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MARCH 1965

Westinghouse
Astronuclear Laboratory

WANEF ANNUAL
OPERATIONS REPORT
1964

MASTER

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EXPERIMENTAL FACILITY*

REACTOR ANALYSIS DEPARTMENT

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SECTION 1

INTRODUCTION

This report fulfills the requirements of Section 7.4 of WANL-TNR-099,¹ Safety Report for the Westinghouse Astronuclear Experimental Facility, which specifies that Westinghouse shall submit to the AEC 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, and actions taken, by the WANL Nuclear Safety Committee.

The WANEF Facility is located on an 850 acre tract owned by Westinghouse Electric Corporation near the town of Waltz Mill, Pennsylvania, 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 Atomic Power Division. Although the two facilities are located in the same building, concrete walls divide the building into two entirely separate areas. A layout showing the relationship between the WANEF and WREC facilities is given in figure 2.

During calendar year 1964 a number of critical experiments were performed in support of the NRX-A2 and NRX-A3 phases of the NERVA program. These two units were designed as high power density, graphite - moderated, beryllium - reflected reactors using fully enriched U^{235} as fuel. Three reactor fuel loadings, with associated approaches to criticality, and two reactor disassemblies were completed during the year. The three reactor assemblies termed PAX, PAXA, and PAXB were virtually identical, the principal changes being the use of different beryllium reflectors and control drums.

The WANEF-WANL organizational relationship is shown in figure 3. Mr. E. J. Ney was appointed WANEF Supervisor on 1 January, 1963 and Scientist-In-Charge (S.I.C.) on 3 January, 1964. Dr. W. P. Kovacik was Experimentalist In Charge (EIC) during this period. The E.I.C. is responsible for execution of approved

programs, including reactor operation, in accordance with approved procedures^{2,3} and is authorized to conduct such experiments in the absence of the S.I.C. Mr. Ney was transferred to Nevada Test Operations in October, 1964 and Dr. Kovacik was named as his replacement on 19

October, 1964. Mr. C. E. Barksdale was appointed E.I.C. at the same time. As of December 1964, the WANEF staff consisted of a Supervisor, four scientists and engineers, five technicians and a secretary. Included in these personnel are six qualified reactor operators.

Figure 1. Waltz Mill Area Map

Figure 2. WANEF - WREC Floor Plan

Figure 3. WANEF - Westinghouse Organizational Relationship

SECTION 2

SUMMARY

PAX initial criticality was attained on 19 February, 1964. It was disassembled on 7 April, 1964. PAXA initial criticality was achieved on 5 August, 1964. It was disassembled on 2 October, 1964. PAXB initial criticality was achieved on 20 November, 1964. This reactor was still in operation at the end of the year. All operations were conducted without accidents and no unsafe conditions existed at any time.

The types of experiments performed at WANEF on the PAX assemblies included initial criticality, control drum worths, reactivity shimming, power distribution, reactivity coefficients of core and reflector materials, and reactivity worth of poison wires used in shipment of the reactor to the Nevada Test Site. Results of most of these experiments are given in references 4 and 5. Hazards analyses were performed on all experiments prior to initiation of the measurements. All such analyses were approved by the Aerojet-General Corporation, the Space Nuclear Propulsion Office, and the Westinghouse Astronuclear Laboratory Safety Committee before the experiment was performed.

The WANL Nuclear Safety Committee reviewed and recommended for approval various WANEF requests for modifications

and tests. AGC and SNPO approval was also received for these requests. Periodic reviews by the Safety Committee and its Operations Sub-Committee and by AGC and SNPO safety personnel were conducted with no adverse reports. A favorable review and inspection of WANEF was also conducted by Mr. F. Shon of the AEC Division of Operational Safety, on 14 December, 1964.

The various types of experiments and their associated hazards are described as follows:

A. Initial Criticality

Fueled clusters, poisoned with B_4C poison wires, were loaded inside the pre-assembled reflector. Due to the large K_{sd} with the poison inserted, no discernible multiplication was present with the core fully loaded. Criticality was obtained by incremental removal of poison wires and subsequent movement of control drums as the increased multiplication was monitored remotely.

