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Westinghouse Astronuclear Laboratory

WANEF ANNUAL OPERATIONS REPORT 1966

MASTER

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SECTION 1

INTRODUCTION

This report is submitted in accordance with the requirements of Section 7.4 of WANL-TNR-099, Safety Report for the Westinghouse Astronuclear Experiment Facility (WANEF), which specifies that Westinghouse shall submit to AGC/SNPO an annual report of operating experience and activities. The report shall be based on each calendar year of operation and shall include:

- a) Operational history of the facility, indicating the number of experimental runs, the integrated power levels achieved, the number of unscheduled shutdowns, and the causes for these shutdowns.
- b) A description and hazards evaluation of each series of tests and experiments.
- c) Items referred to the WANL Nuclear Safety Committee (WANL-NSC), the Space Nuclear Propulsion Office (SNPO), the Aerojet-General Corporation (AGC), and the actions taken on these items.

The WANEF facility (Figure 1) is located on a tract of land, approximately 850 acres, near the town of Waltz Mill, Pennsylvania, about 20 miles southeast of Pittsburgh. Also on the same tract of land and adjacent to, but separated by a concrete wall from WANEF, is the Westinghouse Reactor Evaluation Center (WREC) which performs critical experiments in support of commercial programs of the Westinghouse Atomic Power Division (WAPD). For purposes of security and operational safety, an eight foot high fence surrounds the complete WANEF facility. A layout showing the relationship between WANEF and WREC is shown in Figure 2.

During the calendar year 1966, a number of critical experiments were performed in support of the NERVA program NRX-A6 design. This unit is a high power density, graphite moderated, beryllium reflected reactor using fully enriched U^{235} as fuel. One NERVA reactor disassembly (PAX-D) and two fuel loadings (PAX-E and FCX) with associated approaches to criticality were completed during the year. The PAX-E assembly was virtually identical to the PAX-D except for changes in the beryllium reflector and graphite barrel (inner reflector)

Figure 1. Waltz Mill Area Map

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Figure 2. WANEF-WREC Layout

and modifications to control drums. The PAX-E reactor simulates (nuclear-wise) the NRX-A6 core and reflector in one quadrant. The PAX assembly is shown in Figure 3. The FCX (Flexible Critical Experiment) (Figure 4) reactor, although similar to PAX and NRX reactors in that it contains the same type of NERVA fuel, has a different mechanical design, to provide the flexibility required for variation of core and reflector materials. The FCX design permits clean experiments, unperturbed by the extraneous materials present in the PAX and NRX type reactors. A detailed description of the FCX Reactor is given in Reference 1.

The WANEF staff consists of 10 engineers and scientists, 9 technicians, and 1 secretary, with Dr. W. P. Kovacik appointed as Manager in October 1966, and also Scientist-in-Charge (S.I.C.). C. E. Barksdale and F. S. Frantz were appointed as Supervisors of Reactor Operations and Experimental Physics, respectively, at WANEF in October 1966. They both serve as Experimentalists-in-Charge (E. I. C.) alternating the duties as needed. Included in the WANEF staff are 9 qualified Reactor Operators. All 9 operators were qualified to operate the FCX after having taken an AEC equivalent examination in April of 1966, before FCX initial criticality. Eight of the nine operators are qualified on the PAX reactor assembly.

Figure 3. PAX Reactor and Test Stand

Figure 4. FCX Reactor and Test Stand

SECTION 2

SUMMARY OF ACTIVITIES

The PAX-D reactor, continuing operation from 1965, was shutdown and disassembled on March 30, 1966. FCX was assembled and reached initial criticality on April 20, 1966. FCX was shutdown but not disassembled on June 6, 1966. PAX-E was assembled and attained initial criticality on June 23, 1966, and was still in operation at the end of the year.

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, reactor shutdown measurements by single drum withdrawal and pulsed neutron generator (PNG).

Hazards analyses were performed on all experiments prior to initiation of the measurements. All such analyses were recommended for approval by the WANL Nuclear Safety Committee and approved by the Aerojet-General Corporation and Space Nuclear Propulsion Office before the experiment was performed.

Complete revisions were made to WANEF controlling documents given in References 4, 5 and 9. These revisions were made to incorporate new and modified rules and regulations as well as including accumulated experimental data into safety analyses performed previously by analytical methods.

