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Subcontract NP-1

WANL-TME-1771

17 APRIL 1968

Westinghouse Astronuclear Laboratory

WESTINGHOUSE ASTRONUCLEAR EXPERIMENTAL FACILITY
ANNUAL OPERATIONS REPORT-1967

MASTER

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ANNUAL OPERATIONS REPORT, 1967.

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I. INTRODUCTION

This report is submitted in accordance with the requirements of Section 7.4 of WANL-TNR-099, Revision A, "Safety Report for the Westinghouse Astronuclear Facility (WANEF)" which specifies that Westinghouse shall submit to AGC/SNPO an annual report of operating experience and activities for each calendar year. Included in this report is information pertaining to:

- a) A description and hazards evaluation of each series of tests or experiments.
- b) Matters referred to, material submitted to, and actions taken by WANL Nuclear Safety Committee.
- c) Operational history of the facility indicating the number of experimental runs, integrated power, number of unscheduled shutdowns and their causes.

Westinghouse shall report immediately to AGC/SNPO in writing, any change in the physical condition of the reactor or its operating characteristics that might affect the safe operation of the reactor.

1.1 SITE DESCRIPTION

The WANEF facility is located on an 850-acre tract owned by Westinghouse Electric Corporation which is also the site of the recently formed Advanced Reactors Division (ARD). The tract is near the town of Waltz Mill, Pennsylvania, which is approximately 20 miles southeast of Pittsburgh (Figure 1). Adjacent to WANEF is the Westinghouse Reactor Evaluation Center (WREC) which performs critical experiments in support of commercial programs of the Westinghouse Advanced Reactors Division. The two facilities (WANEF and WREC) are located in the same building but are divided into separate areas by 6 1/2 foot thick concrete walls. Figure 2 is a plan view of the two facilities.

1.2 PAX AND FCX REACTORS

During calendar year 1967, critical experiments were performed in support of the NRX-A6, XE-1, and XE-2 phases of the NERVA program. These assemblies are high power density, graphite moderated, beryllium reflected reactors using fully enriched U²³⁵

Figure 1. Waltz Mill Area Map

Figure 2. WANEF-WREC Layout

as fuel. Two reactor fuel loadings, with associated approaches to criticality, and two reactor disassemblies were completed during the year. The five PAX assemblies termed PAX-EO, PAX-E1, PAX-E2, PAX-E3 and PAX-E4 were virtually identical except for variations in reflector sector mockups, uranium concentration in fuel elements, and in the beryllium and graphite reflector regions.

The FCX reactor (Flexible Critical Experiment) is a reactor used in basic uranium, carbon physics studies and to provide a capability for simulating future NERVA reactors; the FCX assembly uses NRX-type fuel elements. Control rods are used in the FCX rather than control drums as in the PAX assembly allowing variations in radial buildup of the core.

1.3 WANEF STAFF

The WANEF staff consists of 10 engineers and scientists, 9 technicians, and 2 secretaries, with a Manager as Scientist-in-Charge.

Two supervisors, who also alternate as Experimentalists-in-Charge, reporting to the manager are (1) the Reactor Operations Group Supervisor and (2) the Experimental Physics Group Supervisor.

The Reactor Operations Group's primary responsibility is that of safe operation and maintenance of the reactors, overall responsibility for facility maintenance and assistance with experimental mockups.

The Experimental Physics Group has the responsibility for planning, performance and analysis of the experiments conducted at the facility.

The present WANEF staff is listed in Figure 3 and the organizational relationship of WANEF to Westinghouse is given in Figure 4.

Figure 3. WANEF Organizational Chart

Figure 4. WANEF - Westinghouse Organizational Relationship

II. SUMMARY OF ACTIVITIES

The PAX-E0 reactor operations, initiated in 1966, continued throughout the first part of 1967. It was shut down and disassembled on March 28, 1967 with the rebuilt core achieving "clean critical" on May 10, 1967 and designated PAX-E1. The PAX-E1 reactor was disassembled on June 1, 1967 with the rebuild attaining "clean critical" on June 23, 1967. This assembly, designated PAX-E2, was operated until July 31, 1967 when it was shut down for the start of FCX operations. The FCX assembly was operated until August 19, 1967 with the restart of PAX taking place on August 22, 1967 and called PAX-E3. It was shut down after the last run on August 30, 1967. The restart of the FCX assembly was initiated on September 6, 1967 with 1/M data obtained for every 20 cm of control rod withdrawal. This assembly, termed FCX-B, operated until September 28, 1967. It was then secured for the rest of the year. The poison wire removal was initiated on the PAX-E4 on September 29, 1967, and after 58 startups was poisoned down on Dec. 21, 1967.

