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**HAZARDS REPORT
FOR THE BF_3 WITHDRAWAL
MECHANISM IN THE SM-1**

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ABSTRACT

This hazards report gives a design and operational description of a BF_3 withdrawal mechanism planned for installation on one of the two startup channels at the SM-1. A failure analysis involving conceivable malfunctions of this system is provided.

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HAZARDS REPORT FOR THE BF₃ WITHDRAWAL MECHANISM IN THE SM-1

1.0 INTRODUCTION

The BF₃ withdrawal mechanism for the SM-1 is designed to raise and lower one of the BF₃ chambers used in the startup channels. It is raised in order to remove the BF₃ tube from the high flux area during power operation of the SM-1 reactor and thereby conserve its life and improve its reliability. It is lowered to provide control for a re-startup. This report is issued as an addendum to the hazards report which covers in detail the entire SM-1 plant. (1)

2.0 DESIGN AND OPERATIONAL DESCRIPTION

2.1 Physical Description

The BF₃ withdrawal mechanism does not in any way change the startup channel circuit as described in the summary hazards report. Power input to the motor lifting the BF₃ chamber is controlled by a three-position switch located on the reactor control console. In the RAISE position, the switch applies power to the motor through the RAISED LIMIT switch. This causes the motor to rotate so as to wind up the steel lifting cable and signal cable, thus raising the detector. In the center, or HOLD position, the control switch removes power from the motor, allowing the detector to be stopped at any desired location. In the LOWER position, the control switch reverses the connections to the motor stator and applies power through the LOWERED LIMIT switch. The motor will then rotate in a direction to unwind the steel cable and signal cable, thus lowering the detector. As the lifting drum rotates, raising or lowering the lifting cable and signal cable, a preformed coiled section of the signal cable mounted on a stationary shaft in the interior of the drum winds or unwinds, adding or subtracting turns to absorb the rotation of the drum. This preformed section of the signal cable is secured to the stationary shaft at one end and to the rotating drum at the other end.

If the control switch is left in either the RAISE or the LOWER position, the motor will operate until the corresponding limit switch is actuated. The limit switch will then remove power from the motor, causing the detector to stop at a predetermined upper or lower travel limit. The switch will also energize a corresponding RAISED or LOWERED indicator lamp on the reactor control console.

A transmitter synchro, driven by the reduction gearing, transmits position information to an indicating synchro located on the reactor control console. The indicating dial is set to read zero at the lower travel limit, and will indicate

the position of the detector in feet above this point. A block diagram of this system is shown in Fig. 2.1. The preceding information has been obtained from the vendor's operating and maintenance instructions. (2) The actual installation of this device at the SM-1 is shown in Dwg. R9-46-1153.

2.2 Function of the Counter and Withdrawal Mechanism

The BF_3 counter is designed to be used as a startup monitor for the SM-1, the objective being not to measure the reactor power level accurately but of following it reasonably smoothly as the control rods are withdrawn and the count rate rises above source levels. It provides input to a recorder interlock which in turn provides protection against starting the reactor up without a count rate of 2 cps. This assures that the channel is functioning before the control rods can initially be moved. There are two startup range channels available and both cover the region of about $10^{-8}\%$ of reactor power level to about $10^{-4}\%$ of full power. The lifting mechanism will be used on only one of these channels until sufficient experience is generated to warrant another approach. These detectors are arranged circularly in instrument wells surrounding the reactor pressure vessel. These dry wells are positioned between the first and third steel shield rings as seen in Fig. 2.2 and extend downward well below reactor level and upward to the platform, where the detectors may be extracted by removing flush cover plates. (1)

