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RESEARCH PROGRAM ON PLASMA CORE ASSEMBLY

by

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ABSTRACT

An operating critical assembly having a 1.024-m-diam by 1.055-m-high cavity reflected by 0.48 m of beryllium has been constructed of residual beryllium reflector segments, control drums, drive motors, and control console from the solid core nuclear rocket development program. The critical mass for uranium distributed throughout the cavity is 16.9 kg U(93.2), which is high because of neutron undermoderation in the reflector due to porosity and poison contaminants in the beryllium and graphite reflector components.

A flux trapping beryllium annulus, 0.546-m-i.d. by 0.89-m-o.d., centered in the cavity, reduced the critical mass to 6.7 kg U(93.2). This arrangement will permit operation with a UF_6 zone inside the flux trap driven by an outer uranium-graphite fuel zone. The fission density inside the flux trap is appreciably higher than in the outer fuel zone.

I. INTRODUCTION

The initial phase of the research program on the NASA plasma core critical experiments consisted of three parts: 1) design and fabricate a static cavity critical assembly from existing components from the Rover program, 2) perform supporting neutronic calculations to aid in the interpretation of experimental results and to guide the design of future experiments, and 3) design and carry out the initial critical experiments.

A. PCA Reflector

The beryllium reflector of the Plasma Core Assembly (PCA) is described in Appendix C of LA-5679.[1] The end plugs of Nuclear Furnace and Honeycomb reflector pieces, shown in Figs. 1 and 2, consist of beryllium that averages 90% of normal density. Graphite fillers, 38-mm-thick separate these from 190-mm-thick NRX and Kiwi B sectors of beryllium, also 90% normal density. A succeeding graphite annulus 44-mm-thick is followed by a 200-mm-thick Phoebus II assembly which except for 18 control drums is beryllium at 87.5% normal density. The 1.024-m-diam by 1.055-m-high cavity accommodated the following sequence of cores.

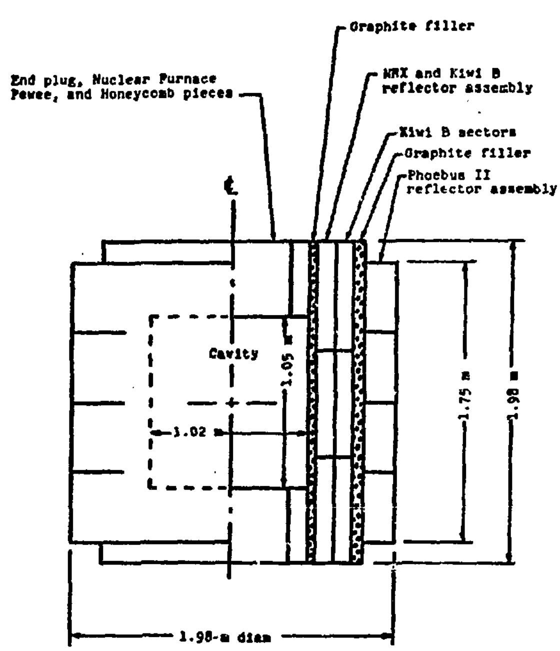

Fig. 1
Beryllium reflector for PCA.

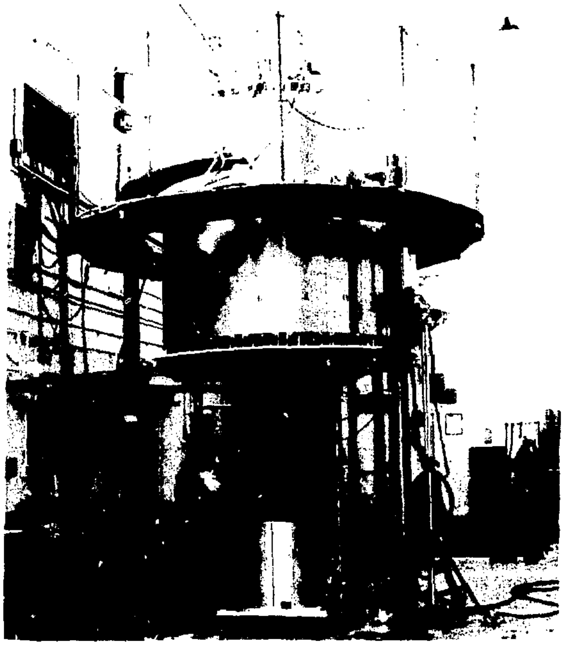

Fig. 2
PCA with core No. 1 retracted.

