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Subcontract NP-1

WANL-TME-2694
May 1970

Westinghouse Astronuclear Laboratory

WESTINGHOUSE ASTRONUCLEAR EXPERIMENTAL FACILITY

WANEF ANNUAL OPERATIONS REPORT

1969

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1969

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INFORMATION CATEGORY

Unclassified

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AUTHORIZED CLASSIFIER

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PREVIOUS REPORTS IN THIS SERIES

WANL-TME-1128, "WANEF Annual Operations Report - 1964", March 1965

WANL-TME-1387, "WANEF Annual Operations Report - 1965", March 1966

WANL-TME-1582, "WANEF Annual Operations Report - 1966", March 1967

WANL-TME-1771, "WANEF Annual Operations Report - 1967", April 1968

WANL-TME-1927, "WANEF Annual Operations Report - 1968", May 1969

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1.0 INTRODUCTION

This report is submitted in accordance with one of the requirements of Section 7.4.4 of WANL-TNR-099, Revision C, "Safety Report for the Westinghouse Astronuclear Experimental Facility," which specifies that Westinghouse will submit to AGC/SNPO an annual report of operating experience and activities for each calendar year. The report shall include:

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

1.1 SITE DESCRIPTION

The WANEF facility is located on an 850-acre tract owned by the Westinghouse Electric Corporation. The site is approximately 20 miles southeast of Pittsburgh and is the headquarters of the Advanced Reactors Division with the associated engineering support activities including analytical chemistry and hot cell laboratories. In addition to the Astronuclear Experimental Facility, the site also contains the PWR Systems Division Nuclear Training Facility, the Astronuclear Hydrogen Experimental Site and a High Voltage Test Facility of the Power Systems Planning Department of the East Pittsburgh Advanced Systems Technology group. Figure 1 shows the Waltz Mill Site layout.

In October, WANEF acquired the test cell and associated offices and laboratory space formerly occupied by the Reactor Evaluation Center. A small staff of the Pressurized Water Reactor - Systems Division is still conducting a training program for customer personnel on the Critical Experiment Station (CES). This activity is referred to as the Nuclear Training Center (NTC). Figure 2 shows the WANEF-WNTC facility layout.

Figure 1. Waltz Mill Site Map

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Figure 2. WANEF-WNTC Layout

1.2 PAX AND FCX REACTORS

During calendar year 1969, critical experiments were performed in support of the development phase of the NERVA program. These critical assemblies are graphite moderated, beryllium or graphite reflected reactors using fully enriched U^{235} as fuel. The PAX/R-1 reactor assembly was used to obtain data in support of the Shielding Provision Trade Study, Nuclear Subsystem Preliminary Design Review (NSS-PDR), and various Engineering Critical Component (ECC) designs. The PAX/R-1 assembly was used most of the year except in December when the control console was connected to the Flexible Critical Experiment (FCX) assembly. The operation of the FCX consisted solely of a physical fuel inventory and annual maintenance activities through the end of the year.

1.3 WANEF STAFF

The WANEF staff experienced a net reduction of personnel during the year through the loss of one Reactor Operator and one Reactor Operator-in-Training.

Four engineers were designated as Reactor Operators-in-Training, and one engineer was designated as Experimentalist.

The WANEF staff is comprised of the Experimental Physics group and the Reactor Operations group. The operations group has the prime responsibility of safe operation and maintenance of the reactors, overall responsibility for facility maintenance and assistance with the experimental mockups. The Experimental Physics group has the responsibility for planning, performance, and analysis of the experiments conducted at the facility. The organization structure of WANEF is listed in Figure 3 and the relationship of WANEF to Westinghouse is shown in Figure 4.

Figure 3. WANEF Organizational Chart

Figure 4 - WANEF - Westinghouse Organizational Relationship

2.0 SUMMARY OF ACTIVITIES

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

Hazards analyses were performed on all experiments prior to initiation of the measurements. Experiments not specifically covered by WANEF controlling documentation, or falling within the intent of this documentation are submitted to the WANL Nuclear Safety Committee with the request for concurrence by the Committee and approval by the Aerojet Nuclear Systems Company and the Space Nuclear Propulsion Office before the experiments are performed. No experiments were conducted during the year that required this action.