The BF_3 chambers have been plagued with failures since the startup of the SM-1. (3) Reference (3) lists the instrument failure data from 16 April 1957 to 6 April 1959, which clearly points out this problem. The present lifetime of this chamber at the SM-1 is unpredictable. One chamber was suspected of failure after 6 weeks; however, the average lifetime seems to be around 9 months, although the chamber presently used has a 2-yr guarantee. The reason the counter does not live up to this life expectancy is attributed to the very high neutron and gamma fluxes the chambers experience during power operation. A factor contributing to the failure rate of the startup channel is that the signal cable for the startup chamber is also subjected to these very high neutron and gamma fluxes. These high fluxes breakdown the insulation characteristics of this cable and cause malfunction. The only feasible solution for the SM-1 is to move the startup chamber out of the high flux region after it has performed its necessary function. This is expected to preserve the reliability of the chamber and extend its lifetime considerably. The chamber will be withdrawn to the position labeled "upper limit of travel" on Fig. 2.2 after startup. This upper limit of travel was determined because there is a weldment in the tube at this position. The possibility of having the counter "hang up" on this weldment if it was elevated beyond this position determined this upper limit. This weldment is 6 ft 8 in. above the core centerline, 11 ft 2 in. below the platform deck, 9 ft 2 in. above the bottom of the shield tank and 7 ft 3 in. above the bottom of the instrument well. The insulated BF_3 assembly is shown in Dwg. C9-51-1174. It can be lifted so that the center point of the BF_3 chamber itself is at 5 ft 8-5/8 in. above core center-

FIG. 2.1
LIFTING MECHANISM, BLOCK DIAGRAM

Fig. 2-2 - Primary Shield - Elevation

DATE	LET	REVISION RECORD	AUTH	DR	CHK

PART NO
C9-51-1174

SECTION A-A

10	2	STN STL TYPE 304	RODS, 3/16" DIA X 17" L6 10-32 THDS 1/16" BOTH ENDS
9	8	STN STL TYPE 304	NUTS, HEX #10-32
8	2	STN STL TYPE 304	WASHERS, PLAIN #10
7	2	STN STL	SETSCREWS #10-32 X 1/4 (300047-10)
6	1	A9-51-2032	RING
5	1	B9-51-2033	LIFTING LUG
4	1	A9-51-2034	SHIELDING
3	1	A9-51-2031	INSULATOR (LOWER)
2	1	A9-51-2030	INSULATOR (UPPER)
1	1	N WOOD LAB MODEL G-10-12	BF ₃ NEUTRON COUNTER
PC NO	QTY	MATERIAL OR DWG NO	DESCRIPTION

ALCO ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPT.
SCHENECTADY, N. Y., U S A.

SCALE	FULL	REF	DR	A. Patta	9-28-61
MATERIAL SPEC	TR	CHK	W. A. H. H.	9-28-61	
	APPR	APPR	W. A. H. H.	9-27-61	
	NET		W. A. H. H.	9-27-61	

NAME INSULATED BF₃
CHAMBER ASS'Y SM-L

PART NO
C9-51-1174

BREAK SHARP EDGES
REMOVE ALL BURRS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES OR FINISHED
FRACTIONAL DIMENSIONS
TO BE 8

✓ F NISH AS INDICATED
IN MICRONS

(1) MACHINE FINISH ROUGH

(10) FLAME CUT OR SAW

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
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line before the shield of this assembly approaches the weldment in the well. The top of the shield on the insulated BF_3 chamber assembly will not be withdrawn more than 6 ft above core centerline. This will correspond to a 5 ft 5/8 in. withdrawal of the center point of the chamber. The latest shielding measurements⁽⁴⁾ at the SM-1 indicate that the movement of the chamber of this position will result in a reduction from 10^6 to 10^3 R/Hr in gamma dose rate at full power and a reduction in neutron dose by a factor of at least 100.

