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Criticality Excursion of November 10, 1961

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ABSTRACT

A criticality excursion occurred at the Oak Ridge Critical Experiments Laboratory on November 10, 1961 as enriched uranium metal, neutron reflected and moderated by hydrogen, was being assembled. It is estimated that the energy yield was between 10^{15} and 10^{16} fissions. There was no personnel exposure or property damage. Fission product contamination, both air borne and contained in the metal, decayed sufficiently overnight to allow unhindered continuation of the experiment. The excursion was caused by a too rapid approach of the two sections of uranium constituting the experiment.

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Criticality Excursion of November 10, 1961

An unscheduled burst of radiation was produced during the course of some experiments in the Oak Ridge Critical Experiments Laboratory on November 10, 1961. If personnel radiation exposures resulted directly from the burst they were less than 5 mrem and only insignificant amounts (< 100 mrem) were incurred by health physicists while subsequently making surveys of the area. There was no property damage. Less than 1-1/2 hours working time was lost after the incident and operations would have been resumed at 8 A. M. the following day had it not been Saturday. The following is a brief review of the accident and of the measures taken to reduce the probability of its recurrence.

The fissile material concerned was $\sim$ 93% U^{235}-enriched uranium which was neutron reflected and moderated by paraffin. The mass of uranium was about 75 kg; its configuration is not readily describable. The materials were divided into two parts and arranged on equipment, described recently by Rohrer et al.,[1] whereby one part was moved vertically upward, by a hydraulic piston acting through a magnetic coupling, to contact the other. The initial speed of approach of the parts was controlled by the air pressure applied to the hydraulic system. A step reduction of this speed was effected at a preset separation by a switch operated by the moving member itself. The point at which this step change occurred was manually adjustable at the equipment. This reduction in speed was effected by a valve, also manually adjustable, in the hydraulic system. There was no method for altering the speed from the remote control point. The over-all rate of displacement was regulated by the action of the control switch, operating appropriate valves in the hydro-pneumatic system, for time intervals commensurate with the status of the experiment.

During the experiment in discussion, the initial, faster speed was 16 in./min and the transition to the slower speed occurred when the assembly parts were separated 1.94 in. The device indicating the position of the movable section of the apparatus was underdesigned and did not follow the fast motion promptly. Closure was correctly indicated by limit lights.

The rate of separation for normal shutdown was, of course, greater than the rate of closure and was at least 40 in./min. The rate of separation upon emergency shutdown was about 12 in./sec over the first inch of travel, 60 in./sec for the next 9 in., and 10 in./sec for the remainder of the downward stroke.

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1. E. R. Rohrer et al., "Neutron Physics Division Annual Progress Report for Period Ending September 1, 1961," ORNL-3193, p. 168.

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The time required for collapse of the current to the magnet supporting the lower (movable) section of the assembly following the receipt of a signal from the scintillation detector was the order of 1 msec. The time required for the magnet to disengage was $\sim$ 50 msec. An unknown but small additional delay in the safety action was incurred during the increase in signal strength to that required for actuation of the safety circuit.

In this series of experiments, which was to be terminated by the one in question, the reactivity of the system was incrementally changed by adding more units of uranium, or more moderator or reflector. All previous assemblies had been subcritical. The final alteration was the addition of a large reflector.

The usual "blue glow" was observed as the assembly became critical.

Tests after the incident showed the system to be delayed critical when the two sections were separated 2.7 in. and that, in this region, the sensitivity of the system was \$8.6/in. It is obvious that delayed critical was achieved when the approach was still at the higher speed which corresponded to a rate of increase in reactivity of \$2.3/sec. Fifty milliseconds after the magnet disengaged ($\sim$ 100 msec after the detector signaled a high level) the reactivity had decreased \$5. The average rate of decrease over the first inch of travel was $\sim$ \$100/sec.

Air borne fission-product contamination in the test cell that evolved from the uncoated uranium was estimated[2] to be between 2×10^{-7} and 1×10^{-6} μc/cc (1.5 mc, maximum, total contamination) 30 min after the release. The air contamination was zero at the time of the next convenient observation 15 hr later.

The shiny appearance of the uranium and the absence of alpha-particle contamination within the area were evidence that no uranium oxidation had occurred. The surface temperature of the uranium had remained below about 70°C since there was no indication that the paraffin in contact with the metal had melted.

