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CORE DESIGN OF THE UPGRADED TREAT REACTOR

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ABSTRACT

The upgrading of the TREAT reactor involves the replacement of the central 11 x 11 subzone of the 19 x 19 fuel assembly array by new, Inconel-clad, high-temperature fuel assemblies, and the additions of a new reactor control system, a safety-grade plant protection system, and an enhanced reactor filtration/coolant system. The final design of these modifications will be completed in early 1983. The TREAT facility is scheduled to be shut down for modification in mid-1984, and should resume the safety test program in mid-1985. The upgrading will provide a capability to conduct fast reactor safety tests on clusters of up to 37 prototypic LMFBR pins.

INTRODUCTION

Since its construction in 1959, the principal use of the TREAT reactor[1] has been to test reactor fuel rods under conditions simulating various postulated LMFBR accidents. The TREAT Upgrade project was undertaken to increase the transient LMFBR safety testing capability of the TREAT reactor, while maintaining the capability for low-power ($\leq$120 kW), steady-state operations. The test capabilities provided by the upgraded facility are discussed elsewhere in the Proceedings of this meeting.[2] In this paper the salient features of the reactor design are summarized. An overall core description is presented first, followed by details of core layout, reactor control system, plant protection system, reactor shielding and penetration, core support and alignment, and cooling systems.

OVERALL CORE DESIGN CONSIDERATIONS

Like TREAT, the upgraded TREAT reactor (Fig. 1) is an adiabatic power pulse reactor that is also capable of low-power, steady-state operation. The fueled portion of the core is appropriately 6-ft square by 4 to 5 ft high, and is fueled by a dilute dispersion of fully-enriched UO_2 particles of approximately 10-μm average diameter in graphite. Super prompt critical power transients are produced by high-speed, hydraulic-driven

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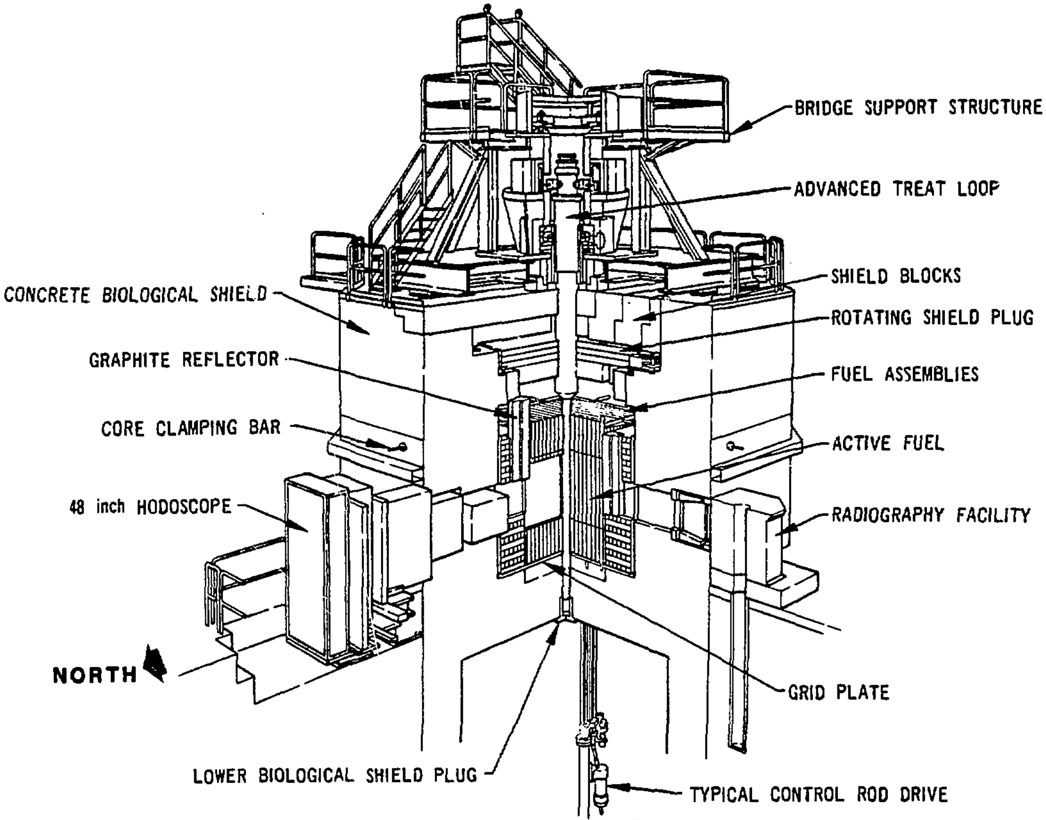