The types of experiments performed at WANEF on the PAX and FCX reactors included initial criticality, control drum worths, reactivity shimming, power distribution, reactivity coefficients of core and reflector materials, dosimetry measurements and reactor shutdown measurements by the single drum withdrawal method.

Hazards analyses were performed on all experiments prior to initiation of the measurements. Those experiments not specifically covered by WANEF controlling documentation or falling within the intent of this documentation were submitted to the WANL Nuclear Safety Committee with the request for concurrence by the Committee and approval by the Aerojet-General Corporation and Space Nuclear Propulsion Office before the experiments were performed.

Revisions were made to the WANEF controlling documents to incorporate new and modified regulations as well as to incorporate accumulated experimental data in safety analyses performed previously by analytical methods.

III. OPERATIONAL EXPERIENCE

3.1 REACTOR OPERATIONS

During calendar year 1967, a total of 422 reactor startups were made while producing a total of 13.7 Kw-hrs of integrated power and 192.5 hours of reactor run time. During operations, 21 inadvertent reactor scrams occurred. Nineteen of these unscheduled scrams occurred as a result of instrument malfunction, principally as a result of noise transients in the linear picoammeters actuating the electronic trips. These transients are primarily due to noise pickup in the patch panels used in selecting either PAX or FCX instrumentation. A 60-cycle noise pickup is superimposed on the signal from the patch panel, and the width of the band is such that on some ranges the upper level trip can be activated. This system has since been improved as described below.

A new coaxial patch panel and low-noise coaxial cables were installed after PAX-E2 operations and have significantly reduced the number of scrams caused by noise transients. The cables were also routed through a separate metal conduit again reducing the possibility of noise pickup from adjacent wiring. Seventeen noise transient scrams occurred prior to this modification. Only two such scrams occurred following the modification while operations continued on PAX-E3, PAX-E4 and the FCX reactor for a period of approximately four months.

One scram was caused by the armature current trip and the remaining scram was activated by a drive power supply failure. There were no scrams attributed to operator error. The breakdown of operating history is given in Table I.

TABLE 1
WANEF OPERATING HISTORY - 1967

	FCX-A1	FCX-B1	FCX-B	FCX-E0	PAX-E1	PAX-E2	PAX-E3	PAX-E4	Total
Number of Startups	15	22	59	125	65	60	18	58	422
Integrated Power (watts 1 hour)	1094.6	22.3	911.8	5065.4	298.1	4337.2	107.45	1898.8	13,735.65
Run Time (hours)	48.2	8.4	12.5	43.2	31.9	21.8	5.8	20.7	192.5
Unscheduled Shutdown									
(1) Operator Error	----	----	----	----	----	----	----	----	----
(2) Instrument Noise Transient	1	----	----	11	3	3	----	1	19
(3) Armature Current Trip	----	----	----	----	----	----	----	1	1
(4) Drive Power Supply Failure	----	----	----	----	1	----	----	----	1

Personnel radiation exposures for the year were under the permissible level with an average of 38.2 mr/wk/man. No person received an exposure in excess of the quarterly limit of 3 rem and the highest exposure for the year was 3.1 rem, which is under the yearly limit of 5 rem.

3.2 PERSONNEL TRAINING

3.2.1 Reactor Operator Training

Prior to becoming a reactor operator, all personnel must undergo training in the area of (1) basic nuclear physics, (2) health physics, (3) the electrical system associated with the reactor, and (4) the mechanical systems including a thorough understanding of the reactor itself. These lectures are scheduled by the Supervisor of Reactor Operations at WANEF and are conducted by WANL technical personnel best suited to speak on the subjects.

In addition to lectures, experience and familiarity is gained by simulated operation of the reactor followed by a period in which a candidate is designated Operator-in-Training and performs daily operations under the supervision and guidance of the Experimentalist-in-Charge.

A reactor operator's test, equivalent to an AEC examination, is given which includes all aspects covered in the training. Upon successful completion of this test, the staff member becomes a qualified reactor operator. One such series of lectures and training was given this year. Two trainees completed the training and passed the final examination which was given on November 10, 1967 and were appointed reactor operators.

