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Addendum

June 1966

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SAFETY REPORT FOR THE WESTINGHOUSE ASTRONUCLEAR EXPERIMENTAL FACILITY

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Prepared By:

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INTRODUCTION

This addendum to the Safety Report for the Westinghouse Astronuclear Experimental Facility describes the auxiliary shutdown system for use on the PAX reactor at WANEF and discusses the nuclear safety aspects of the system.

The text may be inserted in WANL-TNR-099, Section 4, in accordance with the paragraph numbers as identified.

4.3.4 PAX Auxiliary Shutdown System (PASS)

4.3.4.1 Introduction

An auxiliary shutdown system has been designed and constructed for use on the PAX reactor. The mechanism is designed to provide a "last ditch" reactor shutdown capability by inserting nuclear poison worth at least 1\$ in reactivity, thereby cancelling the positive reactivity insertion associated with the maximum credible accident in the PAX (i.e., a one-drum rollout accident). It is not intended that this system be interlocked to provide an additional automatic scram; rather, it will be manually actuated from the control room if the need exists. The time necessary to insert the auxiliary poison will be on the order of a minute, in contrast to the automatic shutdown system (control drums) which takes less than one second.

4.3.4.2 Description of the Shutdown System

The PAX Auxiliary Shutdown System shown in figure 4A consists of two complete and independent units, each of which consists of a poison storage hopper, gear motor, dump valve, a flexible stainless steel discharge tube, and a discharge nozzle. Both units are supported by a welded support structure so that they are approximately 14 feet above and laterally displaced about 4 feet from the PAX.

The support structure, which is fabricated from aluminum pipe, is bolted to steel brackets which are, in turn, bolted to the test cell west wall ledge above the PAX. It has a safety factor of 4.8 with a 200 lb. man standing on the first rung down from the top. The two poison storage hoppers, each of which contains about 20 lb. of poison granules, are bolted to the ends of the support structure. The dump valve was designed to open in the direction of poison flow so that there would be no binding. It consists of a tapered plug held up against the hopper bottom by a rod which passes up through the center of the hopper and is attached through a linkage to the gear motor. When the system is actuated, the gear motor drives the rod and plug down away from the hopper bottom permitting the poison granules to flow out of the hopper. Limit switches control the extent of linear motion of the plug.

The upper end of the stainless discharge tube has a funnel permanently attached to it and this funnel is bolted to the bottom of the poison storage hopper. The other end of the discharge tube attaches, by means of a fitting, to a nozzle which fits into the annulus between the inner and outer reflectors and bolts to the nozzle end support ring. The poison material is thus discharged into the annulus between the outer and inner reflectors.

The gear motors require 12 volts DC for operation which is supplied from a storage battery by means of a dump switch on the console. The switch is conveniently located on the console for easy access by the operator or other control room personnel. A cover prevents inadvertent dumping of the poison material but is easily removed to actuate the switch when required. A pilot light, mounted on the console, also lights when the voltage from the power supply drops below a value such that the gear motor would not function. Both the dump switch and pilot light are appropriately labeled.

The poison material used is natural boron carbide (B_4C) granules of a -14+20 mesh size. The granules measure between 1/32 and 1/16 inch in diameter and have excellent flow characteristics.

4.3.4.3 Tests

A full-height model of a 120° section of the annular gap between the inner and outer reflectors (complete with mockup springs) was constructed with viewing ports in the outer wall to permit visual observation of the poison flow and distribution. When tests were conducted using 5 pounds of B_4C granules in a prototype poison storage hopper, about one-half minute was required for all of the materials to run into the model after being released. The B_4C granules flowed smoothly like dry sand around the mockup springs, building up into a pyramidal distribution in the annular gap. From the observed distribution of the granules it is estimated that 12 pounds of B_4C from one hopper would form a similar pyramid whose base surrounds one-half of the core and which extends vertically to the discharge nozzle. That is, it would fill one-fourth of the annular gap volume. Subsequent tests, conducted after

system installation, in which 30 lb. of B_4C were released from each hopper and discharged into buckets, required 40 seconds for complete discharge.

Reactivity worth measurements on a small sample of the B_4C , placed in the reflector region of PAX, qualitatively agree with calculations, verifying that the material is, indeed, natural boron carbide.

4.3.4.4 Analytical Determination of K_{sd}

Analyses have been made to determine the shutdown available under several different situations. These results indicate that one hopper, dumping approximately 12 pounds of B_4C into the reflector gap would provide approximately 3.70\$ worth of negative reactivity. The distribution of B_4C pellets in the reflector gap is such that at the base of the reflector, B_4C would enclose 180° of the reactor and assume a pyramidal effect with a peak at the reflector top. Two hoppers dumping approximately 24 lbs. of B_4C into the reflector gap on opposite sides would provide approximately 7.40\$ worth of negative reactivity. Thus, there is no reactivity interaction between the two pyramids of poison. The negative reactivity inserted due to a full height rectangular segment of B_4C between the inner and outer reflectors with a width equivalent to one 30° sector is approximately 1.25\$.

