40

MAY 1 1963

~~CONFIDENTIAL~~

UNCLASSIFIED

LAMS-2893

Copy No. 118 A

AEC RESEARCH AND DEVELOPMENT REPORT

MASTER

LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA • LOS ALAMOS NEW MEXICO

Classification cancelled (or changed to _____)

by authority of Doc

by H.F.C. TIC, date AUG 29 1973

Exempt from CCRP Re-review Requirements
(per 7/22/82 Duff/Caudle memorandum)

MONTHLY STATUS REPORT OF LASL ROVER PROGRAM

FOR PERIOD ENDING MARCH 20, 1963

(Title Unclassified)

NK 3/17/05

DO NOT MICROFILM
COVER

UNCLASSIFIED

~~This document contains Confidential Restricted Data
relating to civilian applications of atomic energy.~~

~~RESTRICTED DATA~~

1 1404

~~This document contains
information of the atomic energy~~

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

~~Its trans-
mission is prohibited.~~

~~CONFIDENTIAL~~

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

UNCLASSIFIED

NOTICE
PORTIONS OF THIS REPORT ARE ILLEGIBLE
It has been reproduced from the best available copy to permit the broadest possible availability.

LAMS-2893
C-91, NUCLEAR REACTORS
FOR ROCKET PROPULSION
M-3679 (28th Ed.)

This document consists of 23 pages
No. 1 of 253 copies, Series A

LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA LOS ALAMOS NEW MEXICO

REPORT COMPILED: April 1963

REPORT DISTRIBUTED: April 26, 1963

LAMS--2893

DE84 016874

MONTHLY STATUS REPORT OF LASL ROVER PROGRAM
FOR PERIOD ENDING MARCH 20, 1963
(Title Unclassified)

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

UNCLASSIFIED

Contract W-7405-ENG. 36 with the U. S. Atomic Energy Commission

All LAMS reports are informal documents, usually prepared for a special purpose. This LAMS report has been prepared, as the title indicates, to present the status of the LASL ROVER program. It has not been reviewed or verified for accuracy in the interest of prompt distribution. All LAMS reports express the views of the authors as of the time they were written and do not necessarily reflect the opinions of the Los Alamos Scientific Laboratory or the final opinion of the authors on the subject.

MASTER

UNCLASSIFIED

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

EEB

MITED

BLANK PAGE

SUMMARY

A study of the pressure and power oscillations observed during startup in the full-power run of Kiwi-B-1B indicates that the two oscillations are related. The calculated reactivity change due to hydrogen density variation caused by the pressure oscillation is of the correct magnitude to explain the low-frequency (1 cps) power oscillation.

Core assembly of the Kiwi-B-2B-CF reactor at NRDS should commence shortly. A detailed outline of the instrumentation system has been prepared and work is under way on the production of new parts and the modification, as required, of existing parts.

Simple models of two-phase flow oscillations have been used in an attempt to account for the characteristics of the oscillations in inverse period observed in the hot run of Kiwi-B-4A. It is concluded that data from the Kiwi-B-4A-CF runs are required to elucidate the possible role of two-phase flow oscillations in producing core vibrations.

The assembly of Kiwi-B-4A-CF at NRDS is proceeding close to schedule. The core has been stacked on the support plate, with all core instrumentation mounted. It is expected that the system should be ready for transfer to the test cell early in April.

Core components for Kiwi-B-4B-CF are being fabricated. The support plate and support hardware and the reflector system components are on hand.

Cylinder modification drawings that provide for the addition of a hot-end seal have been completed and are being released for fabrication.

It has been decided to base the redesign approach of Kiwi-B-4, to be designated Kiwi-B-4D, on a sealed core periphery. Sealing by tightly fitting outer filler strips is being considered as well as by the use of a metal wrapper. Analysis of core peripheral cooling and leakage and of other problems is under way.

A variety of tests are being made on the components for the Kiwi-B-5A reactor. A two-dimensional water flow model for visualization of leakage has been operating successfully and preliminary data have been recorded photographically.

