Subcontract NP-1

WANL-TME-1295

Revision E

January 1969

Westinghouse Astronuclear Laboratory

WESTINGHOUSE ASTRONUCLEAR EXPERIMENTAL FACILITY OPERATING LIMITS

MASTER

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OPERATING LIMITS

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2. DESIGN SPECIFICATIONS

2.1 REACTOR DESCRIPTION

a. PAX

The PAX reactor has essentially the same nuclear characteristics as the NRX and the NERVA I type reactors, although modifications have been made to the reactor to simplify component changes. Basically, the reactor includes the core assembly, a core bundling mechanism, a lateral support system mockup (plate or barrel form) and the outer beryllium reflector. The core assembly is comprised of clusters of fuel elements held together by either tie rods or by studs threaded into each end of special central elements surrounded by graphite filler strips. Immediately surrounding the core assembly is a core bundling mechanism which is used to hold the core under a slight amount of compression. The graphite barrel or liner plates are located between the core and the beryllium reflector. The beryllium reflector is made up of sectors which can be interchanged to provide numerous mockups of NRX and NERVA I type reflector configurations. The reflector also houses the rotating control drums which are used to control the PAX reactor.

b. FCX

The FCX reactor consists of fuel clusters vertically supported and located by a 1 - 1/2 inch thick aluminum core support plate and stabilized by top-mounted hexagonal support rings. The fuel clusters are held together at both the top and bottom by means of cluster plates through which a stud is threaded into the center element. The peripheral elements are held in place by pins in the cluster plates. A reflector may be used, which may be

composed of clustered elements of graphite, beryllium or other material, or it may be of other shapes with mechanical position restraints. Bare and reflected cores with various C/U (65 to 300) ratios and void fractions will be assembled. Reactor control is provided by vertical traveling "flux trap" control rods with fuel followers.

2.1.1 Brief Description of Fuel Elements

a. PAX

The standard NRX fuel element is a long prism with coolant holes. The fuel material is a uranium compound in a graphite matrix. The uranium is in the form of highly enriched (93% U-235) uranium dicarbide, which is coated with pyrolytic graphite. The fuel loading is less than $500 \text{ mg/cm}^3 \text{ U}$. KIWI fuel, which may be used, is similar to NRX type but does not have the pyrolytic coating.

b. FCX

The FCX reactor has been designed to utilize either reject NERVA fuel as described above, KIWI fuel or standard FCX fuel. All three types of fuel are long prisms. The standard FCX fuel contains UO_2 enriched to 93 percent U-235 in a graphite matrix. The fuel loading will vary, depending on the type of fuel being used, to a maximum of $500 \text{ mg/cm}^3 \text{ U}$. The standard FCX fuel will have the NRX fuel outer dimensions but will contain a 0.350 to 0.500 inch diameter axial hole. Insertion of either cylindrical fuel or graphite rods will be incorporated in the FCX to permit a range of C/U and void fractions.

2.1.2 Maximum Total Mass of Highly Enriched Uranium in the Core

a. PAX

Less than 300 kilograms.

b. FCX

Less than 650 kilograms.

2.1.3 Number of Operative Control Elements and Drives Installed

a. Twelve (ten required) PAX type, provided requirements of Section 3.1 are met.

2.1.4 Brief Description of Control Element Including Nuclear Poison Material

a. PAX

The PAX control element is a core length beryllium cylinder to which a poison plate is fastened. The PAX poison plates are a dispersion of elemental boron (highly enriched in the B-10 isotope) in an aluminum matrix having a nominal composition of 20 w/o B-10. The R-1 type control element, when used, is essentially the same as the PAX element with the exception that the poison plate is a dispersion of boron in a copper matrix having a nominal composition of 24 w/o B-10.

b. FCX

The FCX control rod is a flux trap type with a fueled follower utilizing a rod approximately twice the length of the core. The top part of the rod is a 2 inch diameter stainless steel tube which encases the absorber section of the rod. The absorber section contains a cadmium sleeve surrounding a polyethylene rod. The bottom portion of the control rod contains fueled and/or graphite elements. A long steel rod traverses the axial length of the control rod assembly and holds the internal components together in compression.

2.1.5 Brief Description of the PAX Auxiliary Shutdown System

The PAX Auxiliary Shutdown System consists of hoppers connected by flexible tubes to special nozzles in the PAX core. Granules of B_4C stored in the hoppers can be released by a manually activated switch at the reactor console.

2.2 INSTRUMENTATION

2.2.1 Minimum Number of Operative Channels During Startup and Power Operation

Minimum operational instrumentation shall include:

- a. one source range neutron-sensitive detector and indicator with associated "flux-up" source-up interlock (minimum count rate of 120 cpm required).
- b. three neutron-sensitive detector driving amplifier systems with the capability of flux level monitoring, and including one period and three flux level scrams. The source level must be visible on one of the recorded flux level channels.
- c. one gamma level detector and indicator with a gamma high level alarm.
- d. a total of three pulse channels for initial criticality of new assemblies.

2.2.2 Monitors for Radiation Level Detection

Monitors for radiation level detection shall include portable survey instruments in the control room, permanently installed gamma monitors in various locations, one permanently installed air monitor, excursion monitors and portable dosimetry.

2.2.3 Neutron Source

The neutron source shall be Po-Be, triple encapsulated, initially nominal 7.5 curies, and removable during operation. A source-out-of-storage indicator shall be conspicuously located in the test cell.

2.3 ACTIVATION OF REACTOR SHUTDOWN SYSTEMS

2.3.1 Manual Activation of Shutdown Systems

Means shall be provided for manual activation of shutdown systems, including at least one device in the test cell for the automatic systems.