The PAX assembly, simulating the NRX-A2 and NRX-A3 reactors, contained a large number of B_4C poison wires uniformly dispersed throughout the assembled core. Calculations indicated that this system was sub-critical by at least 30\$. Criticality

was obtained by removing poison in increments of 10 percent of the total complement or 50 percent of the quantity needed to achieve criticality as determined by extrapolation of the inverse count rate curve. Four data channels, utilizing BF_3 proportional counters, amplifiers and scalars, were used to obtain counts after each poison wire removal. No hazards were anticipated for the experiment and the predicted critical configuration was in excellent agreement with the experimental results.

B. Drum Calibration

The reactor control drums were calibrated by two methods. The first method consisted of an individual drum and the two drums adjacent to it being moved from zero to 180 degrees while the core reactivity balance was maintained by means of the remaining nine drums. The second consisted of the entire drum bank worth being measured in increments from 180 degrees to 90 degrees as the final group of poison wires was removed.

After delayed criticality was attained the differential worth of the entire 12-drum bank was determined. This was done by measuring the worth in increments from the 180-degree position (full out) to the 90-degree position as a function of poison wire removal. Additionally, all control drums were scrambled from various delayed critical positions. This was done to obtain K_{sd} information from rod drop measurements. The differential worth of individual drums was obtained by the rod bump method. Each type of measurement employed standard techniques and involved no hazard since the required K_{sd} was maintained at all times.

C. 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 1¢ in reactivity to the system thus minimizing the problem of uncertain reactivity additions.

D. Reactivity Coefficients

Material reactivity coefficients were measured for uranium, graphite, niobium, hydrogen and other reactor materials at various locations in the core and reflector. These measurements were made utilizing the standard method of placing the material in position and measuring the difference in reactor periods with and without the material.

Expected reactivity changes for materials were carefully analyzed prior to the measurement and comparison of expected changes to those measured by the Los Alamos Scientific Laboratory in their KIWI test series. The addition of these materials to the reactors was always made in quantities equivalent to some reactivity value less than 33¢.

E. Power Distribution and Radiation Environment

PAX gross and localized power distributions were taken in both radial and axial directions. Gold and uranium-aluminum wires and foils were placed in various positions throughout the core, to determine power profiles as well as azimuth

variations as a function of drum settings. Fuel elements were also counted in power distribution determinations. Neutron and gamma ray measurements were also made external to the reactor.

The hazards involved in the power distribution experiments are virtually the same as those for Power Calibration described in paragraph C above, since the techniques are nearly identical. The major difference is the use of a miniature fission chamber positioned near the reactor; however, this contributed no additional reactivity to the system.

F. B_4C Poison Wire Worths

To permit shipment of the NRX-A2 reactor as an integral unit, additional shutdown margin was provided by the use of small diameter stainless steel tubes filled with boron carbide. Analytical determinations of poison wire worths were verified experimentally for both dry and flooded cases. CH_2 was used to simulate (mockup) water in the case of the flooded core.

To mockup a dry worth for poison wires, several poison wires were added to the reactor in the flow channels and the difference in delayed critical measured. Based on the measured worth of poison wires, the wires were removed from the assembly in increments of 33¢ or less. Wire worths for a flooded core mockup were determined by placing the B_4C poison in the core in increments and then placing small polyethylene rods, the length of a fuel element, in channels adjacent to the poison wires. Since the addition of polyethylene constituted a positive reactivity change, care was used to insert rods in increments of 33¢ or less.

LASL experiments utilizing these materials were used as a basis for the determination of reactivity coefficients. In removing the wires and polyethylene from the core, the polyethylene was always removed first thus assuring that the minimum shutdown for the system was always available.