During the year 1966 WANEF conducted training programs in the areas of fuel handling and reactor operations. Specifically, the two programs are as follows:

Fuel Handling

A training program is 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 Criticality Hazards Control Procedures," WANL-TME-646. This training, conducted by the WANEF Manager, is culminated by an oral quiz to determine if each employee thoroughly understands these procedures.

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) a thorough understanding of the electrical system associated with the reactor, and (4) a knowledge of the mechanical systems including a thorough understanding of the reactor itself. These lectures are scheduled by the Supervisor of Reactor Operations at WANEF and employ the use of WANL technical personnel best suited to speak on the above mentioned subjects.

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

A reactor operator's test, equivalent to an AEC examination, is finally given including 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 with the final examination given on April 11, 1966.

Figure 5. WANEF - Westinghouse Organizational Relationship

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SECTION 3

OPERATIONAL EXPERIENCE

During the calendar year 1966, a total of 600 reactor startups were made while producing a total of 8.70 Kw-hrs of integrated power and 465.25 hours of reactor run time. During operations, 23 inadvertent reactor scrams occurred. Seventeen 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. A new patch panel which provides more complete shielding from neighboring signals, grounds, and high voltage leads, is planned for installation as soon as time permits. Three scrams were caused by the opening of interlocked doors leading to operational areas. Two scrams were caused by complete facility power failures. One scram was caused by a period signal introduced by the pulse neutron generator while measuring shutdown, although the reactor was subcritical and control rods partially withdrawn, the introduction of the initial burst of neutrons from the generator caused the period scram. There were no scrams attributed to an operator error. A breakdown of 1966 operating history is given in Table 1.

Personnel radiation exposures for the year were under the permissible level with an average of 25.7 mr/wk/man. The highest exposure for any one employee for the year was 4.04 rem, which is under the yearly limit of 5 rem.

TABLE 1

WANEF OPERATING HISTORY DURING 1966

	PAX-D	PAX-E	FCX
Number of Startups	172	335	93
Integrated Power (Watts-Hours)	3317	4396	988
Run Time (Hour)	144.7	257.9	62.6
Unscheduled Shutdowns:			
1) Instrument Malfunction	1	13	2
2) Operator Error	---	---	---
3) Opened Interlocked Door to Operational Area	1	---	2
4) Period Transient Scram Due to Inst. Noise		1	---
5) Period Transient Scram Caused by Pulse Neutron Generator	1	1	---
6) Power Failure	1	1	---

SECTION 4

REACTOR EXPERIMENTS & HAZARDS CONSIDERATIONS

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 except for substandard components such as fueled elements, inner graphite reflector and support blocks. The PAX assembly, shown in Figure 3, is described in detail in WANL-TNR-099, Safety Report for the Westinghouse Astronuclear Facility.⁽¹⁾

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 to provide the flexibility required for variation of core materials, carbon/uranium ratios, reflector materials, and reflector thickness. Furthermore, the design permits clean experiments, unperturbed by extraneous materials present in the NERVA reactors. The FCX Assembly is described in Reference 8.

Hazards analyses were made for each type of experiment prior to initiation of the measurement. In addition to the analytical interpretation of hazards involved, information obtained from Los Alamos Scientific Laboratory in support of the KIWI Program, provided an excellent basis for evaluation of the NRX system. Certain limitations, as given in the WANEF Operating Limits⁽⁵⁾ impose restrictions which are a necessity to the safety of the facility. These restrictions are given in Table 2.

Power Calibration

Reactor power was calibrated using uranium-aluminum and gold wires as well as sectioned fuel elements. Standard wire counting techniques were used and normalized to reactor power as determined by radiochemical analysis of sectioned elements. Core reactivity changes, due to the insertion of foils or wires, contributed no more than 1μ in reactivity to the system thus minimizing the problem of uncertain reactivity additions.^(2, 3) No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

