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The Fast Flux Test Facility Built on Safety

HANFORD

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N

o other high-tech industry has grown as fast as the nuclear industry. The information available to the general public has not kept pace with the rapid growth of nuclear data -- its growth has outpaced its media image and the safety of nuclear facilities has become a highly debated issue.

This book is an attempt to bridge the gap between the high-tech

information of the nuclear industry and its understanding by the general public. It explains the three levels of defense at the Fast Flux Test Facility (FFTF) and why these levels provide an acceptable margin to protect the general public and on-site personnel, while achieving FFTF's mission to provide research and development for the U.S. Department of Energy (DOE).

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Fast Flux Test Facility — Built on Safety

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he FFTF, located on the Hanford Site near Richland, Washington, is a 400-MWt, sodium-cooled, fast-neutron reactor designed for irradiation testing of nuclear reactor fuels and materials.

The US DOE has made a significant commitment to ensure public health and safety, preserve the environment, and maintain national security during the development of nuclear materials and facilities. No other industry has been built with greater concern for public safety than the nuclear industry.

Safety was emphasized as an integral part of the FFTF Project from inception of design, through engineering, construction and testing, and finally to daily operation and maintenance. The FFTF began operation in April 1982 and has completed nine successful operating cycles to date.

Safety is literally built-in at the FFTF through three levels of defense. Major programs of analysis, development, operation and testing support the adequacy of the design at each level. The first level of safety is provided by passive safety features designed into the plant equipment. This level provides high assurance that accidents are not initiated through the design features of the plant itself and through the quality, redundancy, testing, inspection, and fail-safe design of the plant's systems and components.

The second level is the plant protective features. This level provides protection systems and other features that arrest off-normal events or limit their consequences to defined and acceptable levels. If an off-normal condition should occur, the plant is designed to detect the event and respond automatically to ensure that

FFTF is the largest test reactor of its kind in the world.

the reactor is always in a stable, safe, and known condition.

The third level is the engineered safety features. This level supplements the first two levels by designing the plant with added margin. This margin provides further assurance for containment of hypothetical events without exceeding accepted guidelines for the protection of public health and safety.

Safety is literally built-in to the FFTF on three levels of design.

The FFTF is located on the Hanford Site near Richland, Washington.

Passive Safety Features — The First Level of Safety

This first level of safety addresses the prevention of off-normal events not only through the intrinsic features of design but also through the application of quality, redundancy, testing, inspection, and fail-safe features of the reactor's components.

A more stringent engineering approach than that typically used in either commercial or developmental projects was used to design the FFTF. This approach recognizes reliable normal operation as the first requirement of a fundamentally safe reactor design.

Analyses were made and an unprecedented extensive test program was conducted to identify all malfunctions or faults that could affect reliability or operation. These conditions have been guarded against by design, quality construction, or fail-safe features as appropriate.

Cutaway of reactor vessel showing core and component arrangement.

Cutaway of FFTF showing principal system structures.

Sodium provides an excellent intrinsic capability to remove heat because of its favorable combination of viscosity, conductivity, and specific heat. These properties of sodium, along with design features of FFTF, allow the use of simple, reliable methods of emergency decay heat removal by natural convection. In addition, because the sodium-cooled FFTF operates at hundreds of degrees below the boiling point of the coolant, the reactor and the Heat Transport System are only pressurized to very low levels.

The FFTF incorporates multiple protective systems and design features.

100% power natural circulation test results.