All design work on Kiwi-B-6A has been stopped. A description is being compiled of the analytical and experimental work already done.

An experimental system is being fabricated to permit the study of pressure and flow oscillations of the type which have been observed in Kiwi reactor runs when the LH_2 first enters the warm reactor.

Experimental Plan III-C, representing the acceptance tests on the Rocketdyne NFS-1 electric-drive pumping system, was completed on March 14, 1963. The pump operated for 60 sec at 26,400 rpm and a pump discharge pressure of 1060 psi; the total flow rate was 77 lb/sec. In addition, dynamic response measurements were made on the rpm control loop.

The new tooling for extrusion of bead-type fuel element material yields excellent hole locations, but is not yet completely satisfactory in eliminating transverse cracks as the material emerges from the die. Although some improvement has been realized, more development work is required.

As a result of changes in the curing process, there has been a great improvement in the quality of loaded bead-type fuel elements after graphitization. Of 43 specimens, only one was rejected for transverse cracks. The elements exhibited remarkable uniformity both within each element and from one element to another.

Screw-extruded graphite has been found to have excellent uniformity both in strength and density. The good quality of this material is attributed to the continuous nature of the production process and the close control that is possible.

From the results obtained so far, it appears that a modification of the one-tenth scale system may be expanded into the full scale Simulated Water Entry Test device to be used in connection with Nuclear Flight Safety studies.

KIWI-B-1B

Power and Pressure Oscillations

A study of the pressure and power oscillations observed during startup in the Kiwi-B-1B high-power run indicates that the two oscillations are related. The calculated reactivity change due to the hydrogen density variation occurring in the pressure oscillation is of the correct magnitude to explain the low-frequency (1 cps) power oscillation. It is not possible to tell from the immediately available data whether the pressure actually fluctuated the 10 psi required to produce the observed 10 cps power oscillations. IBM 7090 autocorrelation of the multiplexed pressure data will be attempted in an effort to determine whether this was the case or not.

KIWI-B-2A-CF

A detailed outline of the Kiwi-B-2A-CF instrumentation system has been completed and channel requests will be distributed. There are a large number of temperature sensors in the nozzle-reflector system and an equally large number of dynamic instruments (strain gages, accelerometers, etc.) in and about the core structure.

Work is under way on about 20% of the new parts required and existing parts that must be modified; the remainder await release of drawings and specifications to the shops.

Core assembly should begin at NRDS during the week of April 8.

KIWI-B-4A

Analysis of Test Results

A memorandum has been issued on the Kiwi-B-4A thermal asymmetry, which is attributed to asymmetrical bypass flow between the core and reflector cylinder.

Additional expanded and high speed data on the run have been requested for continuing analysis.

A memorandum is being prepared to cover the fuel element temperatures that should have existed at 1100 MW. The calculations are based upon fuel element fission distributions as determined by radio-chemical analysis.

The fission density was observed to be abnormally high at the Kiwi-B-4A core boundary in regions where the loss of graphite slats and pyrographite plates was severe. Calculations have shown that filling the consequent void with dense hydrogen could account for the high fission density.

Two-Phase Flow Calculations

Simple phenomenological models derived to describe two-phase flow oscillations in the reflector mockup experiment (1961) have been used in an attempt to calculate the frequency-time and amplitude-time curves of the oscillations in reactor inverse period observed in the hot run of Kiwi-B-4A. With the aid of several assumptions, which are to be checked in cold flow experiments, the agreement between observed and calculated frequencies is quite good. However, the calculated amplitude variation

does not agree well with that observed. No satisfactory mechanism has yet been suggested for coupling the two-phase pressure oscillations to the core to produce the core radial vibrations believed necessary to explain the observed oscillation of reactor power and inverse period. The Kiwi-B-4A-CF runs should help to elucidate the possible role of two-phase flow oscillations in producing core vibrations.