TABLE 2

<u>Operating Variables</u>	<u>PAX</u>	<u>FCX</u>
Maximum Reactivity Worth of Individual Control Element	1.00\$	4.00\$
Minimum Shutdown Control Margin in Control Elements	2.8\$	10.00\$, 5.00\$***, with personnel present
Minimum Physical Shutdown of Reactor not Connected to Control Console	10.00\$	10.00\$
Minimum Effective Shutdown of Reactor not Connected to Control Console with People Present	9.55\$*	5.00\$**
Maximum Reactivity Addition Rate by Control Element	0.064\$/second	0.2\$/second
Maximum Reactivity Increase to be Allowed in any Single Increment for any Experiment by Hydrogen Addition, Poison Removal, Fueled Experiment Addition, or Other Method	0.33\$ steps to max. excess of 6.2\$	0.33\$ steps to max. excess of 0.50\$
Maximum Operating Power	1000 watts	1000 watts
Setting of Scram Points	2000 watts (max.) 5 second period (min.)	2000 watts (max.) 5 second period (min.)
Maximum Excess Reactivity	6.2\$	0.50\$
Maximum Number of Control Elements to be Moved Out at One Time	1	1
Maximum Total Scram Delay Time and Safety Element Insertion Time	1 second	1 second
Minimum Shutdown Control Margin in the Auxiliary Shutdown System****	1.0\$	Not applicable

*Based upon +15¢ worth for each of 3 people.

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

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

****This limit shall be met in all cases except for those experiments in which the Auxiliary Shutdown System cannot be connected physically to the reactor. In the aforementioned cases, the approval of AGC and SNPO-C as well as the recommendation for approval by the WANL Nuclear Safety Committee must be obtained prior to performing the experiments.

Reactivity Shimming

Reactivity shimming was performed to obtain the desired delayed critical drum bank setting. Experiments were also made in conjunction with power distribution measurements to determine what effect shims have on power shapes as a function of shim location in the core. The reactivity coefficient of shim material had been previously calculated by WANL and determined experimentally by WANEF during tests on PAX mockups of NRX-A2 and A4. These measurements, and the techniques used, presented no credible hazard.⁽²⁾ No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

Fuel Reactivity Check (FRC) for the NRX-A5 Reactor

A fuel reactivity check was performed by substituting the PAX elements with elements representative of the NRX-A5 reactor. The purpose was to determine if element material compositions were in accordance with specifications as given by the fuel manufacturer's data packages giving uranium loading, graphite content, and niobium masses and profiles of each element. These data packages were used to determine, by analytical methods, what reactivity changes could be expected due to the fuel change.

The fuel reactivity check was made following a complete reactivity analysis of the two sets of fuel elements. The two types of elements, although containing the same constituents, differed slightly in mass content. These mass differences and the reactivity coefficients were utilized on each element substituted to determine, as a function of core location, what reactivity effects would be encountered. Excellent agreement was found between calculation and experiment. Care was used never to exceed the maximum manual reactivity insertion limit of 33¢ or the minimum shutdown of 2.8 \$ on PAX.⁽³⁾ No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

Control Drum Calibration

PAX control drum calibration was determined by: (1) scrambling individual drums from various delayed critical positions and measuring the prompt flux decay on the recorder

to obtain K_{sd} in formation, (2) differential drum bank worth were determined by adjusting the drum bank from the 180 degree delayed critical position to the delayed critical position of about 90 degrees as poison wires were removed, and (3) by the use of an analog computer. The computer measured both positive and negative reactivity changes, associated with drum movement, from the non-asymptotic behavior of the flux in the reactor. The computer was able to calculate the reactivity change instantaneously with the movement of a control drum taking the reactor from about 20 ρ supercritical to about 10 ρ subcritical. Each incremental change in reactivity due to drum insertion was measured by the analog computer and recorded on chart paper. No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

Measurement of Control Instrument Response (INIS)

The power level and control of NRX-A5 and A6 were to be monitored using a group of Westinghouse type WX 5362 compensated ion chambers. These chambers were enclosed in a boral container and moderated with zirconium hydride powder. An experiment was performed at WANEF using one of the above chambers with a geometry similar to NRX-A5 and A6 for the purpose of verifying calculations performed by the Radiation and Shielding Group with experimental data.^(2, 6)

Reactor Shutdown Measurement by Single Drum Withdrawal

A method for determining the shutdown of a reactor prior to initial criticality by withdrawing a previously calibrated control drum has been developed at WANEF and used at NRDS while removing poison wires from the NRX-A5 in the R-MAD building. Interest in this method continues as it is being considered for use when the poison wires are removed from XE-1 at NRDS. Two sets of experiments were performed on PAX-D and reported previously.⁽³⁾ The second set utilized exaggerated source-core-detector geometries to show the influence which these play. Because the reflector region of the present PAX-E build is quite different from that of PAX-D, single drum withdrawal shutdown measurements on PAX-E were performed to evaluate the method with the different reflector geometry.