Passive Safety Features (Continued)

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he FFTF was designed with a number of features that avoid the occurrence of off-normal events. Examples of these safety features are:

- Three independent Heat Transport Systems with the primary system components of each installed in its own reinforced-concrete, steel-lined inerted cell. Malfunction or damage of any one system is confined to that system and will not prevent continuous operation of the other two.
- Provisions for and demonstration of the natural-circulation capability in the Heat Transport
- System to ensure removal of decay heat from the reactor core with no requirement for electric power.
- Primary system component guard vessels and elevated piping to maintain continuity of core coolant in case of a sodium leak.
- A 2-in. thick reactor vessel wall to ensure proper fabrication, handling, and increased energy absorption capability. (Code requirement is less than 1 in.)
- A significant sodium inventory above and around the reactor that decreases the severity of

The three independent Heat Transport Systems are designed and constructed to contemporary quality standards.

temperature transients through the system, reduces the embrittlement effect of irradiation on the vessel walls, and ensures coverage of the core and outlet nozzles with sodium even if a large sodium leak should occur.

- A conservative Doppler coefficient of reactivity to enhance stability in normal operation and provide limitations of reactivity excursion consequences.
- An inlet plenum that provides multiple inlet passages and yet prevents flow blockage by prohibiting the passage of foreign material greater than 1/4 in.

Design and implementation of accepted standards resulted in the FFTF's meeting or exceeding all existing regulatory and project safety criteria.

View of secondary loop sodium system piping during construction.

Plant Protective Features — The Second Level of Safety

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he FFTF incorporates multiple protective systems and design features that constitute a second level of safety. This second level of safety protects against such off-normal events as reactivity insertions (sudden power increases) or failure of part of the control system or other equipment.

This level of safety is provided by:

- A program of development and testing to clearly identify and define the nature and consequences of off-normal

events that might result in a malfunction.

- A number of reliable protective devices, systems, and plant features designed to ensure that such events will be prevented, arrested, or accommodated safely.

There is a high degree of assurance that off-normal operational, equipment, or system events will not result in damage to the plant and that there is no undue risk to the health and safety of the public or to on-site personnel.

REDUNDANT AND DIVERSE TRIP INPUTS FOR REACTOR SHUTDOWN SYSTEMS

PRIMARY SHUTDOWN SYSTEM

Primary Power Range Nuclear High Flux
 Primary Power Range Nuclear Low Setting
 High Startup Flux
 Primary Flux-Decreasing Delayed Flux
 Primary Flux²/Loop Pressure
 IHX Primary Outlet Temperature
 Reactor Vessel Coolant Level
 Flux/Primary Closed Loop Flow
 Closed Loop IHX Primary Outlet Temperature
 Experiment-Associated Trip Functions
 Primary Flux-Increasing Delayed Flux
 Pressure Permissive
 Manual Scram

SECONDARY SHUTDOWN SYSTEM

Secondary Flux/Total Flow
 Secondary Flux-Increasing Delayed Flux
 Secondary Flux-Decreasing Delayed Flux
 Low Primary Loop Flow
 High Primary Loop Flow
 Low Secondary Flow
 Loss of Off-site Power
 Reactor Outlet Plenum Temperature
 Closed Loop Outlet Temperature
 Experiment-Associated Trip Functions
 Flux/Closed Loop Flow
 High Closed Loop Flow
 Power Permissive
 Manual Scram

Watchstanders supervise the FFTF's numerous controls, instrumentation, and computers used for power operation. The skillful performance of the operators contributes to the successful operating record of the FFTF.

Plant Protective Features (Continued)

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he second level safety features include:

- Two redundant, independent Plant Protective Systems that provide for prompt automatic shutdown of the reactor when necessary to correct for off-normal conditions. Each system is complete with diverse sensors, logic, circuitry, and actuating separate sets of neutron-absorber rods.
- Reactor and primary coolant systems that are contained within nitrogen-inerted and steel-lined cells. Guard vessels and elevated piping ensure core coverage and continuity of core cooling. Extensive leak detection is provided to ensure that any potential leak is detected in its incipient stage.
- Vital systems and components designed to withstand or be protected from the effects of off-normal environmental conditions, such as earthquakes and tornados.
- A three-loop design that provides a redundancy of heat removal features during full-power operations to maintain core cooling, even if an active component of another loop is disabled, with simultaneous loss of normal power or a break in the primary boundary.
- Physically separate air dump heat exchangers. A sodium leak and possible sodium fire in one unit will not affect the heat removal capability of the other units.
- A conservative margin for confinement of releases of radioactive gases or sodium from the reactor system provided by a low-leakage steel containment building, conservatively designed and completely housing the reactor, the fuel storage areas, and the primary reactor coolant system.

