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Westinghouse Astronuclear Laboratory

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING
HELD WITH SNPO AT WANL ON MARCH 28, 1968
(Title Unclassified)

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NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING HELD WITH SNPO AT WANL ON MARCH 28, 1968
(Title Unclassified)

Westinghouse Electric Corporation
Astronuclear Laboratory
P. O. Box 10864
Pittsburgh, Pennsylvania 15236

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by authority of ____ TIC, date ____
by ____

E. A. DeZubay
E. A. DeZubay, Manager
Thermo-Flow Laboratory

C. J. Rowan 4/11/68
C. ~~L. Meuche~~, Manager
Engineering Mechanics

~~INFORMATION CATEGORY~~
~~Confidential-Restricted Data~~
~~E. A. DeZubay 4/6/68~~
~~Authorized Classifier Date~~

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WANL-TME-1774

April 16, 1968

NOTES OF MONTHLY DEVELOPMENT TEST PROGRAM REVIEW MEETING HELD WITH SNPO AT WANL ON MARCH 28, 1968 (U)

G. T. Downs	WANL	G. A. Kalvin, Jr.	SNPO-C
R. N. Eichbauer	WANL	C. L. Meuche	WANL
N. J. Ettenson	WANL	N. Norman	AGC
H. J. Fix	WANL	R. L. Oelrich	WANL
W. J. Havener	WANL	W. J. Rowan	WANL
R. R. Holman	WANL	L. A. Salvador	WANL
E. G. Igne	WANL	E. A. Watjen	WANL

The Monthly Development Test Program Review Meeting was held on March 28, 1968.

This report is divided into two discrete sections. The first section covers the activities of the Thermo-Flow Laboratory and the second, those of the Engineering Mechanics Laboratory. Table I of each section lists the tests performed during the reporting period and those planned for the next period. Discussions of the individual tests follow.

SECTION A

MONTHLY REVIEW OF THERMO-FLOW LABORATORY TESTS

TABLE I

THERMO-FLOW LABORATORY TEST SCHEDULE

PERFORMED THIS PERIOD (March)	PLANNED NEXT PERIOD (April)
Tests for NRX-A6	
TFL-2.a Core Periphery Test - WANL-TME-1717 completed, reviewed, and submitted for reproduction.	
TFL-3.a Control Drum Flow Impedance - Completed fabrication, initiated testing.	Complete testing, issue report.
TFL-3.f Reflector Thermal Transient Test - Continue fabrication.	Assemble and check-out.
Tests for PEWEE	
TFL-1.b Single Element Tests - Total - 34 3 - PEWEE production elements at A6.03 conditions. 11 - PEWEE production elements at A6.04 conditions. 8 - PEWEE production elements at P1.02 conditions. 12 - Test and chuck development tests at P1.01 and P1.02 conditions.	Tests of PEWEE production elements at A6.04 and P1.02 test
Tests for XE-1	
TFL-1.b Single Element Tests - Total - 6 3 - Y-12 hydrolized elements at nominal XE-1 reactor conditions for a planned 10 minutes. 3 - Y-12 hydrolized elements at NRX-A6 test conditions for a planned 10 minutes.	No additional tests planned.
XE-1 Readiness Review Component test data compiled for support blocks, fuel and critical components. Review held on March 8, 15, 25, and 26.	Document information presented at review.
Tests for R-1	
TFL-1.b Single Element Tests - Total - 6 3 - Test and chuck development tests at A6.04 and R1.07 conditions employing XE-2 non-OD elements.	Conduct additional tests including multiple cycle tests.