Revised documentation were issued that indicated the changes made to the PAX for the R-1 sector mockup.

A simulated emergency exercise was held to familiarize personnel with the emergency procedures and escape routes of the expanded facility.

To reduce the overall fuel inventory, 344 low-loaded NERVA fuel elements, no longer needed at WANEF, were shipped to WANL for disposition as scrap.

Several new "Crit-Zones" were added to the facility to expedite the handling and storage of fuel. The Crit-Zones, their locations and purposes are:

- Crit-Zone 8 - Established within the fuel storage vault to provide space for storing U-235 foil and wire material that was previously located in other Crit-Zones throughout the facility.
- Crit-Zone 9 - Encompasses the fuel element lathe in the fabrication area and permits fuel to be handled in this area, under controlled conditions.
- Crit-Zone 10 - Located in the northeast quadrant of the south test cell and to be used primarily for bulk fuel shipments.

3.0 OPERATIONAL EXPERIENCE

3.1 REACTOR OPERATIONS

During calendar year 1969, a total of 237 reactor startups were made while producing a total of 25.76 Kw-hrs of integrated power. During operations, 13 inadvertent reactor scrams occurred. Ten of these unscheduled scrams occurred as a result of instrument malfunction, principally as a result of noise transients in the linear and logarithmic picoammeters actuating the electronic trips. Two scrams were caused by the armature current trip and the remaining scram was activated by an interlock switch action. There were no scrams attributed to operator error. The breakdown of operating history is given in Table 1.

Personnel radiation exposures in the critical facility for the year were under the permissible level with an average of 29.2 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 3.6 rem, which is well under the yearly limit of 5 rem. However, one man while working with a Co^{60} source at the Radiation Calibration Facility, a licensed activity*, received an overexposure of approximately 17 rem. This occurrence has been duly reported and documented with the AEC in accordance with the requirements of the By-Product Material license.

3.2 PERSONNEL TRAINING

3.2.1 Reactor Operator Training

Prior to becoming a reactor operator, personnel are instructed in the areas 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 instructions are conducted by the Supervisor of Reactor Operations at WANEF.

In addition, experience and familiarity with procedures 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 of the Experimentalist-in-Charge. Emergency exercises are also conducted to maintain Staff proficiency.

* Located approximately 1200 feet from WANEF.

TABLE 1. WANEF SUMMARY OF OPERATIONS, JANUARY 1969 - DECEMBER 1969

Unintentional Shutdowns		Type	Power Level		Remarks
Date	Cause		Amps	Watts	
1/8/69	Linear Channel No. 3	Level	3×10^{-7}	30	Switching Noise Transient
1/13/69	Log Channel No. 4	Pd	Subcritical	-	Electronic Noise Transient
1/15/69	Armature Overload	-	1.5×10^{-6}	150	During Leveling Manipulations
1/29/69	Log Channel No. 5	Pd	Subcritical	-	Electronic Noise Transient
1/29/69	Log Channel No. 5	Pd	Subcritical	-	Electronic Noise Transient
2/4/69	Linear Channel No. 3	Level	3×10^{-8}	3	Electronic Noise Transient
3/18/69	Linear Channel No. 3	Level	4×10^{-8}	4.8	Electronic Noise Transient
3/24/69	Linear Channel No. 3*	Level	Subcritical	-	Electronic Noise Transient
4/2/69	Linear Channel No. 2	Level	Subcritical	-	Electronic Noise Transient
4/21/69	Rear Gate	-	Subcritical	-	Interlock interruption
4/29/69	Armature Overload	-	2.2×10^{-8}	2.4	During Leveling Manipulations
5/12/69	Linear Channel No. 3	Level	Subcritical	-	Switching Noise Transient
5/22/69	Log Channel No. 5	Pd	1×10^{-9}	.12	Electronic Noise Transient