Fig. 1. TREAT Upgrade Reactor

control rod removal under open- or closed-loop feedback computer control, and are "turned around" by the inherent negative temperature coefficient of reactivity that results from increased leakage upon graphite heating. The graphite fuel stores the energy of the power pulse, and the open-cycle air filtration/cooling system subsequently removes the energy over a 4- to 10-h cooldown period. Shaped transient pulses of 4100 megawatt-seconds, lasting several tens of seconds, reaching peak powers of 16,000 megawatts, and with initial periods as short as 100 ms are achievable.

These power pulses are used to irradiate test clusters of LMFBR fuel pins located in test loops at the core center, so as to enable the study of fuel behavior under simulated LMFBR accident conditions. Experiments with test clusters of 7 pins and fewer will continue in the upgraded core in the MK III and SPTL class of loops, which are now in use in TREAT. The principal purpose for upgrading TREAT, however, is to permit experiments on clusters of up to 37 pins in the Advanced TREAT Loop (ATL).[3] The need to accommodate this 8 in.-diameter loop, the design of which is based on a passive heat sink melt-through protection approach, and which constitutes a massive neutron absorber located at core center, leads to an upgraded core design that incorporates graded fissile loading to maintain high fission density, even in the presence of the absorptive loop that strongly depresses the flux.[4] Furthermore, the test cluster power profile flatness requirement in the 37-pin test clusters can be achieved only with a much harder spectrum of neutrons at the test than is available in the highly thermalized TREAT core; the heavier fissile loadings near core center in the upgraded design serve to harden the neutron spectrum and, thereby, to promote a flatter power profile in the test cluster. A full energy burst in the upgraded facility will produce approximately twice as many fissions as bursts now do in TREAT.

CORE LAYOUT AND COMPOSITION

The TREAT Upgrade reactor core is shown in plan view in Figure 2. The core is approximately 6 ft square and is surrounded by approximately 2 ft of graphite reflector. The center 11 x 11 fuel-assembly-position modified core zone, which is cross hatched in Figure 2, contains new fuel assemblies that are provided as a part of the upgrading of TREAT; the remaining positions in the 19 x 19 array are filled with the existing TREAT fuel assemblies. The new assemblies have a fuel height of 5 ft with 18-in. axial reflectors, whereas the existing TREAT assemblies have a fuel height of 4 ft, with 24-in. axial reflectors. The reference cores have an outer radius corresponding approximately to the 17 x 17 assembly array, but, if necessary, the core size can be increased by expanding to the 19 x 19 array, to provide additional reactivity.

The fuel is fully enriched UO_2 particles (10 μm average diameter) dispersed in graphite. The carbon-to-uranium (C/U) atom ratio is graded radially from approximately 700 near core center to 5000 at the outer extreme of the 11 x 11 central array of new fuel assemblies. The remainder of the reactor, called the driver, has a (C/U) atom ratio of 10,000. The neutron spectrum varies from near epithermal at core center to highly thermalized in the driver. The experimental loops, containing breeder reactor fuel pin clusters, are positioned along the core vertical axis at the radial center of the core. A 3 in.-wide voided slot is created on a radius from core center to the north edge of the core, to permit viewing the test loops by the fast neutron hodoscope.

