

# Application of High-Speed Photography PAPER L-1 in Nuclear Reactor Development

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*Examples of high-speed motion pictures obtained as part of the nuclear reactor engineering studies at Argonne National Laboratory have been recorded on 16mm film. These high-speed records have contributed to the understanding of many factors in the design and operation of nuclear reactors and related systems. Subject material for the high-speed studies included uranium-chemical reactions, heat-transfer studies, mechanical component analysis, sodium water reactions, fuel element fabrication, and reactor power transients. A series of power transients culminated in the deliberate self-destruction of an early nuclear reactor.*

ARGONNE NATIONAL LABORATORY, as one of the national laboratories of the United States Atomic Energy Commission, has responsibilities for nuclear research in the physical sciences, life sciences, engineering and specific reactor development.

Numerous disciplines are associated in this scientific community, and each is provided with the facilities and technical services needed for effective, creative work. One of the services of the Graphic Arts Motion Picture Section is high-speed photography. The cameras used operate in the speed range from 1000 to 8000 frames/sec and are accompanied by the appropriate timing devices.

Argonne reactors, such as The Argonne Fast Source Reactor, the Experimental Breeder Reactor I, the Transient Reactor Test Facility, Argonaut, the Experimental Breeder Reactor II, the Research Reactor—CP-5, the Experimental Boiling Water Reactor, and critical assemblies like the Zero Power Reactor III, are the result of extensive nuclear research.

In the engineering of these reactors, high-speed camera application has dealt primarily with control rod function, fuel fabrication, chemical reactions, heat transfer, and experimental reactor power transients. Control of reactivity (neutron production) in the Argonne low-power reactor is accomplished by the manipulation of neutron absorbers (control rods) within the reactor.

Emergency shutdown procedure for the transient reactor test facility requires the control rods to be inserted by air pressure through 5 ft of travel in a maximum time of 100 msec. An examination of the magnetic latch of a double rod drive indicated a delayed, uneven magnetic release. After changing the magnet material and altering the air gap, examination showed the desired uniform release of the rods. An examination of the deceleration at the end of travel verified the proper design of the hydraulic dash pot bringing the 250-lb mechanism to rest in the final 6 in. of travel.

Zero power reactors are extremely flexible machines for investigating reactor physics. In contrast to reactors designed to operate by removal of neutron absorbers,

zero power reactors are controlled by adding either fuel or reflector material to achieve the desired neutron production, and are shut down by the prompt removal of these materials. ZPR VI and IX require the fuel drawers to be ejected 6 in. in 75 msec including magnet release time. The performance was verified by the high-speed camera. Such performance must also allow smooth deceleration with a minimum of bounce at the end of the stroke.

A major effort of heat transfer engineering is the study of the behavior of water in a water-cooled and moderated power plant. One aspect of this is the study of bubble formation. The increase in the number of bubble centers is accompanied by an increase in the heat-transfer coefficient.

The close coupling of heat generation and void formation provides an inherent safety shutdown mechanism for boiling water reactors. A series of transient experiments with the boiling water reactor, Borax I, studied the effectiveness of void formation in self-regulating the reactor power. In each experiment sudden excess reactivity additions were made by ejecting the control rod. The transient phenomena ranged from about  $\frac{1}{2}$  sec to 10 msec.

The power rise heats the water moderator and the steam voids generated reduce the reactivity, thereby canceling the excess added when the rod is ejected. In the more violent of these transients the power level may rise from a few watts to several hundred million watts.

Following the planned series of experiments, the reactor was modified to permit a 4% reactivity addition that would give rise to an energy release estimated to destroy the reactor. This experiment was considered important to determine an upper limit even though the accidental addition of so much excess reactivity could not be realized in an operating reactor. The results of the experiment were as expected. Most of the fuel plates were melted. The pressure resulting from the molten metal in contact with water burst open the reactor tank, carried away the control-rod mechanism, and ejected the remains of the reactor core. The total nuclear energy released in this experiment was  $1.3 \times 10^8$  joules and the maximum power was over  $10^7$  kw.

The high-speed camera also serves the study of chemical reactions in the treatment of reactor materials. One example is the reaction of uranium-zirconium

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*Edit. Note:* This text is the narration that accompanied the film presented at the Congress.

alloys on treatment with nitric acid for pickling, etching and dissolution. A black surface coating forms on the metal during treatment. In this condition the reaction may take place spontaneously or as a result of mechanical shock. Similar, but less violent, reactions take place with dried samples when the partially reacted metal is struck or sparked in air. The explosive hazard was overcome with the addition of fluoride to the nitric acid bath.

Fuel pins for EBR II are fabricated remotely from reprocessed alloys by injection casting. The reconstituted charge, melted by induction heating, is forced into the Vicor molds by a pressure differential across the submerged ends. Study of the speed of metal injection indicated that the force of the metal was lifting the mold. This phenomenon caused a starvation of metal, producing a porous cast that had to be corrected.

Final closure of the  $\frac{3}{16}$ -in. diameter EBR II fuel jacket presented a problem of weld defect in about every

sixth closure. Observation of the welding operation disclosed a large gas bubble revolving within the weld metal. Based on this it was determined that the gas was being entrapped in a recess of the closure plug. Redesign of the closure plug resulted in a consistent high-integrity weld.

The Transient Reactor Test Facility, TREAT, is designed for experiments requiring bursts of intense radiation. It is now being used for the experimental study of reactor fuel under abnormal conditions. Among the special characteristics of TREAT are design features which will permit observation of the destruction of the sample reactor fuel elements positioned in the center of the reactor core.

Numerous similar applications for the high-speed camera are routine. This service is available and its use is dependent upon the requirements of the scientific community.