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[redacted]

TABLE I - THERMO-FLOW LABORATORY TEST SCHEDULE (Continued)

PERFORMED THIS PERIOD (March)	PLANNED NEXT PERIOD (April)
Tests for R-1 (Continued)	
TFL-2.a Core Periphery Test (TFL-2.a.0004) Test requirements modified by ARD. Test design modified. Thermal analysis based on new requirements. Ordering activity for model components completed. Coating of hardware in process. Fabrication of components in process. Inspection of received hardware in process.	Continue design, procurement, and analysis of model and components.
General Development Tests	
TFL-1.b Single Element Tests - Total - 57 10 - Phase II-Fb elements at R1.05, R1.06, or R1.07 conditions. 18 - GP-72 elements at R1.06 or R1.07 conditions for single cycles of 60, 80, or 100 minutes. 13 - Phase IV-B elements at A6.02, A6.03, or R1.05 conditions. 1 - Test of a high void element with 2-inch long hot end carbide tip. 12 - Test and chuck development tests at A6.03 and R1.06 conditions. 3 - Tests for WANL furnace checkout.	Additional tests of Phases II-Fb and GP-72 elements.
TFL-2.a Core Periphery Tests - TFL-2.a.0003b furnace checkout model assembly 90% complete.	Complete assembly and formulate test plan.
Facilities	
Liquid Hydrogen Facility at WANL.	
WANL Cells 1 and 2 Reactivation. SE-1 system checked-out and operational. Continue FS-1/CL-1 loop fabrication. Continue Control room installation.	Complete loop fabrication. Install instrumentation.

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TESTS FOR NRX-A6

TFL-2.a **Core Periphery Test**

WANL-TME-1717 was completed and reviewed by both Reactor Design and Thermal Nuclear Design Departments. Their comments were incorporated into the document and the report was published. This report is a milestone report for March 1968. It covers the results of the TFL-2.a.0003 test of the NRX-A6 periphery configuration.

TFL-3.a **Control Drum Flow Tests**

Design, drafting, procurement, fabrication, and assembly of the control drum model was completed (see Figure 1). Cell clean-up, hydrogen, helium, and air flow system installation and other facilities installations were completed. Data acquisition systems consisting of the data acquisition trailer with control console, a data cart, T/V system, and photo system were complete and are operational. The test procedure document has been written and approved. A computer program is available for digital data reduction.

The flow system has been leak checked and two system blowdowns were conducted to determine the system flow characteristics prior to model installation. The hydrogen flow rate was approximately 2 lb/sec; the pressure and flow control was satisfactory. The model was installed in the A-11 pressure vessel, the pressure lines routed to the data cart (gauges, transducers, and thermocouple reference junctions) and all connections were leak checked. All gauges, transducers, and data trailer components are now calibrated.

A test was conducted on March 27, 1968, however, some valve cycling was experienced. A second test is scheduled to check out the data points. An additional test will be conducted to determine the effect of the transverse slit which occurs between the reflector rings during full reactor power.