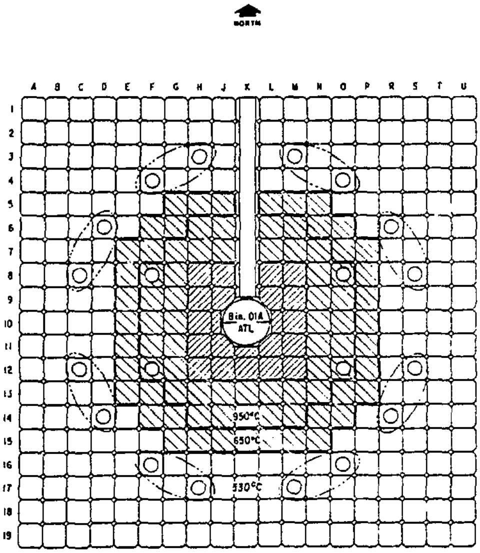

Fig. 2. TREAT Upgrade Core Layout

Although the existing TREAT fuel assemblies are operated at power densities no higher than their service conditions in the present TREAT (their post-adiabatic power pulse temperature is well below 600 °C), the new fuel assemblies operate at higher power densities and reach peak clad temperatures of up to 860 °C. The temperature limits are set by the properties of the fuel assembly clad, Inconel 625 for the new assemblies and Zircaloy 3 for the existing TREAT assemblies.

The upgraded TREAT reactor will have three basic core configurations, which depend on the particular test loop and the associated geometrically and neutronically matched fuel assemblies that are loaded into the reactor. Two of these configurations are used to accommodate a 37-pin ATL and a MK III Loop. The third configuration is provided by reconstituting the existing TREAT configuration. The capability to revert to the pre-upgraded configuration is a functional requirement imposed to retain the TREAT capabilities for future tests, if required.

The core is comprised of four (approximately annular) radial zones of fuel assemblies, centered on the experimental loop hole at core center—three zones in the 11 x 11 modified fuel zone and one zone beyond it. The center 5 x 5 assemblies comprise the "insert" zone. Three separate sets of insert assemblies are designed; one for the 37-pin ATL, and two for the MK III/SPTL loops. The fissile loadings and the geometries of these sets of inset assemblies are tailored to maximize the neutron source on the test pins of the separate loops (which vary substantially in physical size and in neutron absorptiveness). The clad on the insert assemblies operates at temperatures of up to 860 °C. The C/U atom ratios range from approximately 700 to 1200.

The fuel assemblies surrounding the insert and extending through the 9 x 9 array comprise the "converter" zone. The assemblies in this array (and all others to be discussed below) are common to all upgraded core configurations. The clad on these assemblies operates to temperatures of up to 860 °C. The assemblies function both to provide reactivity and to contribute neutrons to impinge on the test clusters. *The C/U atom* ratios range from 1000 to 1500.

The 11 x 11 annular ring surrounding the converter comprises the "buffer" zone. The assemblies in this zone operate to temperatures of 650 °C fuel and provide a thermal buffer between the high-temperature converter assemblies and the lower temperature, existing TREAT assemblies in the driver zone. The C/U atom ratios range from 2500 to 5000. The buffer zone is used also as the location of unfueled boron-loaded control assemblies, which can be used to trim the excess reactivity of the as-built core.

The region of the core beyond the buffer and filling out the 19 x 19 array contains existing TREAT fuel assemblies and is operated to fuel temperatures not exceeding 600 °C. This driver zone is responsible for the bulk of the negative temperature coefficient of reactivity. The fissile loadings in all driver fuel assemblies are the same; and the C/U atom ratio is approximately 10,000.

The fissile loadings in the 11 x 11 modified fuel assembly zone are varied both radially and azimuthally, so as to achieve a spatially flat power profile. Radial variation is necessary because of the neutron absorption of the test loop; azimuthal variation, because of the voided slot provided for hodoscope viewing of the test.