TOTAL NUMBER OF STARTUPS: 236
 TOTAL NUMBER OF UNINTENTIONAL SHUTDOWNS: 13
 TOTAL INTEGRATED POWER: 25.76 Kw-hrs

CORRECTIVE ACTION ON UNINTENTIONAL SHUTDOWNS:

Electronic noise	-	Instruments were repaired, as necessary	{ *Solid state trip circuit modified to eliminate noise sensitivity.
Armature overload	-	Meter control circuits modified.	
Rear gate interlock	-	Mechanical setup reworked to provide a positive action.	

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. This year four reactor operators-in-training, one fuel handler, and one experimentalist were designated.

3.2.2 Fuel Handling and Emergency Procedures

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 Nuclear Safety Manual", WANL-TME-646.

Staff personnel regularly participate in simulated emergency drills so that existing procedures may be revised, if necessary. These drills are critiqued by members of WANEF Management, Industrial Hygiene and Safety, as well as members of the WANEF staff. One such drill was conducted this year.

3.3 FACILITY INSPECTIONS

Periodic inspections by members of the Industrial Hygiene and Safety group have been conducted throughout the year. Security inspections have been conducted as well as compliance investigations by members of SNPO, Aerojet Nuclear Systems Company (ANSC), and AEC. Internal audits by technically competent Westinghouse personnel have also been made.

There have been no nuclear safety violations. The several industrial safety recommendations have been implemented.

4.0 REACTOR EXPERIMENTAL PROGRAM

4.1 INTRODUCTION

Tests at WANEF are performed on critical assemblies termed Permanent Assembly Experiment (PAX) and Flexible Critical Experiment (FCX). The PAX assembly, shown in Figure 5 and described in detail in WANL-TNR-099, "Safety Report for the Westinghouse Astronuclear Experimental Facility," is a nuclear and mechanical mockup of the NERVA reactor. The FCX reactor has a mechanical design that is different from the PAX and NERVA assemblies even though the fuel material concentrations and element shape are similar. This characteristic provides the flexibility required for the variation of core materials, carbon/uranium ratios, reflector materials and reflector thickness. The design also permits clean experiments unperturbed by extraneous materials found in NERVA reactors. No changes were made to the FCX during the year.

The north and west walls of the south test cell in the vicinity of the PAX reactor have been lined with two inches of borated polyethylene sheet and 1/8 inch of lead sheet. This lining material serves to reduce neutron and gamma background that can introduce sizable errors in the experimental data. A view of the cell showing the polyethylene and lead sheet and associated supporting structure is shown in Figure 5.

Hazards analyses were made for each type of experiment before its initiation. The Operating Limits Document (WANL-TME-1295) imposes restrictions on the design specifications, the operating variables and procedures and the administrative procedures which are necessary for the safety of the facility.

Figure 5. Polyethylene & Lead Sheet on North and West Walls
Near the PAX Reactor

4.2 PAX EXPERIMENTS

The experiments performed at WANEF during the calendar year 1969 were in support of the NSS Shield Provision Trade Study and the Engineering Critical Component Designs.

Measurements of reactivity worths of several configurations of cluster hardware, reflector materials, and variations of fuel element composition were conducted during the year. Radiation environment measurements (interior and exterior to the core), with several shield mockups, were also made using active and passive dosimetry techniques. Brief descriptions of these experiments are given in the following paragraphs.

In all of these experiments the reactivity changes were below the .50\$ maximum and no unevaluated safety conditions were encountered during the conduct of these experiments. A picture of the PAX reactor is shown in Figure 6.

The initial PAX reactor build this year attained criticality in January and was designated as a PAX-G0. This build contained the 12 KIWI sectors and drum mechanisms and mocked up the R-1 design as to the fuel loading and the modified inner reflector. A complete set of redesigned filler strips was installed to accommodate the increased core size and interface with the outer reflector. New cluster tie rod hardware was designed and utilized to expedite the clustering and the removal of individual elements from the core.