II. CORE NUMBER 1

A. Initial Approach to Criticality

For the initial fuel loading intended to simulate a homogeneous uranium distribution, U(93.2) metal foil was laid on a set of ten 0.90-m-diam aluminum discs spaced 100 mm apart, Fig. 2, which nearly filled the cavity volume. The approach to criticality was based on the standard operating procedures for the Pajarito Critical Assembly Facility.[2] A critical mass of 19.1 kg of U(93.2) was found for this configuration. Correcting this for the aluminum in the fuel support fixture and cavity end plug supports gives a critical mass of 16.9 kg U(93.2) for foils without structure.

B. Control Drum Calibration

Control drum calibrations and material reactivity worth evaluations were established by positive period measurements. To facilitate this, two control drums were equipped with high-speed drives for rapid reactivity insertion rates.

The incremental worth of one control drum was measured at 10-degree intervals. The total reactivity swing for the test drum moving from 0 to 180° is 0.34 \$. Figure 3 gives the control drum reactivity calibration curve based on 18 active drums.

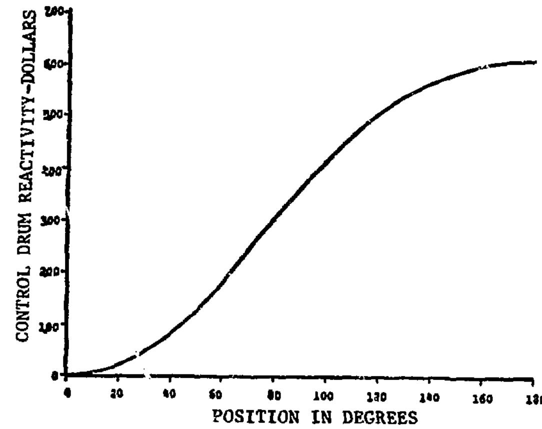

Fig. 3
PCA control drum calibration for core No. 1.

C. Materials Evaluation

The reactivity worths of U(93.2), aluminum and carbon in the cavity, as evaluated from positive period measurements, are listed in Table I.

TABLE I

Material	Material Location	Worth (\$/kg)
Uranium	Distributed through cavity	+0.727
Aluminum	Distributed through cavity	-0.030
Carbon	Bulk sample at end of cavity	+0.025

III. CORE NUMBER 2

A. Critical Loading

An early goal for the Plasma Core Assembly was to operate with a central zone of UF_6 gas surrounded by a zone of solid uranium fuel. To mock up this situation, core No. 2 consisted of uranium metal foil attached to a 0.94-m-diam thin-walled aluminum cylinder centered within the cavity. A critical mass similar to that for core 1 was indicated by subcritical comparison.

The critical mass of about 17 kg is a factor of two higher than calculated for uniformly distributed fuel in an idealized reflector. Such a large critical mass for this system indicates undermoderation in the reflector and/or contaminants having high thermal neutron absorption cross sections in the beryllium and graphite. Neutron leakage through the large number of small, straight, beryllium coolant channels tends to increase the critical mass value.

The known neutron absorbing contaminants in the reflector materials are iron in the beryllium and boron traces in the graphite. The beryllium specifications limited the iron content to less than 0.18% by weight. One-dimensional criticality calculations showed that this amount of iron would increase the critical mass by about 9%.

Two-dimensional criticality calculations examined the effect of boron in the reflector graphite zones, with results shown in Fig. 4. Two-hundred parts per million boron contaminant would account for the excess critical mass if boron alone were the cause. An analysis for this contaminant is planned. Actually, the cause of the large critical mass is believed to be due to a combination of the effects discussed above.