MODIFIED FUEL ASSEMBLY

The modified full fuel assembly is approximately 4 in. x 4 in., 9 ft in length, and weighs approximately 120 lb. The fueled portion is 5 ft high, and the top and bottom graphite axial reflector segments are 18 in. high. The entire graphite structure is evacuated and sealed inside of a steel vacuum boundary. This evacuation boundary is comprised of top and bottom end fittings of Type 304 stainless steel, and a cladding of solution-heat-treated Inconel-625, 25 mil thick. Rounded corners in the lateral dimensions provide flow channels for reactor coolant at the corners of the assemblies. Pyrolytic graphite insulators approximately 0.1 in. thick separate the graphite fuel from the Inconel-625 clad on the fuel assembly flats. An evacuated gap 0.014 to 0.070 wide separates the graphite fuel from the Inconel-625 clad on the fuel assembly corners.

The UO_2/graphite fuel inside the assembly is comprised of sixteen columns, nominally 0.94 in. square (a 4 x 4 array) (see Fig. 3). Each column has a different fissile loading, but is uniformly loaded axially, and each 60 in-high column is composed of a series of fuel pieces 3 in. to 8 in. long. The axial break points on the fuel columns are staggered in a "brick wall" fashion. The UO_2/graphite fuel is manufactured by an extrusion/bake/high-fire/machine process, which achieves a density of > 1.8 g/cm^3.

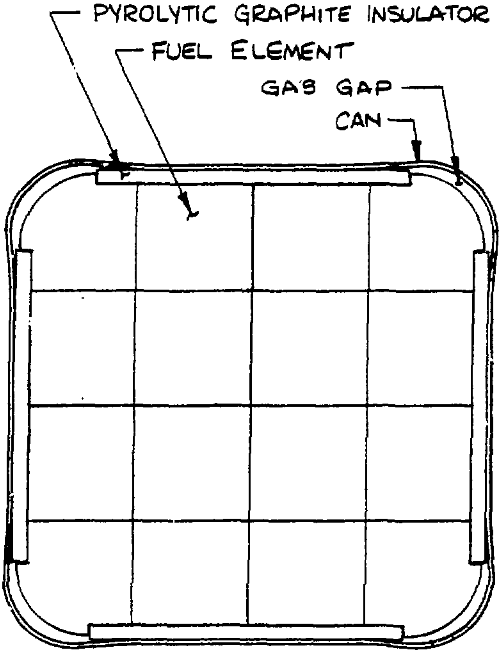

Fig. 3. Cross Section of Modified Fuel Assembly

The pyrolytic graphite insulators on the assembly flats are 2.54 in. wide by 6 in. to 10 in. long. They are recessed into the graphite fuel pieces so that the external pressure holds the corner fuel pieces in position. The axial break points on the insulator are so arranged relative to the axial break points of the fuel columns, as to avoid coincidence of break points. The pyrolytic graphite insulators are formed by vapor deposition at 2200 °C, followed by machining. The material has a thermal conductivity ~0.005th that of copper in the deposition direction, approximately the same as copper otherwise, and has a density of 2.19 g/cm^3.

The clad consists of a square cylinder of solution-heat-treated Inconel-625, 25 mil thick, 8 ft long, with rounded corners that provide for air flow passages at the fuel assembly corners. The cylinder is fabricated of mill-annealed Inconel 625 sheet stock by forming a sheet into right circular cylinder shape, making a seam weld, solution-heat treating, and forming to square shape with rounded corners. The seam weld is located at the center of one corner. At room temperature, the inside perimeter of the clad (14.268 in.) is 0.253 in. longer than the projected perimeter of the graphite it encloses, thereby allowing for assembly. Furthermore, upon vacuumization, this excess perimeter establishes the corner gap between fuel and clad that best matches the thermal impedance of the insulations on the flat and, thereby, minimizes azimuthal thermal gradients around the perimeter of the clad.

The clad external flat-to-flat dimension at the top end fitting is 110 mils less than the fuel assembly pitch of 4 in. At the center of the flat, at the axial center of the core, with the clad sucked down against the internal fuel and pyrolytic graphite by the internal vacuum, the flat-to-flat dimension at room temperature is 150 mils less than the 4 in. fuel assembly pitch.