Boron Addition to Core

Boron at low concentration distributed uniformly in the Kiwi-B-4A core was estimated to be worth $\sim 1\text{¢}/\text{g}$ compared to a value of $\sim 5\text{¢}/\text{g}$ obtained for the Kiwi-B-1A geometry.

KIWI-B-4A-CF

The Kiwi-B-4A-CF assembly is proceeding close to schedule. The core is stacked on the core support plate with all core instrumentation mounted. It is expected that the reflector cylinder will be in place by March 29, and the system should be ready to go to the test cell on April 8, 1963.

Kiwi-B-4A-CF vibration transducers have been tested dynamically at cryogenic temperatures to increase the probability of obtaining good measurements at NRDS. Transducers which are sensitive to temperature or rates of change of temperature have been thermally insulated by encapsulation in polyurethane foam.

KIWI-B-4B-CF

Cylinder modification drawings that provide for the addition of a hot-end seal for the Kiwi-B-4B-CF reactor have been completed and are ready to be released for fabrication. Instrumentation machining drawings, however, have not yet been prepared. Core components are on order and

[REDACTED]

are partially fabricated. The support plate and support hardware and the reflector system components are all on hand. Instrumentation and parts lists will be completed by April 5, 1963.

KIWI-B-4D

Design

It has been decided to base the redesign approach of Kiwi-B-4, designated Kiwi-B-4D, on a sealed core periphery. Sealing by tightly fitting outer filler strips is being considered as well as by use of a metal wrapper.

Analysis is under way on the effects of core bundling. Initially, attention is being devoted to the basic relationships pertaining to the bundling problem, particularly the magnitudes and effects of intersurface friction.

Analysis of the core peripheral cooling and leakage problems is being continued. Analyses are being carried out on the following:

1. Temperature distribution in the support block-reflector cylinder-nozzle region.
2. Chilling of filler strips and fuel elements by bypass flow under seals.
3. Leakage between elements.
4. Cooling requirements and temperature gradients for seals, filler strips, and other perimeter parts.
5. The startup transient effects of filler strips in contact with outer fuel elements.

The average relative fission density per fuel element from Kiva assembly measurements is to be supplemented with data for each of the 19 channels per element. The fine structure of this required resolution is to be measured first in a 60° sector of a Zepo mockup.

Test Section in Zepo

The test fuel element section with reduced loadings was run in Zepo with control rods set at 90° and elements extending 15 in. to 30 in. from the inlet end. The pattern of deviations in fission distribution from a smooth radial function is not readily explained on the basis of effects due to edge graphite, support elements, and control rod proximity.

Fine structure measurements indicate very little perturbation due to varying thickness of graphite edge strips.

KIWI-B-5

Component Test Work

The fixture for testing the lateral support characteristics of the Kiwi-B-5A system has been operating. It indicates so far that the kinematics of the shoe behavior are satisfactory, even under high deflections. It appears less likely than originally expected, however, that it will be possible to obtain any quantitative information on the friction and damping characteristics of the system.

The cycling apparatus for testing of the Kiwi-B-5A shoe springs has been received and these tests have been started.

The test fixture and parts for testing of the fuel element-to-support block joint have been completed.

The two-dimensional water flow model for visualization of leakage has been operating satisfactorily. Preliminary runs have been made and recorded photographically.

Final design drawings are being made on the half-scale seal tester.

Design drawings were completed of a test fixture to measure the transverse spring rate of the tie rods at the inlet end.

A proposal was prepared outlining a series of tests to be conducted on graphite reflector cylinders. Both static load tests to fracture and dynamic load tests are included.

KIWI-B-6A

All design work on Kiwi-B-6A has stopped at the instruction of SNPO-W. A description of the design analytical and experimental work already done is being compiled in a report.

The revised analysis of the base plate was completed for pressure drop loads. The thermal stress analysis will be held in abeyance.

Experimental work on the 30° flow model base plate in progress will continue, and the results will be incorporated into the design report.

KIWI-B GENERAL

Analytical and Programming Work

Programming of the improved parallel channel code has continued. A tentative description of the problem scope was distributed for review, and a working code with many of the proposed optional features should be available by April 15, 1963.