Additional calculation models will describe the geometry in greater detail and will include neutron absorbing contaminants as they will be known to exist.

IV. CORE NUMBER 3

A. Critical Loading

The simplest solution to the neutron undermoderation problem was to add a zone of beryllium to the cavity. A suitable beryllium annulus, 0.546-m-i.d. by 0.89-m-o.d. by one-meter-high, was formed from Pewee and Honeycomb parts. This structure had a mean density 85% of that for normal beryllium. This was surrounded by the 0.94-m-diam aluminum cylinder to support the uranium metal foil. The initial critical mass with all uranium in the outer fuel zone was 6.84 kg U(93.2). Correction for the aluminum in the core and cavity structure gave a critical mass of 6.70 kg U(93.2).

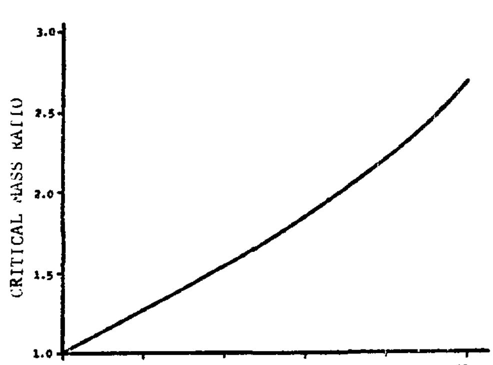

Fig. 4
Effect on critical mass of boron in graphite.

B. Control Drum Calibration

The reactivity worth of the control drums is influenced by the amount of uranium in the core. Since core No. 3 with its added inner beryllium zone sharply reduced the critical uranium loading, the control drums were recalibrated using the procedures described above. The reactivity swing for one control drum is 0.224 $, thus giving 4.03 $ for the 18 control drums. At the position of maximum effectiveness, 75°, the measured worth per degree of rotation of the 18 drums was 0.045 $. Figure 5 gives the calibration curve for the entire 18 control drums.

C. Materials Evaluation

Table II lists the reactivity worths of uranium, aluminum, and carbon for indicated position in core No. 3.

TABLE II

Material	Material Location	Worth ($/kg)
Uranium (93.2)	On axis	+33.50
Uranium (93.2)	Near end of aluminum support	+5.54
Aluminum	On axis	-0.108
Aluminum	At aluminum support	-0.030
Honeycomb C	On axis	-0.014
PCA reflector C	On axis	-0.032

It should be noted that the uranium worth values of Table II imply an appreciably greater fission density in the central zone than in the

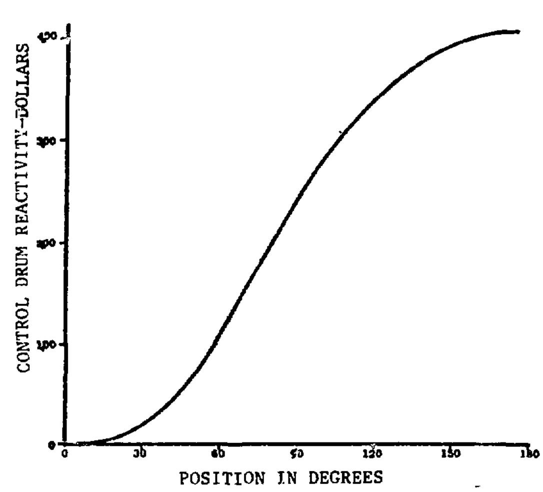

Fig. 5
PCA control drum calibration for core No. 3.

outer fuel zone. This will be a distinct advantage for the excitation of UF_6 gas in the central region and for ensuing photonic measurements.

The effects of flux trapping by an additional beryllium zone within a cavity surrounded by an undermoderating reflector was examined using one-dimensional neutron transport calculations on an equivalent spherical mockup of the PCA cylindrical geometry. The calculated fission density in the central zone was 2.3 times that for the outer, or driver, fuel zone.