It is interesting to note that the delayed gamma-radiation field 20 ft from the source decreased three orders of magnitude during the interval between 2 min and 1 hr after the activation and that the field at the surface of the uranium was as much as 10 r/hr at 19 hr.

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2. T. J. Burnett, ORNL Health Physics Division, personal communication.

The energy release could not be evaluated directly because of the impracticability of destructive sampling and analysis and the complex, undetermined power distribution within the assembly. A yield of 10^{16} fast (> 1 kev) neutrons was estimated from the activation of components of a threshold detector although there is at least a factor of two uncertainty in this value due to the low activation. Further, no correction, which may amount to as much as 25%, was made for activity in the detector resulting from neutrons back-scattered from the wall on which the detector was mounted. The activities in thermal and epicadmium neutron detectors similarly located were too low for measurement.[3] The location of the threshold detector was, however, such that the fast neutron exposure is an approximate measure of the source even though the assembly was partly enclosed in a thick neutron reflector at the time of energy emission. On these bases the yield is estimated at 10^{15} to 10^{16} fissions.

A comparison of the radiation field attendant to this release at a point some 20 ft distant over the initial 40-min period to that resulting from recently and purposely produced bursts of energy of measured magnitude from the Health Physics Research Reactor gives a yield not inconsistent with the above estimate. Admittedly the conditions of the two measurements are different because of the relative locations of source and detector and the absence of neutron reflector and moderator in the reactor tests. Even order of magnitude agreement may be fortuitous. An attempt to evaluate the yield from estimated personnel exposures incurred during this excursion and those resulting from similar excursions of known size purposely generated in the later program has been unsuccessful because of uncertainties and inconsistencies in measurements of the quantities of radiation encountered. The estimated exposures were of the order of 1 mrem. Indications from this comparison, however, do set the yield at less than 10^{16} fissions.

The energy from 10^{16} fissions would raise the average temperature of the uranium about 35 C^{o} assuming no losses.

The time intervals and rates of change in reactivity show that a 0.12-in. displacement of the lower section of the assembly in 435 msec is required to go from delayed to prompt critical. This time is long compared to what is believed necessary for instrument response. This and other observations, such as the temperature pattern, raise some doubt that the assembly reached prompt critical.

The previous accident most similar to this one has been described by Stratton[4] and occurred at Los Alamos in 1952 with equipment called JEMIMA.

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3. D. M. Davis, ORNL Health Physics Division, personal communication.
4. W. R. Stratton, "Proceedings of the Karlsruhe Symposium on Criticality Control," European Nuclear Energy Agency, 1961, p. 500. See also G. C. Mallary et al., "Neutron Burst from a Cylindrical Untamped Oy Assembly," LA-1477, July 22, 1952.

The greatest dissimilarities are that the uranium in the Los Alamos assembly had neither moderator nor reflector and the instrument response time was 300 msec, about six times that in the present case. In the earlier experiment about 90 kg of U^{235}, in two sections, were being brought together at a rate of \$2 to \$3/sec when delayed critical and, possibly, prompt critical were exceeded. The observed yield was 1.5×10^{16} fissions of which 10^{15} were produced in the initial power spike and the remainder in the equilibrium-power plateau which ensued during the relatively long time required for the safety system to act. As in the present case there was no evidence of metal oxidation.

It is obvious that, in the present instance, the rate of approach of the two parts of the assembly was too fast and that the operational radiation-detecting instrumentation was too sluggish owing, perhaps, to the thick neutron reflector surrounding the uranium. The safety circuits described above functioned properly. The occurrence was the result of errors in judgement by those performing the experiment.

The remedial measures to be effected prior to subsequent use of the apparatus include the installation of an improved position indicator and the adoption of a procedure whereby measurement of closure speeds will be made a part of the pre-experiment equipment check-out.

It is pointed out that, although occurrences of the kind reported here are not to be taken lightly, they should not be considered entirely unexpected in the wide variety of short-range experiments performed in the non-reactor development studies which constitute a major part of the program of the Oak Ridge Critical Experiments Laboratory. It is for this reason that adequate shielding was provided in the design of the laboratory more than a decade ago. Of interest is the fact that during the two-week period following this occurrence and again in early January 1962 pulses of radiation 10 to 100 times greater than this one were routinely produced in the same laboratory area during the proof-testing of the Health Physics Research Reactor.

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