The top end fitting incorporates four lateral bearing faces for positioning the fuel assembly at the top relative to the contiguous elements, a fuel assembly gripping piece that is compatible with existing TREAT fuel handling equipment, an engraved fuel assembly identification and orientation marking, which indicates the unique position and orientation of the fuel assembly in the core, and a substantial shielding thickness of Type 304 stainless steel, to attenuate fission product radiation between the fuel assembly evacuation cavity and the area above the rotating shield plug. The bottom end fitting incorporates a locating prong and a seating taper for positioning the lower end of the fuel assembly in a mating hole in the grid plate and an evacuation tube, which is crimped and seal-welded after the fuel assembly evacuation and bake-out step of fabrication.

The evacuation envelope on the fuel assemblies (clad and end fittings) is designed to the ASME high-temperature code case rules for creep and fatigue, based on Inconel-625 material properties that have been developed specifically for this design. The principal source of stress on the clad is the circumferential thermal gradient that results from the geometry of the thin-wall clad, which achieves good contact with the graphite on the flats and no contact on the corners.

REACTIVITY CONTROL

The kinetic behavior of the reactor core is determined by its tightly coupled core zones, its temperature coefficient of reactivity, its prompt neutron generation time, and the delayed neutron fraction. Relative to the present TREAT reactor, the modifications have hardened the neutron spectrum and, thereby, lowered both the generation time and the size of the negative temperature coefficient. The temperature coefficient (of which approximately 60% is attributable to the driver) is one-half to two-thirds the value in TREAT. The generation time is about 500 μs (approximately half that of TREAT), and the delayed neutron fraction is 0.00713 (basically unchanged from TREAT).

Reactivity trimming of the reactor to accommodate the various test loops and varying test missions is accomplished by suitable combinations of 1) use of the 5 x 5 "insert" arrays of fuel assemblies that are specially tailored to the absorptiveness of the various loops, 2) replacing a subset of the buffer fuel assemblies with unfueled boron-loaded buffer assemblies, and 3) adjustment of the outer core/radial reflector interface.

Reactivity control is accomplished by means of three banks of control rods and associated control rod drives, arranged in two control rod rings (see Fig 2). The inner ring, located in the converter zone, contains four compensation/shutdown rods and associated drives. The outer ring contains eight transient rods (yoked in pairs to four transient drives), and eight control/shutdown rods (yoked in pairs to four control/shutdown drives). These locations are indicated by the ovals in Fig. 2.

The control rods are driven vertically through the core by drive mechanisms located in the subpile room below the core (see Fig. 1). The poison sections are driven upward through guide tubes in special control rod housing assemblies and out of the top of the core for removal. All rods have B_4C poison sections with graphite followers that are encased in steel containments. In the driver zone, the control rod housing assemblies are fueled; in the converter zone, these are unfueled.

The compensation/shutdown rods (in Ring 1) function to compensate for reactivity added upon loop removal. The total reactivity worth of these four rods is approximately $11.60. they are lead screw-driven, have a 60-in. stroke, and use a pneumatically-assisted scram. The rods will be fully withdrawn at the beginning of any reactor operation.

The four control/shutdown drives (8 rods in Ring 2) are provided for reactor control in the steady-state mode. These rod drives are lead screw-driven, have a 60-in. stroke, and use a pneumatically-assisted scram. Their total reactivity worth is $11.00. For transient-mode reactor operation, these rods will be cocked at partially-withdrawn positions at the beginning of the operation. The four control/shutdown rod drives and eight rods provided in TREAT Upgrade will be selected from among those already in use at TREAT.

The four transient rod drives (8 rods in Ring 2) provide for control of the reactor in the transient mode. These rod drives are hydraulically actuated and have a 40-in. stroke. The total reactivity worth of the bank is approximately $4.00. Each hydraulic actuator is controlled by a separate servo, position controller. Input to the controllers comes from the Reactor Control System (RCS). When the reactor is enabled for computer control (transient operation), these rods will be able to move at speeds of up to 170 in./s. During all other times, high-speed withdrawal is locked out and the rods can move at only 2 in./s. The four transient rod drives and eight rods provided in TREAT Upgrade will consist of the two transient rod drives now in use at TREAT, plus two new duplicates.