The methods for specification of fuel element and metering sleeve distributions are being updated to apply relative fission density data for each element channel to the mean fission density data for each element.

A method has been proposed for the calculation of elastic thermal stresses due to energy removal from fuel elements. It is based on an analogy between the two-dimensional thermal elastic equations and those for the bending of a clamped transversely loaded plate. The determination of the deflections and rotations of the laterally loaded plate model can be evaluated and interpreted in terms of thermal stresses. The technique for determination of the plate curvatures and stresses is based upon those of the Moire method.

Core Element Oscillations

Several models of the Kiwi reactor core have been studied numerically in order to examine oscillations of the core elements. The latest model, using realistic masses and leakage path dimensions, oscillates at about the frequency observed in the test of the reactor. Amplitude of the oscillation is not as large as needed to account for the changes in reactivity observed but probably will increase when more realistic inlet pressure conditions are used.

Oscillating Flow Experiments

An experiment has been initiated to study the pressure and flow oscillations of the type which have been observed in Kiwi reactor runs when the LH_2 first enters the warm reactor. An apparatus for investigation of these effects using the 300-liter flow system has been designed and is being fabricated. It consists of four 3/16-in. diameter flow channels drilled lengthwise through a 52 in. long x 2-3/4 in. diameter bar of aluminum. Flow through these channels will empty into an outlet plenum chamber before passing through an orifice to the vent. The volume of the outlet plenum can be varied to study the effect of volume on flow oscillations.

NRDS ACTIVITIES

Kiwi-B-4A-CF

Approximately 90% of the clusters of Kiwi-B-4A-CF were assembled at NRDS in preparation for instrumentation and core assembly. Subsequently, 46 clusters were disassembled and the elements were returned to LASL for radiography. This has been completed and the elements have now been reassembled into clusters at NRDS. Instrumentation mounts have been installed on the clusters.

The delivery of Nozzle No. 2 from Rocketdyne was delayed because of the LASL decision to provide motion picture coverage of the exit face of the cold flow core. This will require alteration of the nozzle to accommodate windows for a camera and light source.

Predicted core pressure and flow distributions have been reported and corresponding pressure and flow distributions have been calculated for the reflector system. The results indicate pressure drops of 61 psi in the core and 51 psi in the reflector for 20 lb /sec GH_2 .

Experimental Plan III-C

After several attempts, Experimental Plan III-C, run on March 14, 1963, completed the acceptance tests on the Rocketdyne NPS-1 electric-drive pumping system. The duration of the run was 60 sec at 26,400 rpm and a pump discharge pressure of 1060 psi; total flow rate was 77 lb/sec. In addition to these acceptance tests, dynamic response measurements were made on the rpm control loop at 12,500 rpm and the LH_2 flow rate loop at 40 lb/sec.

The first attempt to perform the acceptance test was terminated without applying power to the pump because of control channel and power amplifier difficulties. On the second run the load balance adjustment on the dc motors was found to be inadequate to compensate for generator unbalance. During the third attempt, pump efficiency was found to be very low ($\sim 60\%$) and the pump speed was higher than expected based on pump discharge pressure and flow rate measurements. The run was terminated and the pump sent to Rocketdyne for disassembly and inspection. Inspection at Rocketdyne showed that the pump stators had been installed backwards, thus causing the decreased efficiency.

Cooldown Data

Data obtained on the cooldown of cryogenic lines during Experimental Plans II, III, III-A and III-B have been reduced and compared with the cooldown code. For EP-II, the calculated cooldown time was 413 sec

[REDACTED]

compared with the observed time of 405 sec. The calculated total quantity of LH_2 used for cooldown was 565 lb compared with the observed cooldown quantity of 592 lb. Not all of the data agree as well. An attempt has been made to fit the time dependence of the exit gas temperature during cooldown using a time dependent model of the "lumped" cryogenic line, but without success.