The PAX-G1 build incorporated the 60° R-1 reflector mockup with the three R-1 mockup drums and vanes in place of two KIWI sectors.

4.2.1 PAX-G0 EXPERIMENTS

4.2.1.1 Approach to Critical .

An experiment was performed to assist in development of an approach to critical procedure to determine accurate criticality estimates from subcritical multiplication measurements during the poison wire removal operation. The experimental procedure consisted of subcritical inverse count rate measurements at several detector positions taken during one, two and three drum rollout conditions and reported in WANL-TME-1909.

Figure 6. Top View of PAX Reactor

4.2.1.2 Control Drum Spans and Reactivity Coefficient Measurements

Measurements of control drum spans were performed by measuring the reactivity change resulting from the movement of individual control drums from their most reactive position (180°) to their least reactive position (0°). These measurements were made by an analog computer programmed to solve the inverse of the standard point reactor kinetics equations. The integral control drum worth curve for each drum is obtained by continuously recording the output of the computer on an X-Y or strip chart recorder. By differentiating this curve, a differential drum worth curve is obtained. The integral and differential drum bank worth curves may be obtained by adding the individual differential worths. This procedure assumes no interaction between drums.

The reactivity coefficients of several fuel element materials (carbon, uranium and niobium) were determined at four different radii measuring the change in reactivity when the amount of material under investigation was perturbed. The reactivity coefficient is determined by dividing the measured reactivity change by the associated mass change. These data are reported in WANL-TME-1910.

4.2.1.3 Power Distribution Measurements

This experiment provided two types (gross and detailed) of measured radial fission density distributions in the PAX-G0 reactor for use in power distribution analysis calculations. These data will aid in prescribing the R-1 fuel loading distributions. The experimental procedure utilized U-Al wires located at the core midplane to determine the radial fission density distributions. In conjunction with these measurements, the effect of the self-shielding of the uranium in the wires was measured and appropriate corrections applied to the radial fission density distributions. WANL-TME-1911 is the formal report of these experiments.

4.2.1.4 Nuclear Subsystem Shield Provision Study

The several shield mockups of BATH (Boral, Aluminum, Titanium Hydride) as well as the mockup of BSS-LH₂ (Boron Stainless Steel - Liquid Hydrogen) were not intended to be engineering mockups but rather a nuclear equivalent slab-mockup array which would

approximate the smeared region description used in the analytical model. The various thicknesses of BATH mockups were similar to the configuration used in the 1968 experiments. The BSS-LH₂ was a new build which was used for comparison of the attenuation properties between the BATH and the BSS-LH₂. Mockups of comparable weight resulted in identical fast neutron flux and dose rate transmission at the conical engine propellant tank location.

The radiation environment associated with each mockup was determined by the use of active and passive dosimetry techniques. These dosimeters were used to measure the external environment around the shield mockups and fast neutron and gamma ray absorbed dose rates and thermal neutron flux densities internal to the mockups. Active dosimetry consisted of: a Hurst chamber, fast fission chamber ($E > 1.5$ MeV), a carbon-walled gamma ionization chamber and aluminum and beryllium Bragg-Gray chambers. Passive dosimetry consisted of: U²³⁸ and Th²³² foils, sulfur pellets, Phylatron dosimeters, Li⁷ and CaF₂ TLD's, bare and cadmium-covered Dy-Al foils. These data will be formally reported in WANL-TME-1912.

4.2.2 PAX-G1 EXPERIMENTS

4.2.2.1 Reflector Interchange, Control Drum Span, Aluminum Barrel Experiment

Analytical predictions of the worth of the interchange of a 60° R-1 reflector sector containing three R-1 type control drums, were in excellent agreement with the experiments. The R-1 control drums contain vanes that may be interchanged for various material investigations or a change in the span. The vanes used in these experiments were two thicknesses of Al-B¹⁰ from spare NRX vanes which were cropped and re-rolled. The control drums in the 60° R-1 mockup segment can be driven in either direction by small drive motors mounted on the aft end of the reflector. Although they are not included in the PAX scram system, these drums may be required to maintain the required shutdown with personnel present so that provision is made for automatic drum run-in on a scram signal. This build is the first nuclear mockup of an 18-drum R-1 design.