All three rod banks respond to scram shutdowns initiated by the Reactor Trip System (RTS), and all rod banks are designed to a single failure criterion. The rod banks use diverse stored energy sources to provide for scram (pneumatic and hydraulic scram assists). The control/shutdown and compensation/shutdown banks are each, independently capable of providing cold shutdown, even with one control rod drive and the entire other bank stuck out. The compensation/shutdown rods use a hydraulic-actuated scram latch with a release time of < 30 ms; the control/shutdown rods use a magnetic latch with a release time of 60 ms, and the transient rods use a hydraulic valve system, which can reverse the drive from full speed out to full speed in in 32 ms.

REACTOR CONTROL SYSTEM

The upgraded TREAT reactor will be controlled by use of a Reactor Control System (RCS) that replaces much of the RCS now at TREAT. The new RCS is used to control the three independent banks of control rods, and consists of rod-drive interlock logic and power sources, instrumentation, computers, and information display and storage systems. Two modes of control are provided: manual and automatic. In the manual control mode, the core reactivity is controlled from an operator console located in the control building; in the automatic control mode, the transient rods (only) are controlled by a computer-based system located in the reactor building.

Manual control is used to direct the movement of the control/shutdown rods, the compensation/shutdown rods, and the transient control rods for reactor start-up and steady-state operation and during the preparatory phase for transient reactor operations (i.e., during the period before the actual transient burst is initiated). In the manual control mode, the capability for rapid reactivity addition by the transient rods is locked out.

The Automatic Control System is used to direct the movement of (only) the transient control rods during super prompt-critical, shaped transient operations. This mode is enabled under key lock administrative control. The computer controller provides two forms of control of the transient rod drives: open-loop control in which the transient rods are moved according to a preprogrammed rod position sequence, and closed-loop control, in which the transient rods are moved in response to feedback measurements of reactor power, period, and integrated power, so as to produce a prespecified power burst shape. In all cases in the automatic control mode, the compensation/shutdown rods are banked full out, the control/shutdown rods are banked out at as near a uniform withdrawal as possible, and the transient rods are moved in parallel, so as to maintain a core power distribution free of azimuthal tilts. The control computer uses two dedicated channels of nuclear measurements: a log-period channel and a linear channel with auto-range changing under control of the control computer. These channels cover the range of approximately 1 kW to 100 GW. Reactor period, power level, and energy are measured as the experiment proceeds and (in the closed-loop mode) any deviations from the experimenter-prescribed burst shape constitute the basis for an error signal to the controllers of the transient rod hydraulic actuator drives.

The software program that the control computer uses to control the reactor is in the form of a general program that resides in the computer in read-only memory, plus a set of input instructions (to that program), which are specific to the transient experiment of interest. The input instruction set for the specific experiment is generated as part of the preparation for the test, and is validated on the control system itself by digital computer simulations of the reactor and the transient rod drives. Immediately before executing a transient test, the software is rechecked, by causing the control computer to drive the transient rods while the reactor is held subcritical with the other rod banks and a computer simulates the reactor and instruments.

The RCS contains a separate monitor computer system, which uses different hardware and different software (than the control computer) to monitor both reactor and RCS parameters during transient operation. Reactor period, power level, and energy are monitored by this separate computer through buffered lines to the RTS nuclear instrumentation. Transient rod motion and experiment performance are also monitored. If the transient does not conform (within a tolerance band) to the anticipated schedule for power level, period, rod position, etc., at each instant in time, as specified by an experiment specific software-based profile in the monitor computer, the monitor computer will terminate the transient by means of a buffered signal to the RTS, requesting a scram. The transient-enveloping settings of the monitor computer are tailored to each specific experiment and are time-dependent within the transient.