4.3.4.5 Safety Analysis

Modes of possible failure of the system and the resulting consequences are identified below, together with an evaluation of the probability of such failures.

1. System Failures

The failure of house power does not affect the operability of the system as it is supplied by a 12V storage battery. This supply is monitored at the console by a circuit which annunciates before the storage battery voltage falls below the level required to operate the motors. It is considered incredible that the system would fail to operate when required because of a power failure.

The poison material chosen is not hygroscopic and is among the most chemically inert substances so that it will not lump or cake in the storage hopper even when undisturbed for long periods of time. Periodic tests will be made to verify this. Failure of the material to flow when the dump valve is opened is therefore considered to be incredible.

If the limit switch on the motor fails, either electrically or mechanically, the dump valve cannot cycle back to the closed position because of the physical arrangement of the mechanical linkage. Torque limitations on the motor will cause it to stall before the pins in the mechanical linkage will shear. The tapered plug which forms the dump valve might conceivably block the funnel opening if it came off the vertical rods. However, it is fastened with a jam nut against a pre-loaded spring. It is considered incredible, therefore, that the mechanical operation of the valve can fail in a way that will prevent the material from flowing down the discharge tubes.

2. Reactor-Associated Failures

The system will fail to shut down the reactor in the event that the poison material cannot enter the reactor. Such a situation might develop if, under the condition of a reactor excursion, thermal expansion of the core in the radial direction would reduce the annulus in the reflector region to such an extent that the poison would be blocked. A calculation was made of the radial expansion for the maximum credible accident, using the mean coefficient of thermal expansivity in the transverse direction in a current NERVA fuel specification* and the average temperature rise in PAX caused by the accident. The annulus remaining will be 0.165 inches wide, considerably larger than the size of the granules. Therefore, even under the conditions of the maximum credible accident, the system will function.

If the B_4C material should pass on through the reactor and leak out the bottom, shutdown might not be achieved. The annular space into which the poison goes, however, has no openings where leaks can occur. The reflector support, starting with the

* PDS 30093 dated Dec. 15, 1965 (CRD)

PAX-D build, has been designed with this in mind. Seal strips have been provided to use when the removable 30° sector of the PAX-D inner reflector is removed.

Although spillage of the entire amount of B_4C over the top of the core would result in a positive reactivity insertion of about 25¢, this would not lead to an accident when the reactor is shutdown. During operations at delayed critical, such an insertion would result in a period of about 25 seconds, easily capable of being manually controlled. Such an accident is unlikely, however, because of the design of the connection of the flexible hose at the discharge nozzle and the administrative requirement that the hoses when not connected during reactor operations be mechanically retained away from the reactor.

3. Human Failure

The most credible failure of the system is the human failure to connect the hoses after a reactor change. An effective administrative control is the procedural requirement that the EIC check off on the Pre-Startup Checklist the fact that the hoses are either connected or retained away from the reactor before each reactor operation begins.

4.3.4.6 Use of the PAX Auxiliary Shutdown System (PASS)

Because PAX will have to be disassembled in order to remove the poison material, the system will be used only under emergency conditions when the automatic safety system has failed to shut the reactor down. If such an emergency should exist, the system will be actuated by a member of the control room staff at the direction of the Experimentalist-in-Charge. Periodic checkouts of the system will be performed by removing the discharge nozzles from the reactor and dumping the B_4C into buckets.

Although both of the PASS units can be connected to the reactor during operation, one unit by itself provides more than enough shutdown capability to cancel the reactivity insertion which leads to the maximum credible accident. Therefore, only one unit is required

and the Scientist-in-Charge will specify whether one or both hoses will be used for a particular set of experiments.

During manual reactivity changes or other operational reactor changes when the reactor is shutdown, the flexible tubes may be disconnected from the reactor. The tube(s) will be re-connected to the nozzle(s) prior to the startup of PAX and an appropriate entry will be made on the Pre-Startup Checklist.

It is expected that certain experiments will prevent the use of the PASS. In such cases, the approval of AGC and SNPO-C as well as the recommendation for approval by the WANL Nuclear Safety Committee will be obtained prior to performing the experiment.

Detailed procedures concerning the periodicity and detail of system checkouts, entries to the Pre-Startup Checklist and use in emergency situations are included in the WANEF Operations Manual.

Figure 4.A -- PAX Auxiliary Shutdown System