3.2.2 Fuel Handling

A training program was conducted on a continuous basis to (1) train new employees in the proper care and handling of NERVA type fuel and (2) review, with the entire staff, fuel handling procedures as revisions are made to "WANEF Nuclear Safety Manual", WANL-TME-646.

IV. REACTOR EXPERIMENTAL PROGRAM

4.1 INTRODUCTION

Critical tests conducted at WANEF were performed on assemblies comprised primarily of reject NRX reactor components. The assemblies, termed Permanent Assembly Experiment (PAX), are nearly exact nuclear and mechanical mockups of the NERVA reactor. The PAX assembly, shown in Figure 5 is described in detail in WANL-TNR-099, "Safety Report for the Westinghouse Facility".

The FCX (Flexible Critical Experiment) reactor, although similar to present NERVA reactors in that the fuel materials, fuel concentrations and overall element shape are the same, has a different mechanical design than the PAX and NRX assemblies. This provides the flexibility required for variation of core materials, carbon/uranium ratios, reflector materials, and reflector thickness. The design also permits clean experiments, unperturbed by extraneous materials present in the NERVA reactors. The FCX assembly is shown in Figure 6.

Hazards analyses were made for each type of experiment prior to its initiation. In addition to the analytical interpretation of hazards involved, information obtained from previously tested NERVA mockups (NRX-A2, A3, A4 and A5), provided an excellent basis for evaluation of the NRX-A6 and XE-1 systems. Certain limitations, as given in the WANEF Operating Limits, impose restrictions which are necessary for the safety of the facility. These restrictions are given in Table 2.

4.2 PAX EXPERIMENTS

A major portion of the experiments performed at WANEF during calendar year 1967 were in support of the NRX-A6 reactor. These were carried out on various configurations of the PAX reactor and are briefly described in the following paragraphs.

4.2.1 PAX-E0 Experiments

The PAX-E0 reactor was a mockup of the NRX-A6 reactor, wherein a 90 degree segment contained fuel and a reflector similar to the NRX-A6. The remainder of the core and

Figure 5. PAX Reactor and Test Stand

Figure 6. FCX Reactor and Test Stand

TABLE 2
LIMITS ON OPERATING VARIABLES FOR PAX AND FCX

		<u>PAX</u>	<u>FCX</u>
1	Minimum Physical Shutdown of Reactor not Connected to Control Console	10.00\$	10.00\$
2	Minimum Effective Shutdown of Reactor not Connected to Control Console with Personnel Present	9.55\$ ⁽¹⁾	5.00 ^(2, 3)
3	Minimum Shutdown Margin of Isolated Reactor	3.25\$	10.00\$
4	Minimum Shutdown Margin with Personnel Present	2.8\$ ⁽¹⁾	5.00\$ ^(2, 3)
5	Maximum Reactivity Increase in Any Single Increment without Compensating Negative Reactivity	0.50\$ ⁽⁴⁾	0.20\$
6	Maximum Reactivity Increase in Any Single Increment with Compensating Negative Reactivity	2.50\$	5.00\$
7	Maximum Reactivity Increase Permitted by Failure of an Out-of-Core Experiment without Use of Position Interlocks	1.00\$	Δ ⁽⁵⁾
8	Maximum Reactivity Increase Permitted by Failure of an Out-of-Core Experiment When Position Interlocks are Used	2.2\$	Not Applicable
9	Maximum Reactivity Increase Permitted by Failure of an In-Core Experiment	1.00\$	Δ ⁽⁵⁾
10	Maximum Operating Power	1000 watts	1000 watts
11	Maximum Power Trip Setting	2000 watts	2000 watts
12	Minimum Operational Period	10 second	10 second
13	Minimum Period Trip Setting	6 second	6 second
14	Maximum Excess Reactivity	6.2\$	0.50\$
15	Maximum Reactivity Addition Rate by Control Element	0.064\$/sec	0.2\$/sec
16	Maximum Reactivity Worth of Individual Control Element	1.00\$	5.50\$ central 4.00\$ peripheral
17	Minimum Shutdown Control Margin in the Auxiliary Shutdown System ⁽⁶⁾	1.0\$	Not Applicable
18	Maximum Number of Control Elements to be Moved Out at One Time	1	1
19	Minimum Number of Operational Control Elements Required	11	4
20	Maximum Scram Delay Time of Neutronics Safety Circuitry ⁽⁷⁾	200 msec	20 msec
21	Maximum Scram Delay Time of Position Interlock Circuitry ⁽⁸⁾	150 msec	Not Applicable
22	Average Control Drum Insertion Velocity ⁽⁹⁾	500°/sec	Not Applicable
23	Maximum Total Scram Delay and Safety Element Insertion Time	Not Applicable	1 second

(1) Based upon +0.15\$ worth for each of 3 people.

