

The objective of the third line of assurance, LOA-3, is to demonstrate a high probability of maintaining long-term containment integrity under whole-core disruption conditions. Accommodation of accident energetics and core debris is provided by the primary system boundary and by containment. Work in this category has involved modeling and analysis of initiation phase and transition phase events and energetics. An updated code, SAS4A, describing initiation phase events, was recently issued. To cover the longer time period allowing the transition phase, a code system, CONACS, is being developed to analyze the conditions within the plant containment boundary and their challenge to the integrity of the containment. Definitive work on sodium/concrete interaction and hydrogen generation/mixing is continuing.

A number of unterminated transient tests with fresh pins have been performed in TREAT under the US-UK collaborative program--both for transient overpower and transient undercooling conditions. TREAT tests employing pins irradiated in PFR have been initiated, and similar tests for fuel pins irradiated in FFTF are in the advanced planning stage.

Three tests have been conducted in the ETR-SLSF, to examine pin bundle behavior under different operational transients. The W-1 test consisted of numerous LOPI-type (Loss-of-Piping Integrity) transients modeled on the CRBRP design basis accident conditions. The test provided extensive instrumentation and was carried out in steps of increasing severity. The final run was unterminated, and carried through loss-of-fuel-pin integrity, sodium boiling, dryout, pin failure and flow reversal. The test showed considerable conservatisms in predictive capabilities. The W-2 test in SLSF was conducted in the slow transient overpower regime on a 10¢/s ramp from a steady-state power level at which the pin bundle had been fully preconditioned. Multiple disruptive failures occurred, leading to a molten fuel-coolant interaction event and flow reversal. Pretest predictions of pin failures were accurate to within about one second. An extensive post-test examination revealed that an outer pin of the seven-pin cluster failed prior to the central pin, due to effects not anticipated to occur under LMFBR accident conditions. The last test performed in SLSF is the P-4 test, which examined flow blockage and failure propagation within the pin bundle. Analyses of these tests are continuing.

The fourth line of assurance, LOA-4, demonstrates a high probability of attenuating the consequences of a radioactivity release inside containment by inherent attenuation mechanisms, such as rapid high-density aerosol depletion, and by operation of engineered cleanup systems. Large-scale sodium aerosol containment tests were recently completed; a large submerged-bed gravel scrubber, with a capacity of 10,000 ft^3/min has been built and tested to verify the viability of this concept for commercial application.

Plant Safety Conderations involve the establishment of a design criteria for balance-of-plant (BOP) aspects such that these present no hazards to public health and safety. The BOP aspects considered are fuel handling and storage, liquid metal spills and interactions with construction materials, and auxiliary systems. During the past year, a number of sodium-concrete interaction tests were performed and evaluated.

TEST FACILITIES

The major objective of the test facilities effort is to provide an experience base for safety, components, and system operation. This experience provides a proven baseline for scaling up systems and components. It also provides to plant projects and the base technology program a library of developed and verified sound operating and maintenance procedures.

Hot Fuel Examination Facility (HFEF)

The Hot Fuel Examination Facility is located at the Idaho National Engineering Laboratory (INEL) and comprises two adjacent hot cell complexes. The facility supports EBR-II and TREAT experimentation and is being used for postirradiation examination of selected FFTF experiments. In addition, HFEF continues to be used to assemble, disassemble, and examine tests from TREAT.

Transient Reactor Test Facility (TREAT)

TREAT is an air-cooled, thermal, heterogeneous reactor at INEL which is used to simulate various postulated reactor transients and transient undercooling events. It is presently being upgraded to allow accommodation of larger multi-pin reactor fuel bundles and structural materials under conditions simulating various types of nuclear excursions and transient undercooling situations.

Zero Power Plutonium Reactor (ZPPR)

The ZPPR, which is located at INEL, is a large and flexible critical facility, with capability for testing experimental reactor assemblies up to 4m x 4m x 3m. The ZPPR has been used extensively in studies of the CRBRP heterogeneous core configuration. It will continue to guide and confirm core designs which may incorporate features such as heterogeneous configuration, advanced fuels, and high burnup capabilities.

Energy Technology Engineering Center (ETEC)

The Energy Technology Engineering Center, located in the Santa Susana mountains northwest of Los Angeles, is the major DOE component testing laboratory. Principal ETEC facilities include: 1) the Sodium Components Test Installation (SCTI), a 70 MWt steam generator test facility; 2) the Sodium Pump Test Facility (SPTF), used for prototype sodium pump testing; and 3) the Small Components Test Loop (SCTL), used for sodium valve testing. The ETEC static sodium test facilities will continue tests on instruments such as those used to measure sodium flow, level, and pressure in CRBRP and LMFBR test facilities.

Testing will be completed on the CRBRP prototype pump in SPTF during 1983 with test preparations underway for testing the two stage primary pump sodium test unit. Testing will also be completed on the CRBRP prototype steam generator test program in the SCTI during 1983. Preparations will be completed for testing a 70 MWt steam generator test unit in SCTI which is to follow the 117 MWt CRBR Plant prototype test unit.

Fuel Storage Facility (FSF)

The FSF is located adjacent to the FFTF at the Hanford Engineering Development Laboratory. Construction of the FSF was completed in mid-1981, and it will become operational in 1983. It will provide sufficient fuel storage capacity for five to eight years of FFTF operation and includes provision for storing FFTF driver fuel assemblies as well as FMEF canisters containing pins previously subjected to postirradiation examination. The facility uses sodium and NaK as the storage and heat transfer media. The storage vessel contains racks which will accommodate over 450 fuel assemblies.

Maintenance and Storage Facility (MASF)

The MASF is also located adjacent to FFTF. Construction was completed in October 1982. This facility contains systems for removal of sodium from and decontamination of FFTF components. Maintenance and repair can be performed on large components at low activity levels. Self-contained cells are also provided for maintenance of contaminated small components. The facility also furnishes storage for FFTF maintenance equipment.

Fuels and Materials Examination Facility (FMEF)

The FMEF is a large multi-purpose facility, located at the Hanford Engineering Development Laboratory, which will accommodate the SAF line equipment for fabrication of plutonium oxide breeder reactor fuel pins. This line will be the source of fuel for the FFTF and CRBRP. Construction of the FMEF was 63% complete at the end of 1982. The present construction schedule calls for completion of the facility in June 1984.

SUMMARY

The United States is developing the LMFBR as a viable option for future electric power generation needs. Program emphasis is on plant projects and a supporting base technology program. The CRBRP, a 375 MWe demonstration plant, is scheduled to operate by the end of this decade. The follow-on, commercial-size breeder will be largely the responsibility of private industry. The base technology program supports the plant projects by developing and testing the requisite underlying technology and by conducting necessary experiments. This approach enables the private sector to concentrate its efforts on commercializing the LMFBR. Commercialization of the breeder will take place when an economic breeder with proven reliability is available. This could occur as early as the first decade of the next century.