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REACTOR TRANSIENT CONTROL IN SUPPORT OF PFR/TREAT* TUCOP EXPERIMENTS

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The TREAT reactor presents a large negative temperature of reactivity, and hence requires large reactivity insertions to provide power transients. Rapid movement of control rods using 3000 psi hydraulic actuators under closed-loop computer control provides the capability for such reactivity insertions. Power coupling between reactor and experiment is calculated and then measured by irradiating experiment fuel pins at low-level, steady-state power conditions and by irradiating flux monitor wires (low concentration ^{235}U in Zircaloy) under transient operating conditions. (See reference 1.) Using this information, as well as the experiment objectives and thermal-hydraulic characteristics of the experiment, a reactor power shape for the experiment is defined by the experimenter. A reactor control computer program is written to produce the desired reactor power shape as well as any experiment control and interface functions required for the experiment. The control computer program is tested by operating the reactor in the transient mode with a neutronic mockup of the experiment installed in the reactor core. More detailed information about TREAT is given in reference 2.

A normal sequence of experiment reactor operations at TREAT consists of trial transients to verify computer-controlled reactor power shaping and energy deposition and test any computer interactions with experiment hardware, moderately low energy heat-balance transients to verify power coupling, and a final transient in which the test goals are achieved. In the case of the PFR/TREAT TUCOP series experiments (L04, L05, L06, and L07), trial and final transients posed new requirements for operation of the TREAT reactor.

Unique energy deposition and experiment control requirements posed by the PFR/TREAT series of transient undercooling/overpower (TUCOP) experiments resulted in equally unique TREAT reactor operations. New reactor control computer algorithms were written and used with the TREAT reactor control computer system to perform such functions as early power burst generation (based on test train flow conditions), burst generation produced by a step insertion of reactivity following a controlled power ramp, and shutdown (SCRAM) initiators based on both test train conditions and energy deposition. Specialized hardware was constructed to simulate test train inputs to the control computer system so that computer algorithms could be tested in real time without irradiating the experiment.

The required reactor transients for experiments L04 and L06 demanded extensive reactor control computer interaction with experiment hardware. For use during trial transients for these experiments, a device (TREAT Signal Generator) was constructed which allowed real-time simulation of experiment-generated signals; these simulated signals were then transmitted to the reactor control computer system. Simulated signals were used to verify control computer program features such as SCRAM on failure of sodium flow coast-down, SCRAM on failure of sodium flow threshold sensor, and early power burst based on sodium flow threshold sensor output. Experiments L05 and L07, although not requiring the extensive interaction between the reactor control program and the experiment, required trial transients to demonstrate the desired reactor power profile. L07, in particular, demanded a larger than usual number of trials in order to prove that the desired power profile could actually be produced; this was due to the stringent requirements placed on the shape and energy deposition of the burst-portion of the transient.

A variety of final transients were performed for the PFR/TREAT TUCOP-series. Final transients for tests L04 and L06 consisted of a constant-power segment (approximately 4.5 to 9 seconds on figure 1.), a power rise on a constant period (nominally 450 ms, from 9 to 9.5 seconds on figure 1.), and a burst segment (from 9.5 to 10 seconds on figure 1.). The burst segment (with a 165 ms period and a peak power of about 3000 MW) was programmed to commence when coolant flow-reversal occurred (as signalled by a hardware "burst signal generator") in the test vehicle. The final transient for test L05 was similar to that of L04 and L06, except that the burst segment initiation was programmed to occur at a preset energy release, regardless of the status of test train coolant flow. Test L07 was also similar to its predecessors except that critical burst-energy-deposition requirements necessitated initiating the burst by introducing a step insertion of reactivity (rather than by controlling reactor power to produce a constant period.)

References

1. G. Klotzkin et al., "Time Dependence of Test Fuel Power Coupling During Transient Reactor Test Facility Irradiation Experiments", Nucl. Sci. and Eng. 86 206 (1984).

2. G.A. Freund et al., "Design Summary Report on the Transient Reactor Test Facility, TREAT", ANL-6034, Argonne National Laboratory (1960).