Dosimetry Measurements

Dosimetry experiments were performed in the PAX-D and PAX-E reactors using sulfur pellets, TLD capsules, nickel, and bare and cadmium-covered gold. The purpose of these experiments was to measure the gamma and fast flux throughout the core, reflector and outside the reactor. ^(2, 3)

Ping System Development

The experimental design of a series of pulsing experiments has been initiated using the PAX reactor, Pulse Neutron Generator (PNG), in-core detectors, and associated electronics in an effort to: (1) determine the manner in which the distribution of neutrons in a NERVA core changes as a function of time after a pulse of 14 Mev neutrons is introduced into the core at a point on the reactor midplane, and (2) determine the value of β for various locations in the core. ⁽²⁾ All PNG measurements were made with the core in various degrees of subcriticality.

PAX Auxiliary Shutdown System (PASS)

An auxiliary shutdown system has been designed and constructed for use on PAX. This mechanism installed in February 1966, is designed to provide a "last ditch" reactor shutdown and is manually operated from the control room. The shutdown device is comprised of two metal hoppers located at a distance of approximately 12 feet above the PAX assembly and connected to the reactor by means of two stainless steel flexible hoses. The hoppers are filled with boron carbide powder which upon activation from the control room may be dumped into two thin aluminum cans which are permanently installed between the core and reflector. These hoses are normally connected during reactor operation. This system was approved for use by AGC/SNPO June 16, 1966.

Test Cell Fuel Storage Rack

A second fuel storage rack has been installed on the test cell balcony. It is identical to the first one built, and is described in Reference 1.

Initial Criticality (FCX)

The FCX (Flexible Critical Experiment)⁽⁴⁾ reactor, although similar to PAX and NRX reactors in that it contains the same type NERVA fuel, has a different mechanical design to provide the flexibility required for variation of core materials, C/U ratios and reflector materials. In addition, the FCX permits clean experiments, unperturbed by extraneous materials. The initial approach to critical on the FCX assembly was accomplished by inserting fueled and unfueled clusters, in predetermined amounts, into the core starting from the center and proceeding outward in a symmetrical fashion. The FCX fuel was not poisoned and criticality was attained by the addition of fueled and unfueled clusters. During the loading of the core, continuous monitoring of the core multiplication using standard "inverse multiplication techniques" was made using three Data Acquisition System (DAS) channels and the FCX startup channel. No unevaluated safety questions were involved and none were encountered during the performance of the experiment.

FCX Control Rod Worths

In order to ensure the proper margin of control on the FCX core, a series of measurements were made to determine the worth of the control rods. The measurements included incremental worths of the central and peripheral rods, integral worths of various and combinations and the total worth of the entire bank.

The measurements performed on the FCX reactor to determine the control worths consisted of incremental rod worth measurements using the "rod bump" period technique and the total rod worths using the "rod drop" technique. No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

Material Worths in the FCX Assembly

The reactivity coefficients of uranium, carbon, and niobium were measured as a function of radial position in the FCX core region. Carbon measurements were also obtained in the reflector region. The measurement technique in each of these measurements involved

obtaining a reactor period for a given rod position prior to and after the material was inserted into or removed from the core. The periods were then corrected to a reactivity value, and with the mass of the material perturbed, the reactivity coefficient was established. No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

FCX Fission Flux Measurements

Measurements of fission flux distribution were carried out in the FCX core to determine variations in self-shielding, core symmetry, and radial and axial flux distribution. The techniques used were those developed in the PAX series of experiments. No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