V. GAMMA RADIATION LEVELS NEAR PCA

The residual gamma radiation levels in Kiva 1 from PCA reflector and control drum activations acquired during NRDS reactor tests are shown in Fig. 6. A sodium iodide crystal gamma spectrometer resolved the ^{60}Co 5.3-yr. gamma peaks at 1.17 and 1.33 MeV, as well as showed a substantial continuum of lower energy gammas. The ^{60}Co is associated with stainless steel control drum components. For an idea of shielding benefits, some gamma levels were noted with a lead sheet between the survey meter and the PCA reflector. It was observed that 6.4 mm of lead halved the gamma dose.

VI. COMPLETION OF INITIAL PHASE

Additional materials evaluations are required, particularly for an aluminum mockup of the UF_6 canister soon to be installed in the cavity. A uranium metal foil simulation of the UF_6 fuel will be in the canister mockup, and fission distributions will be measured.

The UF_6 handling system and core canister has arrived from United Aircraft Research Laboratories. Work will commence soon on disassembly and cleaning of this equipment followed by checkout to verify its operating characteristics.

REFERENCES

1. H. H. Helmick, G. A. Jarvis, J. S. Kendall, and T. S. Latham, "Preliminary Study of Plasma Nuclear Reactor Feasibility," Los Alamos Scientific Laboratory report LA-5679 (1974).

2. J. D. Orndoff and H. C. Paxton, "Operating Procedures for the Pajarito Site Critical Assembly Facility," Los Alamos Scientific Laboratory report LA-4037-SOP, Rev. (1973).

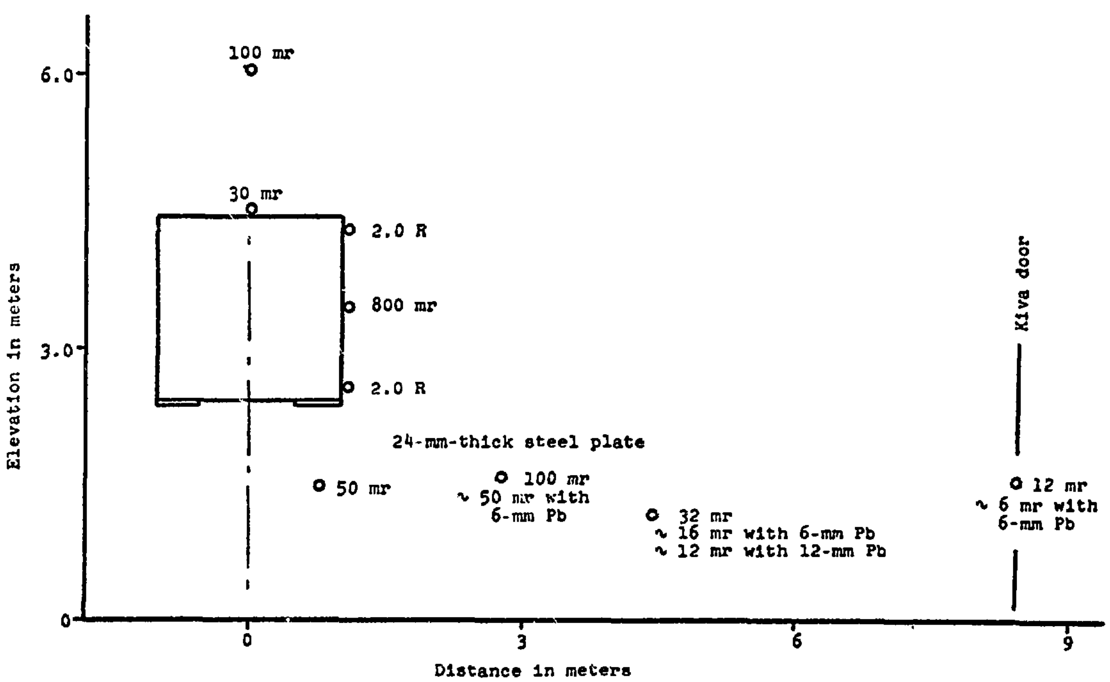

Fig. 6
Gamma radiation levels near PCA.