G. Fuel Reactivity Check (FRC)

A pre-assembly experiment for NRX-A3 was not performed in its entirety. Instead, a number of fuel elements, representative of the central zone of NRX-A3, were substituted for PAX elements to determine if element material compositions were in accordance with specifications as given by fuel manufacturers' Data Packages, giving uranium, cladding and graphite content 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 reactivity insertion limit of 33¢ or the minimum shutdown of 2.8\$.

H. Shimming Experiments

Reactivity shimming was performed to determine how many poison shims were required to provide the desired 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 reac-

tivity coefficient of shim material had been previously calculated by WANL and determined experimentally by LASL in conjunction with WANEF personnel on the ZEPO assembly. These experiments were performed prior to the assembly of the initial PAX. This measurement and the techniques used presented no conceivable hazard.

SECTION 3

OPERATIONAL EXPERIENCE

The pertinent operational data for the 1964 calendar year is summarized in table 1. A quantity of 484 startups were made on runs producing a total of 1.84 kw-hrs of integrated power. Additionally, a total of 28 unscheduled scrams occurred. Eight of these scrams were attributed to operator error. They occurred either as a result of a level trip on a linear amplifier (due to improper range scaling) or to the inadvertent pressing of the scram button. The remaining unscheduled scrams occurred as the result of instrument malfunction. The majority of these latter scrams were caused by fast noise transients in the linear and log picoammeters actuating

the electronic trips. The noise problem was corrected in the log amplifiers by replacement of an underrated resistor in the electrometer section. The time response of the picoammeters was not affected by this change. WANEF is planning to replace the range switch circuitry in the linear picoammeters with a new type of noiseless switch.

Personnel exposures were under the permissible limits with an average of 6.0 mr/week/man (see table 2). The greatest exposure for any one employee was 770 mrem for the year; this was well under the maximum permissible of 5000 mrem.

TABLE 1. WANEF OPERATING HISTORY DURING 1964

	<u>PAX</u>	<u>PAXA</u>	<u>PAXB</u>
Number of Startups	239	171	74
Integrated Power (watt-hours)	1,399	373	67.4
Run Time (hours)	228	160	71
Unscheduled Shutdown			
(1) Instrument Malfunction	11	4	4
(2) Operator Error - Improper Range on Instrumentation or Inadvertent Depressing of Scram Button	7	1	0
(3) Other Causes			
Opened Interlocked Door in Operational Area	1	0	0

TABLE 2. PERSONNEL RADIATION EXPOSURES DURING 1964

<u>NAME</u>	<u>DOSE (mrem)</u>
Barksdale, C. E.	620
*Beene, J. L.	0
Brooks, E. H.	70
Brawdy, R.	250
Christ, D. V.	0
Freidhof, W. E.	580
Kovacik, W. P.	770
Kubancsek, G. E.	650
Makovich, J. J.	420
*Moore, F.	0
*Ney, E. J.	689
Poe, H. D.	30
Rankin, W. D.	19
*Sudarich, L.	0
Thomas, G.	390

*No longer employed at WANEF

SECTION 4 REACTOR EXPERIMENTS AND HAZARDS CONSIDERATIONS

Critical tests conducted at WANEF were performed on an assembly comprised primarily of reject NRX reactor components. This assembly, termed Pre-Assembly Experiment (PAX), is nearly an exact nuclear and mechanical mockup of the NERVA reactor except for sub-standard components such as fueled elements, inner graphite reflector and support blocks. The PAX assembly, shown in figure 4, is described in detail in WANL-TNR-099, Safety Report for the Westinghouse Astronuclear Facility. The results of these experiments are given in References 4 and 5.

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 Limits² and WANEF Operations Manual³ impose restrictions which are conducive to the safety of the facility. Reference 6 presents a detailed plan and hazards analysis for each experiment. The most important of these restrictions are:

- a) Manual changes to the reactor will be made in positive reactivity steps of 33¢ or less.
- b) Only one control drum may be moved to a more reactive position at one time.
- c) The reactivity insertion rate by control drum movement is limited to 0.064\$/second.
- d) Maximum power level of 2 kw.
- e) Minimum K_{sd} allowable is 2.8\$.