Data from the displacement gages attached to pipes at Test Cell C for measuring flexure upon cooldown suggest a resonant frequency of the pipe at 2.4 cps. Amplitudes of 0.4 in. were measured at one point in the pipe when driven by a valve acting as a "water hammer" during hydrogen flow. The pipe motions at 2.4 cps are also observed when either control valve ACV-16 is closed or control valve PCV-91 is opened. The Test Cell A pipe which is much shorter did not exhibit this oscillatory motion during valve exercise although the pipe was not as fully instrumented. Piping support modifications will be made to remove the 2.4 cps resonant frequency.

Test Cell A

General maintenance and repair work has been continued; among the activities were the following: (a) repair of Corblin Compressor No. 1 at the Lake Mead Compressor Station; (b) rebuilding of JBV-1, JBV-3, JBV-5, and JBV-6; (c) reinstallation of Rocketdyne NFS-1 LH_2 Pump; and (d) repair of OBV-38 and OBV-46.

The Annex Building of Test Cell A is essentially complete with only finish work remaining. A minor modification to the new air conditioning system is required to relieve the load on the main building air conditioning system.

The new tank farm hydraulic system is now expected to be complete by about April 10, and the ETL tank farm connection should be finished about April 1. Completion of the ETL high-pressure system modification is now expected by about May 1, 1963.

Test Cell C

The photo tower is expected to be completed about April 10. A contract has been awarded for construction of the north and west camera bunkers. Completion is scheduled for May 1 and June 1, 1963 for the west and north bunkers, respectively.

The cryogenic system vent line modification and the installation of the radiation source container were completed.

Work is in progress on the following modifications and additions: (a) realignment of the CEL cryogenic loop; (b) modification of the CEL vacuum system; (c) additional concrete pads under the dewar area and around the reactor pad; (d) installation of remotely operated actuators on the deluge system shut-off valves; and (e) miscellaneous piping changes resulting from Experimental Plan III-C.

Locations have been selected for installation of calorimeters at Test Cell C. Temperatures are to be recorded at various distances from the source to provide information on heat delivery rates to the Safety Group. Channel request for these have been submitted.

Measurements have been made on the ion chambers that will be used in the Test Cell C neutronics system. It is concluded that (a) compensation characteristics are strongly dependent on gamma level, and (b) it is not possible to select a fixed voltage for the detectors that will provide suitable compensation from source power to design point under conditions of high gamma-to-neutron ratio. A 6-in. lead shield is being erected in front of the water tank. This shield should reduce the gamma level by at least three orders of magnitude without significantly attenuating the neutron flux. Even at the location within the tank producing the most unfavorable neutron-to-gamma ratio, the ion chamber current should be produced almost entirely by neutrons, with the gamma components being negligible.

Quality Gages

Arrangements have been made for installation of three capacitance gages in the Kiwi-B-2A-CF reactor for measurement of fluid quality. The sensing elements will consist of an array of wires stretched between the opposite sides of a box that is open at both ends. Alternate wires are insulated from the box, which serves as a ground on four sides. The array is designed to accommodate ground wires at the open ends of the box so that fringing effects in these regions will be limited. This configuration is expected to be relatively insensitive to dimensional changes occurring during cooldown. Because of its low heat capacity, the unit will cool quickly. It is also suitable for use in a radiation environment.

The units will be located approximately 3-1/4 in. from the downstream face of the reflector and directly over the reflector segment joints at 0, 120, and 240°. Resistance-type temperature transducers in these areas will project horizontally from the inner wall of the pressure vessel at a distance of 3 in. from the reflector face, i.e., beneath the sensing elements. The data from the transducers should indicate the state of the fluid in the capacitance gage.

GRAPHITE FUEL ELEMENT DEVELOPMENT

Development of Bead-Type Elements

A number of extrusion batches were processed with emphasis on tool design to obtain extrusions free of transverse cracks in the "green" state. The Kiwi-B-4 production tooling was very good in this respect, but did not provide the accurate and reproducible hole locations desired in a Phoebus type reactor. The new tooling yields excellent hole locations but is still borderline with respect to the elimination of transverse cracks as the material emerges from the die. The latest tooling modifications were partially successful but more development work is required. The carbon densities of bead-loaded material is still in the range of 1.76 to 1.79 g/cm³ for the high loadings and the extrusion patterns are minimized.