REACTOR TRIP SYSTEM

Reactivity accidents can be postulated to occur as a result of accidental insertion of reactivity at an unplanned time or an unplanned rate because of reactor control system malfunctions. The reactor has a negative temperature coefficient of reactivity that turns a transient around as the core heats up. However, the rate of reactivity insertion is a key parameter that dictates the total energy deposition. For the shaped transients that are to be executed in the TREAT Upgrade reactor, slightly more than half the total reactivity of up to $4.00 is added slowly over approximately 5 seconds, to "precondition" the test fuel to attain prototypical thermal-hydraulic conditions. The remaining (approximately half the total) reactivity is then added rapidly (in a few hundred milliseconds) to produce a simulation of an LMFBR accident. It is apparent that control system malfunctions that cause the reactivity to be inserted earlier in the transient or more rapidly than planned will result in higher core energy deposition and possible clad damage.

Explicit kinetics analyses have shown that the maximum amount of over-energy that could occur in the upgraded reactor upon accidental prompt reactivity insertion with no protective action whatsoever is approximately 150% (i.e., the total will be 250% of planned energy). The over-energy temperature limit for the modified fuel assemblies is set by clad damage temperatures; carburized Inconel-625 has a liquidus temperature of 1220 °C, which is only 44% in adiabatic energy deposition above the operating energy deposition corresponding to 860 °C clad.

Because the unprotected prompt insertion of the reactivity required to run the most demanding shaped transient could lead to 150% over-energies (well above the 44% that can be accommodated without damage), a Reactor Trip System (RTS) has been designed to monitor neutron flux and to intercede with scram action upon indication of a reactivity insertion malfunction. This RTS monitors and trips on period, power, and energy (integrated power) with the trip settings chosen so that fast runaways (trip on period), slow runaways (trip on energy), and all malfunctions in between are precluded. The dynamic response of the system is fast enough to protect against melting of Inconel clad, even for the worst (Faulted) reactor control system failures that can be postulated. For the less severe Emergency class accidents, the RTS limits the clad to approximately 950 °C, and fuel assembly reusability can be assured.

The RTS includes nuclear and other plant parameter sensing instrumentation, trip logic electronics, and logic circuits for control rod drive scram. It is a hard-wired analog system and is arranged for one-out-of-two trip logic at the system level. The RTS has the capability to adapt to either the steady-state or to the transient mode of reactor operation, with the transient-mode period and power trip level set points always operable (the integrated power set point is disabled during steady-state operation), but with the steady-state set points operable only in the steady-state mode.

The RTS is designed to conform to the single-failure criterion of standard IEEE 279. The system functions independently of the RCS and is electronically isolated from it. RCS-initiated scram requests come to the RTS through isolation buffers, and RTS-generated signals are accessible to the RCS only through isolation buffers. All RCS sensing, trip, and scram-actuation equipment is located in the reactor building; operator display information and a manual scram button are provided in the control building.

In the transient mode, RTS trips are initiated by reactor period, power, or energy; also by out-of-range pneumatic and hydraulic pressure on the control rod scram actuators, and fuel thermocouples. The nuclear trip channels incorporate a multilevel power trip point that is switched as a function of energy already deposited. The trip levels on period, power, and integrated power in the transient mode are selected both to permit all transient power profiles contained in the functional requirements to be achieved, and to limit core temperatures to acceptable values for even the most unfavorable time sequence of reactivity introduction physically achievable within the design of the control rods and their drives. In the steady-state mode, the period and power (integrated power trip is disabled) trip settings are selected to permit steady-state operation at 120 kW, but to limit core temperatures to acceptable values for all rod motion that is physically achievable in the steady-state mode.

The RTS is not seismically qualified, except for the rod drive assemblies and the seismic switches. Seismic switches, located between the trip logic circuit boards and the control rod scram latches, will cause the control rods to scram upon detection of accelerations equal to the primary wave (p-wave) accelerations of the safe shutdown earthquake (SSE). The control rods and drives are seismically qualified to be inserted during the p-wave of the SSE. The control assemblies are seismically qualified to remain inserted in the core upon the arrival of the stronger, secondary wave (s-wave) accelerations of the SSE.