Figure 4. PAX Reactor on Test Stand

SECTION 5

NUCLEAR SAFETY COMMITTEE

Procedures have been established for the authorization of modifications and/or tests which are not covered in the WANEF Safety Report. These include:

- a) Changes in the WANEF test specifications.
- b) A change, the effect of which could create hazards of a nature not previously discussed or analyzed in the WANEF Safety Report.
- c) Any change involving an increase in the probability or the consequences of any accident analyzed in the WANEF Safety Report.

The procedure involves the submission by the WANEF supervisor to the WANL Nuclear Safety Committee for review of a report containing

- a) Scope of the change.
- b) Reason for the change.
- c) Methods used in making the modification or conducting the test.
- d) Analysis of associated hazards.

Favorable review by the WANL Nuclear Safety Committee results in the submittal of a report to the Aerojet General Corporation and Space Nuclear Propulsion Office requesting approval for the proposed modification or test.

The WANL Nuclear Safety Committee is comprised of a permanent chairman, three to five permanent members, ex-officio members to serve in a consulting capacity, and a secretary. The organizational relationship of the Nuclear Safety Committee to the WANEF facility is shown in figure 3, and the qualifications of the members are given in reference 1.

Specific requests submitted during 1964 and the results are outlined below:

Requests for approval by WANEF for

- a) Assembly of PAX in support of NRX-A2. ✓
- b) Substitution of NRX-A1 reflector for NRX-A2 reflector.
- c) Fuel storage in vault array without poison.
- d) Multiple control drum insertion.
- e) Reduction in the number of master scram buttons from three to one.
- f) Use of battery power supplies for use on ion chambers.
- g) Approval of additional experiments to be performed in support of NRX-A3 and A4.

All requests were reviewed favorably by the WANL Nuclear Safety Committee, and granted approval by Aerojet General

Corporation and SNPO following a specific justification for each change or modification.^{7, 8}

The following changes or modifications were recommended by SNPO.

- a) Maximum uranium loading in PAX lowered by 100 kg.
- b) Maximum fuel storage in WANEF vault, 500 kg rather than 600 kg.
- c) Dust covers on control rod drives.
- d) Continuous air monitor having intake near top of reactor.
- e) Investigate the installation of auxiliary shutdown system on PAX.

All recommendations have been incorporated into the WANEF operational system with the exception of (e). Considerable effort has been spent in designing a fail-safe method to provide additional shutdown

of the two systems. These studies are being actively pursued and include a cadmium blade that may be inserted between the core and reflector, a hopper containing boron carbide pellets which may be manually activated from the console to drop pellets in a gap between the outer and inner reflector shells. The second method seems more feasible and is presently being finalized into a workable system.

Regular inspections were held periodically at WANEF by the Supervisor of Safeguards Engineering and the Criticality Engineer, both members of the Nuclear Safety Committee. A total of 16 visits were made during the year 1964. Approximately five inspection visits were made by AGC/SNPO Safety personnel during the year. No adverse reports were submitted as a result of these inspections.

SECTION 6

REFERENCES

1. WANL-TNR-099, Safety Report for the Westinghouse Astronuclear Experimental Facility, May, 1963 (CRD)
2. WANL-TME-383, Operating Limits for the Westinghouse Astronuclear Experimental Facility, September, 1963 (UNC)
3. WANL-TME-267, Operations Manual for the Westinghouse Astronuclear Experimental Facility, February, 1963 (UNC)
4. WANL-TNR-158, Results of Pre-Assembly Experiment in Support of NRX-A2, June, 1964 (CRD)
5. WANL-TME-1053, Results of Pre-Assembly Experiment in Support of NRX-A3, February, 1965 (CRD)
6. WANL-TME-355, Westinghouse Astronuclear Laboratory Experimental Facility Experimental Plan, May, 1963 (CRD)
7. WANL-TME-487, WANEF Pre-Operational Systems Test, August, 1963 (UNC)
8. WANL-TME-996, WANEF Experimental Program, NERVA Contract Year 1966, October 1964 (CRD)