Fabrication of U²³⁵ Elements

The 43 fuel elements extruded last month, loaded with 444 mg U²³⁵/cm³ in the form of pyrocarbon-coated UC₂ beads, were processed through the graphitizing stage and subjected to the external eddy current examination. Only one of the 43 pieces was rejected for transverse cracks. The preliminary physical property data from five full-length elements indicated remarkable uniformity both within each element and from one element to another. This was the objective of a change made in the curing process and, on the basis of this preliminary information, the objective was achieved.

Migration of Uranium in Coated Particles

Correlation is being made of the influences of carbon content of the UC₂ core and density of pyrocarbon coating on migration of the U through the coating. There is some indication that carbon contents above 9.5% in the core and densities greater than 1.8 g/cm³ in the coating may reduce migration.

To provide further characterization of pyrocarbon-coated UC₂ particles used in studies of migration of U through the coating, a method has been developed for measuring the average density of pyrocarbon coatings on UC₂ particles. The procedure involves crushing the +125 μ fraction, screening out fines and unbroken beads (retaining the -105 +44 μ fraction), leaching with HNO₃, and, after filtering, washing and drying, determining the density in an Aminco-Winslow Porosimeter by mercury displacement.

Mechanical Strength of Cold Flow Elements

Longitudinal extrusion defects were found in the 19-hole and 1-hole configurations of the elements produced by UCNC for the cold flow core. The flexure and compressive strengths, as measured at room temperature, of these elements were relatively insensitive to the extrusion defects.

Cementing Fuel Elements to Element Supports

Techniques have been developed of cementing Kiwi-B-6 type fuel elements to other pieces of graphite that requires little, if any, machining after cementing. The techniques are being applied to clusters of fuel elements and to laminated graphite bodies.

Fabrication of Solid Rods

To investigate the effect of section size on the fabrication procedure, a number of attempts were made to produce crack-free solid rods of 1.50-in. diam containing UO_2 as the loading material. Regardless of the composition of the mix, type of tooling, slow curing cycles, rapid air circulation, etc., most of the extrusions revealed longitudinal cracks after the curing cycle. Thick sections such as these are extremely difficult to prepare with the same quality as obtained in multihole fuel elements.

Fabrication of Unloaded Center Elements

Several batches of unloaded, hexagonal elements containing a 0.35-in. diam central hole were prepared with the standard 85:15 composition but without the addition of wood flour which is normally added to extrusions possessing relatively thick sections. The elements cured with a slow (63-h) heating cycle appeared visually to be satisfactory after the cure and are being processed through the remainder of the heating cycle. One batch of this material was cured on the fast (17-h) cycle and, as might be expected, cracked and spalled very severely. It is of interest to note that recent batches of unloaded, one-hole graphite elements, similar to the above and cured with the 63-h cycle, yielded graphitized densities of 1.86 g/cm^3 .

Quality of Screw Extruded Graphite

In view of the current interest in the uniformity of extruded products, screw extruded stock was examined. A 4-ft length of unloaded,

19-hole, hexagonal extrudate, which was sound by radiographic inspection, was sectioned for density and crushing strength determinations. Strength values varied by 8.45% over the length with no evident trend. The mean value was 7514 psi for 14 samples with a standard deviation of 45.6 psi. Density increased smoothly from one end to the other with a spread of 0.62%. The mean value was 1.828 g/cm³ for 24 samples with a standard deviation of 0.011 g/cm³. The good quality of this extruded graphite can be attributed to the continuous nature of the production process and the close control that is possible over extrusion rate and temperatures.

