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OPERATING EXPERIENCE WITH COINCIDENT VS NONCOINCIDENT REACTOR SAFETY SYSTEMS

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ABSTRACT

A study of reactor operation shows that systems employing coincidence have experienced more scrams resulting from instrument malfunction than those systems not employing coincidence. Although it is demonstrated that coincidence is not the dominant factor in safety system serviceability, it is planned to employ coincidence at ORNL in order to permit on-line testing of new, more complex safety systems.

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To: W. B. Cottrell, Director, Nuclear Safety Information Center

From: E. P. Epler, Reactor Controls Department, Instrumentation and Controls Division

Subject: Operating Experience With Coincident vs Noncoincident Reactor Safety Systems

During the course of our review of the Holmes and Narver report[1], "A Study of Test Reactor Operating and Safety Experience," we have come upon a statistic of significance to all individuals at ORNL who are engaged in reactor design or operation.

This report deals with the management and method of operation as well as safety and operating experience for the General Electric Test Reactor (GETR), Westinghouse Test Reactor (WTR), Engineering Test Reactor (ETR), Materials Testing Reactor (MTR), and Oak Ridge Reactor (ORR), and tabulates unscheduled power reductions in terms of the events or malfunctions causing the shutdowns. From these tabulations we have extracted the following:

	GETR	ETR	WTR	MTR	ORR
Arrangement of safety channels	2 of 3	1 of 3	2 of 3	1 of 3	1 of 3
Operating period in quarter years	12	13	9	27	17
Number of scrams due to instrument malfunction	22	10	1	2	0
Scrams per year	7	3	0.5	0.3	0

The systems employing the coincidence of two of three channels yielded an average of 4.4 scrams per year; whereas those not employing coincidence yielded only 0.8 scram per year. This is entirely contrary to popular belief and indicates that factors other than coincidence dominate the serviceability of safety systems.

High quality maintenance is essential, but it may not be sufficient. Although the ETR and MTR systems were maintained by the same personnel, the

[1] Prepared under Contract AT(04-3)-424 for the USAEC, HN-172-AEC Research and Development Report UC-80, Reactors-General, TID-4500 Distribu

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scram rates were in the ratio of 10 to 1. The systems were identical, with the exception that the MTR instruments and systems were designed by ORNL; whereas the ETR employed commercial equivalents.

Finally, the response time of the ORR is the order of 10 msec, which is known to be shorter than any of the other installations studied; for example the GETR has a scram delay time of 60 msec (Final Hazards Summary).

It should be noted that the Holmes and Narver tabulation relates to scrams resulting from instrument malfunction, with scrams due to cable and connector faults being included in other catagories. Single-rod drops are also otherwise classified.

In a study of this kind the tabulator must often interpret log book entries, and we might differ in some instances with the Holmes and Narver interpretations. We might also choose to use a different method of classification. As an example, the two scrams attributed to instrument malfunction in the MTR tabulation, on close examination, turn out to be process instrumentation malfunction, thus indicating that the MTR as well as the ORR has a perfect score in regard to nuclear safety instrument malfunction. These differences in tabulation might change the results in either direction; however, we feel that the Holmes and Narver report represents an impartial study and that we are justified in calling attention to this isolated statistic.

The summary which follows, prepared earlier but never offered for presentation, amplifies our position in regard to the use of coincidence. Note that the operating experience here includes the entire nuclear safety system and includes rod drops as well as scrams.

An Evaluation of Coincidence in Reactor Safety Systems

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Oak Ridge National Laboratory

September 1963

Fear of the uncontrolled chain reaction, coupled with the unreliability of existing radiation detectors and related electronics, led to the early development of "fail safe" reactor safety devices. Many ingenious methods were devised whereby almost any conceivable component failure in the electronic equipment could be made to result in a scram. When redundancy was employed to ensure further against the consequences of an undetected failure, this resulted in a satisfactory degree of safety, although the serviceability of the reactor was impaired by an excessive number of unwanted scrams.

In 1947, a safety system was developed at Oak Ridge National Laboratory (ORNL) for application in the Materials Testing Reactor. This system employed fail-safe techniques to a moderate degree and was, in addition, designed with the intent that unsafe failures would be detected by a monitoring system which would cause such failures to be annunciated. In some instances where a choice in design was possible, in order to increase serviceability through the reduction of unwanted scrams, a failure to danger with monitoring was elected in preference to a safe failure, with mandatory shutdown when less than two unfailed channels remained.

This equipment has been used in many reactors, usually in systems having response times from trip level to rod motion of the order of ten milliseconds. Usually three flux-level channels have been employed plus one log-N channel with period trip.

Although the degree of safety afforded by this system was satisfactory, the number of false scrams was still excessive in many applications.

The causes of these false scrams usually fell into the following three catagories:

1. Momentary or complete failures of the ac power system,
2. Failures of the magnet to hold the rod, and
3. Failures in the electronic equipment.

The number of power failures could be reduced by the employment of multiple sources, preferably batteries. Magnet failures are generally due either to mechanical misalighment or trash in the air gap between the magnet and the rod, often aided by a lack of excess holding force. Improved design and maintenance would help; however, it was generally held that latches must ultimately be adopted. We also agreed with others that the serviceability requirements of power reactor operation would make it necessary that the radiation detector channels and associated electronics be arranged in coincidence; i.e., the agreement of two of three or more channels of electronics would be required in order to produce a scram. However, we did not adopt coincidence for research reactor applications.

In 1958, the Oak Ridge Research Reactor (ORR) began operation with the ORNL electronic safety system without coincidence but with latches replacing the troublesome direct-lift magnets. Because false scrams and single-rod drops persisted long after the usual shakedown period, an intensive maintenance program was instituted. As a result, electronic failures have now been virtually eliminated. It was discovered that rod drops were due to latch failures which became more frequent as wear progressed.

The following is the record of false scrams and single-rod drops attributable to the safety system at the ORR for the past two years:

Latches, including magnets	40
Power failures	11
Flux-level electronics	1
Period electronics	0

As a result of this record we have revised our position that coincidence of radiation channels is required for serviceability. The number of scrams attributable to electronic failures in the ORR has no significant effect on over-all plant operation. As a result of this experience, we are also inclined to suspect that when a large number of false scrams is being experienced because of faulty electronic maintenance, safety may be correspondingly impaired by the same faulty maintenance.

Coincidence techniques have, however, been needed to meet the unusually severe requirements of the High Flux Isotope Reactor (HFIR), now being constructed. A complex safety system has been designed which incorporates many computer components as well as electromechanical reset devices. Failure

detection is this system by means of the traditional fail-safe and failure-monitoring techniques would be virtually impossible. Therefore, we have chosen to adopt a coincidence system, not for the usual object of avoidance of false scrams, but for the ability to introduce a test signal to actuate a single channel without producing a scram.

We now believe that, given the required maintenance, a high level of serviceability can be attained even with "laboratory glassware" electronics without resorting to coincidence. Transistors have now reached a stage of development such that, in simple systems, superior serviceability and safety should be attainable, even though the circuits be designed with the intent that every failure result in a scram. Coincidence is, however, firmly entrenched, and, there is even a disturbing trend, in the power reactor field, toward two-out-of-two coincidence to attain acceptable serviceability.

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