(2) Based upon +2.50\$ worth for each of 2 people.

(3) The 5.00\$ represents the maximum permissible reduction in shutdown due to the presence of personnel.

(4) In the case of initial critical approach for previously operated PAX assemblies, all remaining poison wires after initial criticality is attained, may be removed in a single step providing that the initial critical bank position agrees with prior measurements and clean criticality is approached by drum bank rotation in reactivity steps not larger than 0.50\$.

(5) $\Delta = 0.50$ - $\rho_{\text{excess}}$$

(6) This limit shall be met in all cases except for those experiments in which the Auxiliary Shutdown System cannot be connected to the reactor. The approval of AGC and SNPO-C as well as the recommendation for approval by the WANL NSC must be obtained prior to performing the experiment.

(7) Defined to be from the initiation of the scram signal to the beginning of control element motion.

(8) Defined to be from the initial displacement of the experiment to the beginning of control drum motion.

(9) Defined to be from the beginning of control drum motion to 15 degrees (beginning of shock action).

reflector mocked up the NRX-A6 masses but the distribution was somewhat dissimilar. The measurements performed with this configuration were as follows:

4.2.1.1 Beryllium Reactivity Coefficients

Numerous measurements were carried out in a 90 degree segment of the PAX-E0 reflector to determine the axial, radial and azimuthal reactivity effects of beryllium. In one experiment, two 30 degree NRX-A6 mockup sectors were replaced with two 30 degree PAX type sectors to determine the reactivity effects produced by gross changes in the beryllium mass distribution. In all of these experiments, the positive reactivity changes were maintained well below the 0.50\$ maximum permitted and no unanticipated hazards arose.

4.2.1.2 Privy Roof Mounted Shield (PRMS)

Fast neutron and gamma ray attenuation measurements as well as the effect of edge peaking of core flux was measured with the NRX-A3 privy roof mounted shield placed adjacent to the PAX-E0 reactor. This shield, designed to provide protection to instrumentation and mechanical hardware during the Nevada test of the NRX-A3 reactor was constructed of aluminum and filled with borated water. Precautions were taken to prevent any possibility of water entering the PAX reactor. The filling of the shield with water was done near the test cell truck door. During this time, the reactor was sealed by a 1.5 inch thick aluminum plate bolted to the top of the reactor pressure vessel. The shield was sealed and bolted to large I-beams welded to the test cell floor, thus providing assurance that the shield could not fall in the direction of the reactor, resulting in an inadvertent reactivity insertion. Procedures required that both the shield and reactor were sealed during operations. When access into either the reactor or shield was required (e.g., retrieval of dosimetry foils), the shield or reactor remained sealed. No unevaluated safety questions were encountered during the course of this experiment. This experimental configuration is shown in Figure 7.

4.2.1.3 NRX-A6 Post-Mortem Poison Rods

This series of measurements was performed using the PAX-E assembly to determine the worth of boron poison rods located in the outer beryllium reflector area as a function of their

Figure 7. Experimental Configuration of PRMS on PAX-E0 Reactor

number and location. These rods will be used to poison the NRX-A6 core prior to a post-mortem examination of the core and associated assemblies.

The 52 in. long boron poison rods used in the experiment were stainless steel tubes filled with natural boron. The rods were inserted into axial slots located in the beryllium liner of the outer reflector area, between control drums 1 and 12.

The results of the measurements with a single rod in each of five different position slots gave a minimum worth of 2.5¢ and a maximum worth of 9.7¢ per rod.

During these experiments, no unevaluated safety questions were involved and none were encountered.

4.2.1.4 Dosimetry

A series of experiments were performed to determine the fast and thermal neutron activities and gamma dose in the NRX-A6 90 degree mockup of the PAX-E0 assembly.