Dump heat exchangers are sodium-to-air exchangers that transfer heat from the secondary loop sodium to the ambient a

The FFTF includes a relatively simple containment structure.

Design Margin — The Third Level of Safety

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he third level of safety envelops the first two levels through features that provide added margin in the plant design and provide further assurance of public health and safety.

These margins were evaluated against established limits for public safety by constructing and analyzing hypothetical accidents that test the overall design for appropriate response.

The postulated conditions are:

1) 50 ¢/s continuing reactivity insertion and 2) coastdown of the primary pumps following loss of all power. In these cases, if either of the two redundant scram systems is operable, the plant will be safely shut down and no damage to fuel or structures will result.

It should be noted that the assumed 50 ¢/s reactivity insertion exceeds the design maximum rod withdrawal rate by a wide margin and even exceeds the physical maximum rate at which a rod could be withdrawn by the FFTF control rod drive mechanism. These hypothetical accidents are truly unrealistic but, nevertheless, thoroughly analyzed.

Another hypothetical scenario is a flow coastdown or loss of electric power that would initiate the flow decay. However, the source of power supplying the control and shutdown rod holding coils is the same as that supplying the pumps. Therefore, a loss of power to the pumps would cause the rods to drop into the reactor even without action from the Plant Protective Systems.

In all these cases, adequate margins were demonstrated to ensure acceptable levels of public safety.

Inherent safety testing at 50% loss of flow without scram to pony motor.

The U.S. Nuclear Regulatory Commission's Advisory Committee on Reactor Safeguards reviewed the FFTF and concluded that its operation poses no undue risk to public health and safety.

The Fast Flux Test Facility reached criticality in February 1980 and has completed nine successful operating cycles to date.

Safety and The FFTF

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he FFTF is designed to provide safety at three successive levels. Major programs of analysis, development, operation and testing support the adequacy of the design at each level.

Continuing in-depth reviews relative to their respective areas of responsibility are conducted by all organizations involved in the FFTF Project to ensure sound design and passive safety are maintained. Achievement of safety and reliable operation is further supported by planned programs of operation, surveillance, and maintenance by highly trained personnel using thoroughly developed and qualified techniques and procedures.

The FFTF incorporates a wide margin of safety in its design; it starts with basic protection in all aspects of the design; it is amplified by necessary provisions for errors, malfunctions, and abnormalities; and ample margin exists for unexpected off-normal events. The

FFTF's outstanding radiation exposure safety record.

The FFTF is leading the world in burnup.

U.S. Nuclear Regulatory Commission has reviewed the FFTF and concluded that its operation poses no undue risk to the health and safety of plant personnel or the public.

Operation of the FFTF has been outstanding. Performance of the sodium systems has been excellent. The core continues to be very stable and predictable. Improvements resulting from operating experience have been numerous, and this has permitted an increasing plant efficiency factor.

Currently, an exciting area being investigated at the FFTF is the passive safety characteristics of liquid metal reactors, which are believed to be a significant advantage of this technology. Additionally, FFTF's future missions include space power testing, fusion materials testing, isotope production, and potentially electric power production.

The FFTF is the only U.S. liquid metal reactor built and maintained to American Society of Mechanical Engineers' codes.

FFTF's three levels of defense have ensured a safe environment during its five years of operation.

The flexibility of FFTF makes it uniquely qualified to test fuels and materials for advanced liquid metal reactors. Research and development conducted at the FFTF is leading the way for the nation's advanced nuclear power reactors. Above is shown one of today's commercial nuclear power plants.

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