FCX Neutron and Gamma Dosimetry⁽⁶⁾

Neutron and gamma activation measurements were performed in the initial FCX assembly, as well as outside the assembly, by means of various types of detectors. The types of activation measurements performed were: (1) axial and radial distribution outside the core, (2) axial and radial measurements in the vicinity of a control rod, (3) axial measurements in the vicinity of the AI core support plate and (4) radial distribution measurements using gold foils with Cd covers of various thickness. No unevaluated safety questions were involved and none were encountered during the performance of this experiment since all changes in reactivity were considerably less than those specified in the WANEF Operating Limits.⁽⁵⁾

FCX "Fat Man" Measurements

After each core loading increment, the core multiplication was checked with control rods full in, half withdrawn, and full out. To insure personnel safety during loading operations, the effect produced by a simulated "fat man" was measured after each loading increment with control rods full in and full out. The "fat man" mockup consisted of five 5-gallon cans of paraffin weighing a total of 180 pounds. These cans were placed flush with the side

of the core for each measurement. All control rods were inserted when the simulated "fat man" was placed adjacent to the core. 1/M measurements ensured that repetitive placement of the "fat man" adjacent to the core following each fuel loading constituted no hazard. The increased multiplication due to the presence of the "fat man" was found to be small for the reflected core (the type of core tested).⁽⁶⁾

No unevaluated safety questions were involved and none were encountered during the performance of this experiment.

SECTION 5

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, operation 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 Operation 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, The Criticality Hazards Control Procedure, which do not fall within its present intent or the ground rules of the Criticality Hazard Control Guide.
- 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

* 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 if, (3) there is an increase in the consequences of an accident previously analyzed.

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.

Items Submitted to SNPO/AGC for which Approval was Granted

3/21/66	Approval granted for use of extended fuel storage <u>tags</u> .
4/4/66	Approval from AGC to proceed with limited FCX operations in accordance with governing document.
6/16/66	Authorization for use of PASS system
10/3/66	Authorization for continued operation of PAX and FCX

Recommendations by AGC

3/8, 9, 10/66	Safety audit recommends 1) Requests answers to AGC questions regarding PASS system (increased spring tension, flow characteristics of boron,)
10/3/66	Safety Audit by AGC, NO RECOMMENDATIONS
6/16/67	AGC request that WANL review Safety Clauses of NP-1 contract.

These items were completed in accordance with comments and answers forwarded to AGC.

Items Submitted to AGC/SNPO for Which Approval had not been Received 1/1/67

WANL-TME-1295, Revision C to WANEF Operating Limits
WANL-TME- 267, Revision E to WANEF Operations Manual
WANL-TNR-099, Safety Report for the WANEF - Revision A

Items Submitted to AGC/SNPO for Information Only

1/11/66	WANEF 787 "Performance of a PTX on XE-1
2/17/66	WANEF 35-66 "NRX-A5 (WAFF) Fuel Reactivity Check (FRC)" Preliminary
3/4/66	WANEF-54-66 "Reactor Shutdown Measurements from 1/M data with Single Drum Withdrawal"
3/22/66	WANEF-67-66 "Flux Distributions from PAX-D 186 and 189 effects on Power from Unfueled Partial Elements."

4/2/66 WANEF-75-66 "NRX-A6 30° Sector Mockup Reactivity and Drum Worths"
4/4/66 WANL-TME-646 "Westinghouse Astronuclear Facility Criticality Hazards
Control Procedure"
4/16/66 Experimental Plan, PAX in Support of NRX-A6 (PAX-E).
6/14-66 WANL-TME-1403, WANEF Critical Experiments in Support of NERVA Quarterly
Report - 2nd Quarter CY-66
6/30/66 WANEF-92-66 Measurement of Fast Neutron Decay Constant Alpha
7/5/66 WANEF-143-66 FCX Initial Criticality
7/12/66 WANEF-153-66 PAX Fission Flux Distribution and Dosimetry Measurements of
XE-1
7/25/66 WANEF-158-66 FCX Fission Flux Measurements
7/25/66 WANEF-141-66 FCX Channel Locations
7/29/66 WANEF-118-66 Measurement of Control Instrument Response in NRX-A5 (PAX)
8/1/66 WANEF-161-66 Material Worths Measurements in the first FCX Core

In addition to the above Safety Items Monthly Telecon Reports were made to
AGC and SNPO Cleveland with regard to WANEF Operations.