Die Pressures in Screw Extrusion

Measured die pressures in screw extrusion were found to be relatively low using a furfuryl binder formulation. Using a 3/8-in. solid, hexagonal die with a sharp approach, 7/8 in. land, and a finish of approximately 40 x 10⁻⁶ in., the back pressure varied from 2000 to 2300 psi. These pressures corresponded to die flows of 2.5 to 6.5 in.³/min. Pressures were measured indirectly using the grease injection method applied immediately upstream of the landed surface.

Hexagonal Module

A screw-extruded hexagonal module was graphitized slowly and then subjected to the standard shock heating test. In common with many of the modules prepared by different means, the sample was destroyed by this treatment. The module failed by cracking transversely at intervals of 2 to 4 in. No splitting fractures were observed, although the sample initially contained small, longitudinal surface cracks.

Protective Coatings

Eleven experimental leaching runs (88 elements) were carried out in a program to select a standard leaching procedure for coated fuel elements. The last six batches (10 elements per batch) were leached at 1900°C, for a

period of 1 h, with a mixture of 12 l/min of He and 12 l/min of HCl. An average loss of 8-9 w/o U (by weight measurement) was observed. Four of the batches contained the 32 Oy bead elements of Special Lot A. These have been submitted for a more precise determination of U losses.

Eight developmental coating runs have been carried out on batches containing natural U bead elements. Most of the coatings were of poor quality, apparently due to a lack of reproducibility in the quantity of NbCl₅ delivered by the new, large saturators. Experiments are underway in order to determine control factors necessary for reproducible operation.

An unloaded 19-hole NbC vapor coated element was tested for ten 5-min cycles at 67 lb/h H₂ flow at 2475°C; it lost 1.5% of its weight. Similar vapor coated elements lost 0.2-0.6% of their weight in three 5-min cycles. Unloaded 19-hole NbC tube lined elements lost 0.3-1.4% of their weight in one 5-min test cycle.

The beta-scatter gage for the measurement of NbC-coating thickness has been fully instrumented for manual operation and has been used successfully. The sensitivity of the measurement has been established to be 0.2 mil. The data furnish good information on the thickness distribution of the coating along the entire axis as well as from bore to bore. These data are important for the improvement of the coating process. They are also used to determine the absorption coefficient and, therefore, the correction factor to be applied to the gamma measurements of U loading and of U loss during the leaching process.

The beta-scatter gage is able to detect voids, cracks, or other defects in the coating having an area equivalent to a circle of 20-mils diameter.

A total of 48 center support element lengths (8 in.) of the current Kiwi-B-4B design and an experimental 13-hole design were coated with TaC for experiments evaluating Ta as a poison.

METAL FUEL ELEMENT DEVELOPMENT

Powder Metallurgy: Pressing of Metal Powders

Work is proceeding in the study of the effect of changing the environmental gas pressure in the die cavity on the green pressed density of tungsten powder compacts. The compacts have been sintered at 1900°C for 2 h in flowing hydrogen and the densities measured. Some evidence was obtained of air entrapment but the results were not in complete agreement with expectation.

The effect was determined of particle size and environmental gas pressure during compaction on shrinkage ratio, i.e., the ratio of the percent change in diameter of the sintered compact (as compared to the green compact) to the percent change in length of the sintered compact. The data show that (a) the radial shrinkage is greater than axial shrinkage in all cases and (b) there are indications that the curve for compacts pressed under 1 atm air pressure may show a maximum whereas that for compacts pressed under 10^{-4} mm Hg pressure may exhibit a minimum.

Powder Rolling

In order to improve the quality of the green strip in the powder rolling of W and W-UO₂ powders, another rolling mill is being used. This can be operated at slower speeds — 6 in./min compared with 30 in./min of the mill formerly used, and the rolls have a longer diameter — 10 in. as against 8 in. The setup of the feed hopper, side retainers, uniformity of discharge measurement, etc., was installed on the new mill. Preliminary experiments in the range of roll speeds of 6-10 in./min, with both W and W-UO₂ powder mixes, indicated a vast improvement in the quality of the powder rolled strip. This is attributed mainly to the much slower roll speed, but some improvement may be due to the larger roll diameter. Cursory evaluation of the effect of powder height in the roll bite indicates that this variable is not nearly so important with the slower roll speeds.