2.3.2 PAX Out-of-Reactor Position Interlocks

A minimum of two position interlocks in series shall be used for any PAX out-of-reactor experiment which upon failure would insert more than 1.0\$ into the

TABLE 2-2
ABNORMAL OPERATIONAL INDICATORS

<u>Abnormal Condition</u>	<u>Indication</u>
Test Cell Veto Activated	Red light on console
Log, Linear, or Period Tripped	Red light on console
Startup Channel Hi-Voltage Supply Off	Red light on console
Door or Fence Gate Open	Red light on console
Excessive Control Element Drive Current	Red light on console
Test Cell Basement Water Level Activated	Red light on console
Door Interlock Conditional Bypass Activated	Yellow light above console
PAX Auxiliary Shutdown System Power Off	Amber light on console
PAX Out-of-Reactor Position Interlock Activated	Red light on console
Magnet Power not at Control Element	Red light on console

2.7 MAXIMUM AMOUNT OF SPECIAL NUCLEAR MATERIAL TO BE STORED

2.7.1 Vault

500 Kg U-235

2.7.2 Test Cell Rack

900 Kg U-235

2.8 BASIC METHOD BY WHICH INADVERTENT CRITICALITY IS PREVENTED

2.8.1 Vault

Vault is designed for subcriticality in either flooded or unflooded state by spacing and non-removable cadmium.

2.8.2 Test Cell Rack

Rack is designed for subcriticality in either flooded or unflooded state by spacing.

2.8.3 Pax

Reactor cover is secured during non-reactor operations; control elements are locked in least reactive position; poison shutdown wires are available, and liquids in the test cell are controlled administratively (see Section 4.2.12).

2.8.4 FCX

Assembly is surrounded by a fence, control elements are locked in least reactive position, and liquids in the test cell are controlled administratively (see Section 4.2.12)

2.9 CHECKS WHICH ASSURE THAT ONLY THE CORRECT REACTOR IS OPERABLE FROM THE CONTROL CONSOLE

A patch-panel interlock circuit permits control elements to be driven out only when the source transfer circuit and both patch-panels are consistent. The key-operated mechanical locks on the FCX control elements utilize the same keys as the locks on the PAX control elements. When the FCX is operated, the excess keys will be captured in the console bypass key switches. An inspection of the patch-panels for correct program board insertion is made during the daily checkout.

3. LIMITS ON OPERATING VARIABLES

	<u>PAX</u>	<u>FCX</u>	<u>PAX/R-1</u>
3.1 Minimum Physical Shutdown of Reactor not Connected to Control Console	10.00\$	10.00\$	10.00\$
3.2 Minimum Effective Shutdown of Reactor not Connected to Control Console with Personnel Present	9.55\$ ^{1/}	5.00\$ ^{2, 3/}	9.4\$ ^{6/}
3.3 Shutdown Margin Required of Isolated Reactor to Assure Requirements in Section 3.4	3.25\$	10.00\$	3.4\$
3.4 Minimum Shutdown Margin of Reactor with Personnel Present Within Three Feet	2.8\$ ^{1/}	5.00\$ ^{2, 3/}	2.8\$ ^{6/}
3.5 Maximum Reactivity Increase in Any Single Increment without Compensating Negative Reactivity	0.50\$ ^{4/}	0.20\$	0.50\$ ^{4/}
3.6 Maximum Reactivity Increase in Any Single Increment with Compensating Negative Reactivity	2.50\$	5.00\$	2.50\$
3.7 Maximum Reactivity Increase Permitted by Failure of an Out-of-Core Experiment without Use of Position Interlocks	1.00\$	^{5/}	1.00\$
3.8 Maximum Reactivity Increase Permitted by Failure of an Out-of-Core Experiment When Position Interlocks are Used	2.2\$	Not Applicable	2.2\$
3.9 Maximum Reactivity Increase Permitted by Failure of an In-Core Experiment	1.00\$	^{5/}	1.00\$
3.10 Maximum Operating Power	1000 watts	1000 watts	1000 watts
3.11 Maximum Power Trip Setting	2000 watts	2000 watts	2000 watts
3.12 Minimum Operational Period	10 second	10 second	10 second
3.13 Minimum Period Trip Setting	6 second	6 second	6 second
3.14 Maximum Excess Reactivity	6.2\$	0.50\$	6.2\$
3.15 Maximum Reactivity Addition Rate by Control Element	0.064\$/ sec	0.2\$ /sec	0.064\$ /sec
3.16 Maximum Reactivity Worth of Individual Control Element	1.00\$	5.50\$ central 4.00\$ peripheral	1.00\$
3.17 Minimum Shutdown Control Margin in the Auxiliary Shutdown System ^{6/}	1.0\$	Not Applicable	1.0\$
3.18 Maximum Number of Control Elements to be Moved Out at One Time	1	1	1
3.19 Minimum Number of Operational Control Elements	10	4	10
3.20 Maximum Scram Delay Time of Neutronics Safety Circuitry ^{7/}	200 msec	200 msec	200 msec
3.21 Maximum Scram Delay Time of Position Interlock Circuitry ^{8/}	150 msec	Not Applicable	150 msec
3.22 Average Control Drum Insertion Velocity ^{9/}	500°/sec	Not Applicable	500°/sec
3.23 Maximum Total Scram Delay and Safety Element Insertion Time	Not Applicable	1 second	Not Applicable

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 Based upon + 0.20\$ worth for each of 3 people.

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).

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