Sulfur pellets, bare and cadmium-covered gold foils and thermoluminescent detectors were irradiated.

The reactivity addition for dosimetry type foils and wires is minimal and during these experiments, no unevaluated hazards were involved.

4.2.2 PAX-E1 Experiments

In order to minimize the reactivity uncertainties in the NRX-A6 reactor, the actual NRX-A6 reflector was installed on the PAX test stand and a series of reactivity measurements was performed, using a rezoned PAX-E/NRX-A6 fuel loading. The experiments performed on the PAX-E1 were as follows:

4.2.2.1 Initial Criticality

Initial criticality of the PAX-E1 was attained on May 9, with a delayed critical angle of 155 degrees. After removing all the poison wires from the core, the "clean" critical position was found to be 118 degrees as compared to a predicted position of 106 degrees.

4.2.2.2 Fuel Interchange Experiment

After achieving "clean" critical on the PAX-E1, a fuel interchange experiment was carried out where in a 90 degree segment of PAX-E1 fuel was removed from the core and replaced with NRX-A6 type fuel. The experiment was carried out in nine steps with the maximum reactivity change of any step being less than 20¢.

4.2.2.3 Control Drum Worth Experiment

Integral and differential worths of all the PAX-E1 control drums were measured using the WANEF reactivity computer. In using the reactivity computer, the individual drum worths were obtained by continuously driving one drum from full "out" to the full "in" position while the computer measured the change in reactivity. In using this method, the reactivity of the core varies from about 15¢ positive to 45¢ negative. Drum bank measurements were also obtained using the "rod drop" technique.

4.2.2.4 Reactivity Coefficient Experiments

A limited number of measurements were made in the PAX-E1 core to determine the reactivity effects produced by changes in the major core materials. These measurements were made by introducing a small amount of the material of interest into a given core position and measuring the resulting reactivity change. In all of these measurements, the reactivity changes encountered were in the order of 10¢ to 20¢ which is well within the 0.50\$ limitation on positive reactivity insertions.

During all of the measurements described above, the PAX-E1 core shutdown reactivity was maintained well within the established limits and in no instance did any evaluated situation arise. All reactivity changes were maintained well within the 0.50\$ limit.

4.2.3 PAX-E2 Experiments

Due to schedular problems associated with the assembly of the NRX-A6 reactor, all of the measurements required in the PAX-E1 could not be completed, thus, after disassembling

the PAX-E1 reactor, the PAX-E2 reactor was built. This reactor contained the PAX-E1 core configuration and the PAX-E0 reflector configuration. The experiments performed on the PAX-E2 reactor are detailed as follows:

4.2.3.1 PAX-E2 Initial Criticality

Initial criticality of the PAX-E2 core was attained on June 6, 1968 with a delayed critical drum angle of 145.3 degrees. After removing all the poison wires from the core and reshimming, the clean critical drum position was 88 degrees.

4.2.3.2 Drum Worth Experiments

Drum worth measurements similar to those described in Section 4.1 were carried out in the PAX-E2 core to determine the difference in control worths between the PAX-E0 and PAX-E1.

4.2.3.3 Reactivity Coefficient Experiments

Since all of the necessary reactivity coefficient measurements could not be completed on the PAX-E1 core, these measurements were continued on the PAX-E2. The methods employed in the measurements were similar to those described in Section 4.2.2.4.

4.2.3.4 XE-1 Shield Penetration Test

A series of experiments was performed with the assistance of AGC personnel, with the following objectives:

- 1) Obtain PAX measurements of thermal neutron streaming in the turbine exhaust line penetration of the XE-1 shield.
- 2) Obtain PAX measurements of fast neutron and gamma streaming to verify (AGC) analytical predictions.
- 3) To verify the penetration shield collar design.