MATERIALS AND FABRICATION

Boral Fabrication

Boral sheet has been rolled to meet the Westinghouse requirements for 48 plates 17-1/4 in. long by 4 in. wide. Tools for forming each plate to curvature and punching fastening holes will be furnished by Westinghouse.

Kiwi-B Metal Support System

An induction coil of small diameter has provided the required magnetic coupling to heat A-286 stainless steel and Hastelloy R-235 rod to the proper temperature for heading. Headed and heat-treated specimens have been submitted for mechanical testing and metallography.

Properties of Plastics at Cryogenic Temperatures

Mylar, Teflon, polyethylene, Armalon, H-film, and Lexan are the materials being considered for the Kiwi reflector sleeve gasket. Samples of the first three are on hand and the others are on the way. These materials will be irradiated at ambient temperature in the Omega West Reactor and tested at cryogenic temperatures by the Beech Aircraft Corporation in Boulder, Colorado. The first samples will be exposed for a period equivalent to 300 sec of Kiwi reactor operation. The duration for subsequent samples will be increased in 5 min increments until such time as the materials are no longer fit for mechanical testing. The mechanical test is one devised by Beech for thin films at cryogenic temperatures, in which a twist, flexure movement is involved.

Hot Hardness

An impact type of hot hardness tester has been constructed, tested, and calibrated against the diamond pyramid hardness scale. The calibration was made at room temperature using heat treated 4340 steel for the range

above D.P.H. numbers of 270 and 303 stainless and nickel below 270 D.P.H. A total D.P.H. range from 80 to 575 was covered and this corresponded to an impact deformation index range of 140 to 745. The relationship was not linear at the lower range of hardness but was very nearly linear above a D.P.H. of 300.

The number calculated from the data obtained with the instrument has been designated the impact deformation index (I.D.I.). It is calculated by dividing the kinetic energy of the projectile by the cube of the diameter of the impression in the specimen.

NUCLEAR FLIGHT SAFETY

Core Disposal by a Nuclear Explosion

Self destruction, making use of rapid control rod motion, does not look as promising as an induced nuclear transient produced by other means. The reliability of this system is rendered somewhat dubious because of the uncertain and low (\$.50 - \$1.00) excess reactivity expected to be available in a spent Nerva engine. Calculations indicate that several different projectiles, consisting of unloaded or loaded moderators, can induce transients which produce sufficient fission energy to vaporize UC_2 beads.

Fuel fragmentation by nuclear transients has been experimentally demonstrated only on fuel which contains appreciable UO_2 . This method of fragmentation is by far the most effective achieved to date and fragments appear to meet reentry size criteria. Calculations are being made to determine whether beaded fuel can be fragmented by nuclear heating in the absence of UO_2 .

Simulated Water Entry Test

The 2-1/8 in. water injection device has been operated at pressures up to 1250 psig and maximum velocities of about 200 ft/sec were obtained. Pressures vs velocity calibrations have been made and the barrel

has been pressure shock tested. The device is ready for use in graphite water impact tests and for water density vs velocity experiments.

Some jets have still been observed on the emerging water surface from the 2-1/8 in. device, but they seem to become smaller as the barrel length is reduced. A shorter barrel is being fabricated.

Parts are being fabricated for further tests on the 1/10 scale device. An explosive valve assembly with an increased flow area will be tested. Experiments will be made on the effectiveness of using the water, as it is forced against a mockup core, to stop the piston. It appears at present that a modification of the 1/10 scale system may be expanded into the full-scale Simulated Water Entry Test device.

PUBLICATIONS

"Effect of Two-Phase Flow in Startup Studies of Kiwi-B," LAMS-2803.

"Pilot Model - Induction Heated Rotating Fluidized Bed," LAMS-2839.

"Computer Data Processing System - Project Rover 1962," LAMS-2845.