REACTOR SHIELDING AND PENETRATION

The TREAT reactor core is contained in a 3- to 5-ft thick heavy concrete structure that provides physical support and radiation shielding. Major penetrations in this structure are provided for the fuel motion diagnostics instruments (north and south faces), the neutron radiography facility (west face), reactor instrumentation (corners), and the thermal column (east face). This structure remains essentially unchanged by the upgrading of TREAT (see Fig. 1).

The top of the reactor core can be accessed through a rotating shield plug after removal of the top concrete shield blocks. The diameter of the penetration through the shield plug and the shield blocks is being increased to accommodate the 19 in. upper diameter of the ATL.

CORE SUPPORT AND ALIGNMENT

The reactor core is supported and positioned at the bottom by a steel grid plate 1 in. thick. The grid plate is supported at its periphery by a concrete shelf at the bottom of the core cavity and across its lower surface by 32 control rod guide thimbles, which extend through the lower plenum under the grid plate and are embedded in the concrete of the subpile room ceiling. Positioning and alignment of the grid plate relative to the shielding cavity is accomplished with four pins imbedded in the concrete of the grid plate support shelf. Each pin engages a slot machined at the midpoint of each side of the grid plate. The slot-pin arrangement allows for radial thermal expansion of the grid plate while maintaining its position at the center point of the core.

The fuel assemblies are positioned at their lower end by alignment pins that penetrate a mating hole in the grid plate. The assemblies are clamped laterally at their top by the spring-loaded core clamping bars now in use at TREAT. The clamp permits axial and lateral expansion of the core.

A cylindrical hole through the subpile room ceiling directly under the center of the core provides a bottom alignment hole for positioning the bottom end of the experiment test loops. Further, the dimensions of this penetration allows for axial thermal expansion of the loops and for the accommodation of loops sized to hold test pins having a bottom fission gas plenum. The lower end of the hole is plugged, to reduce the radiation field in the subpile room. The plug is suitably supported, so as to prevent interference with the control rod drives under any credible event (including seismic).

COOLING AND FILTRATION

The upgraded TREAT reactor is designed as an adiabatic power-pulse facility and, consequently, the core temperatures are maintained within the allowable ranges, even if the cooling system is inoperative during and after a power pulse. Further, the steady-state operation power level of 120 kW could be sustained for 9-1/2 hours before adiabatic integrated power reaches the level attained in a full energy adiabatic pulse. Hence, the cooling function is provided primarily to expedite core cool-down and to remove the argon-41 from the core cavity after a power pulse. Core cool-down is accomplished in 4 to 10 hours, depending on the size of the power burst.

The safety function of the upgraded TREAT reactor filtration/cooling system is to prohibit accidentallly-released radioative material from leaking into the reactor building by maintaining the core cavity at a slightly negative pressure and to filter the effluent of the reactor cavity through a bank of HEPA filters before discharge to the environment. Redundant blowers located downstream of the reactor are used to pull air through the system. Air enters the reactor cavity through two 12 inch-square openings protruding above the top of the reactor biological shield and through various infiltration sources in the biological shield, especially in the top shielding. Approximately 90% of the air then flows downward through the coolant channels formed by the chamfered corners of adjacent fuel assemblies and exhausts through holes in the grid plate into the lower plenum beneath the grid plate. Approximately 10% flows around the permanent reflector and shield and then through slotted orifices at the outer edges of the grid plate into the lower plenum. The air is drawn from the lower plenum through two parallel 10.5 in.-OD ducts penetrating the shield wall, which merge into a common, 19 in.-OD duct. From the 19-in. duct, the air flows through a prefilter, a heat sink, the HEPA filter bank, and the blowers, then out of the stack.

CONCLUSION

The upgraded TREAT reactor design provides a cost-effective modification of TREAT so as to meet demanding functional requirements in a safe manner. The calculational predictions of achievable performance parameters (test energy deposition, radial test cluster power profiles and transient shapes) show that all of the functional requirements for the planned ensemble of test clusters can be met with comfortable margins. The TREAT Upgrade reactor will be a significant new research tool in LMFBR safety research studies.

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