The test package consisted of a 30 degree sector mockup XE-1 shield contained in another 30 degree sector of a concrete box which, in turn, was securely fastened to a 2 inch thick aluminum platform. The 30 degree sector mockup was loaded with steel balls and borated water (1 percent B/weight) and the concrete box was lined with borated (2 percent)

polyethylene. The flux measurements were obtained using Au, Au/Cd foils, TLD's and sulfur pellets in and around the shield mockup. The entire test package, weighing about 6 tons, was suspended by the crane over the PAX reactor when the measurements were made (Figure 8). This experiment required the use of two position interlocks, the function of which is to scram the reactor if there is any test package movement (Reference - WANL-TNR-099, Paragraph 7.4.6.1 "Out-of-Reactor Experiments"). No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

4.2.4 PAX-E3 Experiments

The PAX-E3 reactor was identical to the PAX-E2 core, but since the PAX-E2 was secured for a period of time while FCX-A operations were carried out, the assembly was called PAX-E3 upon restart. The PAX-E3 was operated to obtain additional reactivity measurements required for the final shim specifications for the NRX-A6 reactor. The experiments performed in the PAX-E3 included the measurement of the reactivity effect produced by nickel when inserted into the core, steel in the reflector region, and the effect of the NRX-A6 type lateral support system on reactivity. The removable section of the PAX test stand deck was also removed for a reactivity measurement, which proved to be very small.

In all of these measurements, the reactivity changes encountered were much below the 0.50\$ limit and in no instance did any unanticipated hazardous condition arise.

4.2.5 PAX-E4 Experiments

The PAX-E4 reactor was similar to the PAX-E2 and PAX-E3 reactors with the only difference being the change in shimmed element positions. The shimmed element positions in the PAX-E4 were changed slightly to accommodate the XE-2 Fuel Reactivity Check (FRC) experiment. The XE-2 (FRC) experiment was designed to determine the reactivity difference between NRX-A5 fuel elements and XE-2 candidate fuel.

The experimental procedure involved measuring the reactivity variations in the PAX-E4 core as a result of interchanging NRX-A5 type fuel and XE-2 type fuel. The experiment involved an interchange of approximately 10 percent of the fuel in the core and prior

Figure 8. Configuration for XE-1 Shield Penetrations Test

fuel data package and appropriate reactivity coefficients. The fuel interchanges were made in steps of 66 elements or less, and all reactivity effects were maintained below +0.15\$, which is well below the 0.50\$ maximum.

4.2.5.1 XE Canister Experiment

Control Systems Engineering requested Radiation and Shielding to provide information to assure that the ETS-1 shield mounted detector subsystem would not be overheated during full power XE reactor tests and that adequate response of the detectors will be obtained over the full power range.

The mockup consisted of a 55 gallon drum filled with paraffin containing two aluminum tubes mounted longitudinally for positioning of the BF_3 and compensated ion chambers. There were also varying thicknesses of Boral, aluminum and polyethylene plates placed adjacent to the drum end in direct line between the detectors and reactor centerline at a distance of nine feet.

The experiment proved that the heating rates would be below the maximum predicted and that the compensated ion chamber (WX-5362) would meet the operating current requirements at full power for one suitable position behind a specific thickness of aluminum. The mockup also has shown that a point can be chosen such that the reactor startup detector will see the nominal safety requirement of one count/sec from the reactor startup plutonium-beryllium source.

In this series of measurements, no unevaluated safety questions were involved and none were encountered.

4.2.5.2 Control Vane Dosimetry

The objective of this experiment was to measure the fast and thermal neutron fluxes in NV/watt and gamma dose rates in rad/hr/watt across a control drum vane.

Number nine control drum was used for this experiment. It was designed for removal without reflector disassembly. The drum was not removed until 1\$ worth of poison wires were inserted into the core, following procedures outlined in the Reactor Operations Manual. The control drum was disassembled and dosimetry foils and wires attached to the control vanes, then

reassembled and installed into the reactor.

During the course of this experiment, no unevaluated safety hazards were involved and none were encountered.

4.2.5.3 Gamma Ray Spectrum Measurements

Gamma ray spectrum measurements were obtained around the PAX reactor with a lithium-drifted gamma ray spectrometer. The measurements were obtained with and without a moderator on the PAX core top.

The reactor core was covered with an aluminum plate, which had been bolted into position and the 9 inch thickness of moderator (polyethylene) placed on top in two incremental steps. The reactivity worth of the 9 inch thickness of polyethylene was calculated to be less than 0.50\$, which is within the limit for maximum reactivity insertions. During these experiments, the Auxiliary Shutdown System (PASS) was attached to the reactor and in no instance was any unevaluated hazard involved and none were encountered.