Two experimental methods were used to measure the control drum worths. The first was the standard WANEF method where a drum is positioned at 180° and the remaining drums are positioned at an angle so that the reactor is on a reasonable period (approximately 30 seconds). When a reactor power level is reached which is consistent with the operating limits of the WANEF analog reactivity computer, the control drum is driven from 180° to 0° with the output of the computer being recorded as a function of drum position, thereby yielding the integral control drum span. The second method entailed determining the delayed critical drum bank position where the control drum whose worth was to be measured was positioned at 90° . After the delayed critical position for the remaining bank was determined, the specified control drum was rotated from 90° to 180° and the resultant excess reactivity measured by both the reactivity computer and the period pickoff system. The specified drum was then moved to 0° and a new critical drum bank angle established. The specified drum was then moved to 90° and again the resultant excess reactivity measured with the period pickoff system. The sum of the two reactivities measured during these two steps was thus determined to be the total control drum span of that particular drum. Both methods produced essentially identical results.

The interaction effects for the R-1 mockup control drums were determined by measuring the integral control drum span of the central R-1 drum as a function of the adjacent R-1 drums. Substantial drum interaction between the drums was demonstrated.

The experimental data and the analytical predictions were in good agreement in the aluminum barrel mockup interchange with the graphite lateral support mockup in the 60° test sector. These experiments are reported in WANL-TME-1916.

4.2.2.2 Gross Power Measurements

The purpose and techniques used here are essentially the same as described in the Power Distribution Measurements for the G0 series of experiments described in 4.2.1.3. The formal report of this experiment is WANL-TME-1917.

4.2.2.3 Reactivity Effect Measurements

Measurements to verify analytical methods and to provide data for normalization of R-1 reactor predictions were made with "Q" material and mockup support stem assemblies. This experiment is reported in WANL-TME-1918.

4.2.2.4 Radiation Environment Measurements

Measurements were conducted to determine the radiation levels in the fuel, the reflector, and the region of the cluster hot end support hardware (CHESH). These measurements utilized specially designed and fabricated steel and graphite-wall Bragg-Gray chambers in addition to the passive dosimetry techniques developed at WANEF to detect the thermal and fast flux as well as the gamma levels. These experiments are reported in WANL-TME-1914 and WANL-TME-1915.

4.2.2.5 Azimuthal Power Distribution Measurements

To provide data to verify calculations, the azimuthal power distribution was measured and the scalloping produced in the R-1 sector by the control drums was measured and found to be of lower magnitude than in the remaining part of the reactor where the PAX drums are located.

4.2.2.6 Uniform Core Hydrogen Worth

An experiment was performed to measure the uniform core hydrogen worth to validate analytical predictions. This experiment employed polyethylene wires in fuel element coolant channels to approximate a uniform radial distribution.

4.3 FCX OPERATIONS

The operations of the FCX facility commenced in early December and continued through the end of the month. These operations were concerned with the physical inventory of the fuel in the assembly and annual maintenance checkouts. KIWI fuel elements which were used in the original build of the FCX were replaced with NERVA elements of approximately the same uranium content. The inventory was completed and checkout runs were conducted to verify the loading and shutdown.

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, 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 Reactor 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 General 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.

MATTERS REFERRED TO AND RECOMMENDED FOR APPROVAL
BY THE NUCLEAR SAFETY COMMITTEE DURING 1969

Meeting Number 91 - April 1, 1969

1. Review of six month experimental plan in support of the various ECC Designs.

Meeting Number 95 - November 11, 1969

1. Review of six month experimental plan.
2. Review of expanded facility.
3. Scram history of WANEF operations.
4. Review of staff and qualifications.