3.0 FAILURE ANALYSIS

The operation manual states as follows:⁽⁵⁾

- (1) If the reactor has been shut down long enough to allow the neutron level to decay to the source level, withdraw rods "A" and "B" to 19 inches with the safety rod gang switch. This rod movement should result in an increase in subcritical multiplication of approximately 50% before it is seen on the startup channels. Warning: If sub-critical multiplication is not observed, DO NOT proceed further. Lack of observable multiplication indicates that the startup channels are not in working condition. Proceed with reactor startup only after the instrumentation has been placed in proper operation and sub-critical multiplication is seen. After an increase in sub-critical multiplication has been observed, withdraw the five rod bank by using the gang switch. Withdraw the rods slowly until the count ratio has increased to three times the source level. After reaching this level, withdraw one rod at a time while maintaining the five rods within one-half inch of the average of the five rod bank position. As criticality is approached, the operator will note that relatively small rod movements will result in a rapid increase in multiplication. The operator must bear in mind the fact that the critical rod position will vary rapidly with the primary water temperature and poison conditions within the core. It will also continue to change due to core burnup. No attempt should be made to memorize the previous critical rod positions or to predict the new rod positions. The startup instruments shall be watched closely to determine when criticality has been achieved. (5)

In the lifting mechanism itself, which is the only novel item in the SM-1 discussed in this report, the only conceivable unique failure is that the BF_3 chamber gets hung up in the tube. If it were stuck sufficiently far out, 2 cps would not be available for a restart. In any case, a stuck chamber will affect absolute count rate only and not relative changes. It is this relative change that the operator is trained to observe at startup and not the absolute count rate.

As stated in the Operations Manual ⁽⁵⁾, if a scram occurs while the reactor is operating at or near full power, the operator may have sufficient time to recover from the scram without the use of the startup channels provided the power level does not fall below 0.0004% in the log N scale. Below this point, the rods cannot be driven up until the startup channels have been placed in operation.

It is seen then, that on a "hot" startup, the system is brought back to power without using the startup channels. On a cold startup, the operational procedure leaves no doubt as to the fact that the startup chamber is operating properly before the procedure to bring the system to power is instituted.

4.0 FAILURE DETECTION

In the operations manual for the SM-1 ⁽⁵⁾, in check list No. 15, the first precaution is, "Never operate the reactor unless neutron multiplication can be seen when the two safety rods are withdrawn 19 in. with all other rods in the bottom position." Another section in this check list states, "Caution: If sub-critical multiplication is not observed, do not proceed further. Lack of observable multiplication indicates that the startup channels are not in proper working condition. Proceed only after the instrumentation has been placed in proper order and sub-critical multiplication is seen."

5.0 RELATED SAFETY FUNCTIONS

The source range channel provides the following signals:

1. Log count rate information.
2. Rod interlock signal when count rate is less than 2 cps.
These items have been discussed previously. What is emphasized here is that the lifting mechanism does not violate any of the inherent safety functions of the startup channel.

6.0 EFFECT ON THE MAXIMUM CREDIBLE ACCIDENT

This lifting mechanism does not introduce any conceivable extension of the maximum credible accident as defined in the summary hazards report for the SM-1.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This lifting mechanism does not violate any of the inherent safety mechanisms of the SM-1. It does not significantly add to the probability or extent of any conceivable accident. It has a high probability of increasing the reliability and

operational lifetime of the BF_3 chamber in this channel. Therefore, it is recommended that the lifting mechanism be installed in the SM-1.

The following precautions, however, must be observed:

1. The chambers shall not be moved while the rods are being moved.
2. Steady state conditions must be attained before the chambers shall be moved.

REFERENCES

1. Rosen, S. S., "Hazards Summary Report for the Army Package Power Reactor, SM-1," APAE-2 Revision 1, May 1960.
2. Operating and Maintenance Instructions for Nuclear Detector Lifting Mechanism, Prepared by General Dynamics/Electronics, Prog 93-4419101, September 22, 1961.
3. May, R. E., et al, "SM-1 (APPR-1) Research and Development Program, Task XI Instrumentation and Controls Study," APAE No. 52, Vol. I, October 1959.
4. Alco Products Report on Shielding Measurements-Test A-400 Series, to be issued.
5. Technical Manual for SM-1 Army Nuclear Power Plant, Vol. I, Part I, Operation Manual, 1960.