4.2.5.4 PAX Auxiliary Shutdown System (PASS)

The Auxiliary Shutdown System (Figure 9) was activated during the final run of the PAX-E4 reactor for measurement of actual "shutdown worth" and was found to be about \$2.00 for the one hopper released. The shutdown device consists of two hoppers suspended 12 feet above and slightly west of the PAX reactor which are filled with boron-carbide granules. The hoppers are connected by stainless flexible hose to aluminum "catch" cans located in the outer reflector region of the reactor.

4.3 FCX EXPERIMENT

In order to provide background information to be used in the analysis of FCX material reactivity coefficient results, a series of measurements were made to monitor the "base" reactivity over a period of several days. During this time, the reactor was started up and shutdown with element removal and re-insertion for possible "base shift", also total rod drop scrams versus rod drive in shutdowns. The results of these experiments have shown the reactivity change, due to uncertainties in rod positions, period measurements, etc., to be less than $\pm 0.2\%$.

Figure 9. PAX Auxiliary Shutdown System

4.3.1 FCX-A and FCX-B Experiments

A series of experiments were conducted on the FCX reactor to measure the worths of uranium and carbon as a function of the radial position and the reactivity coefficient of hydrogen both radial and axial. No unevaluated safety questions were involved and none were encountered during the performance of these experiments since all changes in reactivity were considerably less than those specified in the WANEF Operating Limits.

4.4 MISCELLANEOUS EXPERIMENTS

In addition to the experiments described in the preceding paragraphs, numerous experiments were conducted with the PAX and FCX assemblies in support of the detector development program at WANEF. The types of detectors included in this program are: Hurst, Bragg-Gray, Phylatron fast neutron dosimeters, NE-213 scintillator, Li^6 spectrometer, carbon wall ion chambers, U^{238} fission detectors, B^{10} ion chambers, thermoluminescent dosimeters and Ge-Li-drifted spectrometers.

The detecting systems were utilized during operations to provide experimental support for the nuclear, radiation and shielding analysis of the NERVA subsystem.

The experimental program at WANEF also included numerous fission flux distributions and power calibrations on each of the reactor assemblies, in support of design technology.

V. NUCLEAR SAFETY COMMITTEE

The function of the WANL Nuclear Safety Committee (NSC) is to review and consult on all major problems concerned with the nuclear safety of the WANEF facility. It is the responsibility of the committee to review and recommend for approval all experimental programs, operational procedures and proposed modifications to system or facility designs which may affect or change the safety of the facility operation and to provide assurance that boundaries of operational approvals will not be exceeded.

Items which must be reviewed by the NSC include:

- 1) Changes and addenda to the Operating Limits documents and the supporting changes and additions to the Safety Report.
- 2) Changes to the Operations Manual.
- 3) Experimental Details Checklists (EDC) which are not clearly: (a) within the limits of the Operating Limits document, or (b) consistent with portions of one or more standard operating procedure (SOP), or (c) involve unevaluated questions of safety*, or (d) operations which are expected to exceed the radiation exposure limits (AEC Manual, chapter 0524).
- 4) Proposed changes to WANL-TME-646, WANEF Nuclear Safety Manual, which do not fall within its present intent or the ground rules of the Safety Manual.
- 5) Changes to a reactor, the test stands or the facility (a) which are not clearly within the limits of the Operating Limits document, or (b) may constitute an unevaluated safety question.

Items in categories 2, 3 and 5, which the Safety Committee decides are within the scope of the Operating Limits document and framework of the WANEF Safety Report and its supplements, may be recommended for approval to the Project Manager; otherwise, they require modifications to the controlling documents and must be handled as an item in category 1. Items in category 1 may be recommended to AGC/SNPO for approval by the Safety Committee.

* Unevaluated questions of safety exist if (1) there is a possibility of an accident occurring which has not been analyzed in the WANEF Safety Report or its supplements, or if (2) there is an increase in either the probability of an accident previously analyzed, or (3) if there is an increase in the consequences of an accident previously analyzed.