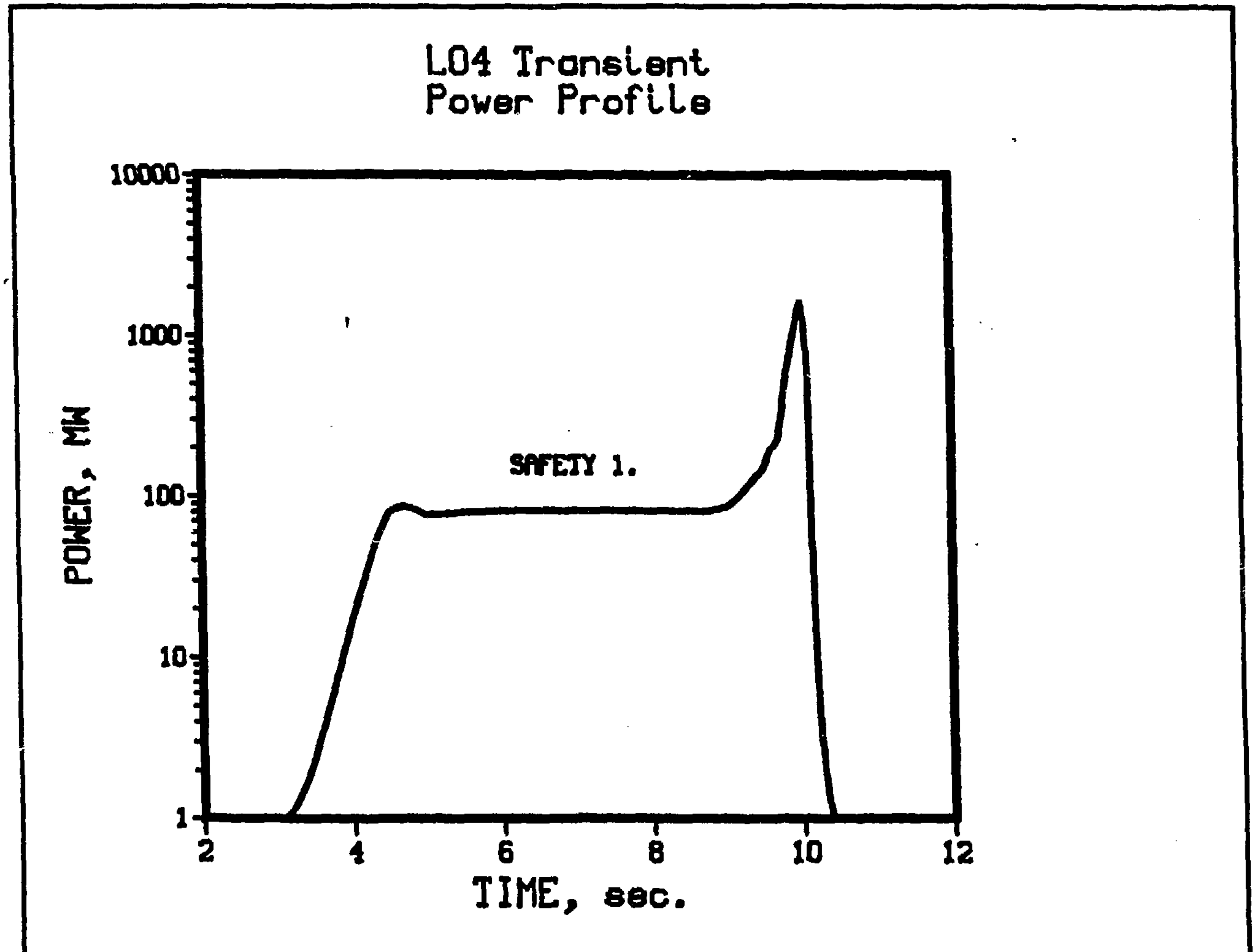

Figure 1. Typical Reactor Power Profile as Produced for PFR/TREAT TUCOP Experiment Series