ITEMS SUBMITTED TO SNPO/AGC
FOR WHICH APPROVAL WAS GRANTED

1/23/67 TLX-23101, C. C. Ross to W. E. Johnson; Subject: Approval for WANEF Operations Under Revised Safety Documentation Included are: WANEF Safety Report, WANL-TNR-099, Revision A, WANEF Operations Manual, WANL-TME-267, Revision E, WANEF Operating Limits, WANL-TME-1295, Revision C

4/27/67 Letter C. C. Ross to R. W. Schroeder, Subject: Approval Granted for WANEF Standard Operating Procedure for PAX Experiments With a Nozzle or Plate Over the End of the Reactor

9/29/67 TLX-29031, C. C. Ross to W. E. Johnson, Subject: Approval for Continued Operation of PAX and FCX

12/18/67 Letter W. O. Wetmore to W. E. Johnson, Subject: WANL-TME-1295, Revision D to WANEF Operating Limits Document

RECOMMENDATIONS BY AGC

4/3/67 Letter C. C. Ross to W. E. Johnson, Nuclear Safety Audits - No Recommendations. Audit Conducted 3/1-2/67

9/18/67 Letter W. O. Wetmore to W. E. Johnson Audits Conducted 8/23/67
Safety Audit by AGC/SNPO recommends:

- a. Congested areas should be eliminated.
- b. Revision to WANEF Nuclear Safety Manual concerning storage of moderator materials.
- c. Facility Log should contain "follow-up" comments on entries made to equipment malfunctions.

Corrective action has been taken in response to the above recommendations made during the Safety Audit by AGC/SNPO. These actions are documented in a letter, WANEF-519-67, dated November 11, 1967, from WANEF to Mr. M. R. Beebe, WANL Manager of Industrial Hygiene for incorporation into a letter containing replies from all WANL Groups Requiring response.

ITEMS SUBMITTED TO AGC/SNPO
FOR INFORMATION ONLY

1/11/67	WANEF-353-66, "NRX-A6 Poison Rod Worths in PAX-E"
4/6/67	Revisions to WANEF Safety Documents
4/13/67	WANL-TME-1560, "Justification Report for NERVA Shield Experiment (NSX) Radiation and Shield Program at WANEF"
4/27/67	WANEF-164-67, "Dy Measurements in FCX"
7/3/67	WANEF-246-67, "Titanium and "X" Worths in the PAX-E Reflector"
7/3/67	WANEF-244-67, "Reactor Neutron Population After PAX-E Operation"
7/3/67	WANEF-243-67, "Comparison of XE-1 EMND and NRX-A6 Control Instruments Response"
7/11/67	"A Code of Good Practices for the Performance of Critical Experiments"
7/19/67	WANEF-261-67, "Power Calibration for PRMS Experiment"
7/31/67	WANEF-302-67, "Reactivity Measurements in PAX-E (PAX Fuel)"
7/31/67	WANEF-280-67, "Measurement of XE-1 EMND Control Instrument Response"
7/31/67	WANEF-270-67, "PAX-E A6/PAX-D Fuel Interchange"
8/4/67	Revision F to the WANEF Reactor Operation Manual, WANL-TME-267
8/21/67	WANEF-315-67, "Reflector Experiments in PAX-E"
8/21/67	WANEF-402-67, "Calibration of the Reuter-Stokes RSG-12A Gamma Ionization Chambers"
8/31/67	WANL-TME-1587, "Critical Experiments in Support of NERVA Quarterly Report - 1st Quarter CY '67"

ITEMS SUBMITTED TO AGC/SNPO FOR
INFORMATION ONLY (CONTINUED)

9/5/67	WANL-TME-1582, "WANEF Annual Operation Report 1966"
9/6/67	"Results of Radiation Streaming Test in XE Shield Segment"
10/9/67	WANL-TME-1677, "WANEF Experimental Program for CY '68"
10/15/67	WANL-TME-1676, "Critical Experiments in Support of NERVA Quarterly Report - 2nd Quarter CY '67"
11/5/67	WANEF-355-67, "Verification of the Poison Content of the NRX-A6 Post-Mortem Poison Rods"
11/21/67	WANEF-487-67, "Calibration of U-238 (2 ppm U-235) Fast Fission Chambers (WX-30748)"
11/30/67	WANEF-483-67, "Measurement of the Gamma Ray Spectrum from the PAX Core"
12/5/67	WANEF-495-67, "Measurement of the Response of a Control Instrument (INIS) in a Modified NRX-A6 Environment"
12/5/67	WANEF-505-67, "Calibration of NRX-A6 Neutron Rate Sensors"
12/7/67	WANEF-543-67, "Fission Flux Measurements with NRX-A6 Build 2 Fuel in the NRX-A6 Reflector"
12/7/67	WANEF-536-67, "90° Fuel Interchange Experiment in PAX-E1 Rezoned PAX-D to NRX-A6 Build 2"