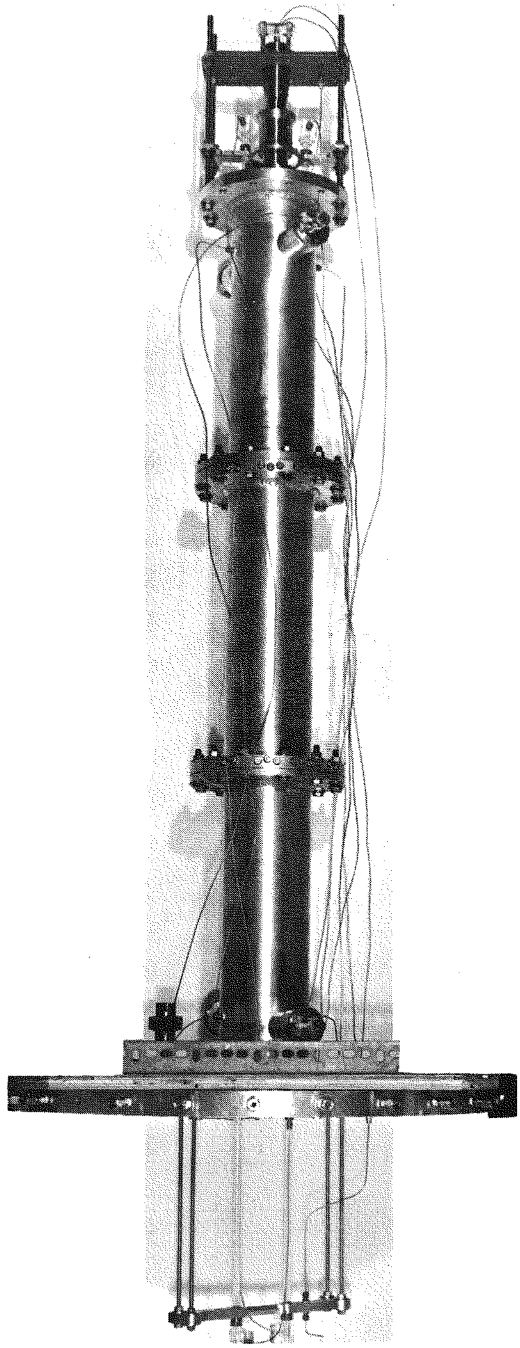

FIGURE 1
CONTROL DRUM FLOW IMPEDANCE MODEL

TFL-3.f Reflector Flow Distribution Tests

The barrels have been fabricated on the thermal and mechanical response test and the paddles are being fabricated. A motor has been procured that will rotate the paddles at 35 RPM. Instrumentation of the NRX-A6 spare ring will begin as soon as it is released by inspection personnel.

TESTS FOR PEWEE

TFL-1.b Single Element Process Development and Evaluation Tests

Thirty-four single element corrosion tests were conducted during this period.

Three tests were conducted at A6.03 test conditions and eleven at A6.04 conditions on PEWEE production elements.

Eight PEWEE production elements were corrosion tested at the P1.02 test conditions.

Twelve corrosion tests were conducted for Test and Chuck Development at P1.01 and P1.02 test conditions. Helium blanket and standard hot end chucks were used in this development program.

Additional tests planned for the next period include PEWEE production elements at A6.04 and P1.02 test conditions.

TESTS FOR XE-1

TFL-1.b **Single Element Process Development and Evaluation Tests**

(C-RD) A total of six single element tests were conducted. Three tests were conducted at XE-1 nominal reactor conditions with Y-12 hydrolized fuel elements. All three elements completed the 10 minute planned test times. Three tests of Y-12 hydrolized elements were conducted at NRX-A6 test conditions for a planned one 10 minute cycle. One element was intact after 10 minutes and the other two failed after 7.5 and 9.0 minutes.

(U) These tests completed the XE-1 reactor simulation series.

XE-1 Readiness Review

(U) The XE-1 readiness review was held in several sessions to discuss critical reactor components as shown below:

March 8	Support Blocks
March 15	Fuel Elements
March 25, 26	Reflector, Control Drums, Tube Liners, Insulating Sleeves, Exit Gas Thermocouple and others.

(U) Representatives from Thermo-Flow Laboratory attended all of the sessions to provide backup data and comments on the component tests related to the components being reviewed. In numerous instances, component test data was presented to clarify a particular design or design approach. This was available in the form of TME reports, test photographs, viewgraphs, and data summary sheets.

(U) A substantial effort was expended in the weeks prior to the presentation in compiling and organizing this data. Of particular importance was the work performed on fuel element corrosion tests and the work performed on the cluster corrosion tests related to NRX-A5 and XE-1.

TESTS FOR R-1

TFL-1.b Single Element Process Development and Evaluation Tests

(U) Six single element experiments were conducted for Test and Chuck Development at A6.04 and R1.07 test conditions. These tests were performed to provide base line data for cycle tests on XE-2 non O.D. coated fuel elements.

(U) Additional tests planned include multiple cycle tests with helium blanket and multi-fingered hot end chucks at R1.07 test conditions.

TFL-2.a Core Periphery Test

(C-RD) The test requirements for TFL-2.a.0004, the first developmental test for the R-1 periphery, were altered by Reactor Design's request to reflect the current design of the R-1. The proposed changes include:

(1) Operation of the test at a wrapper O.D. temperature of 2500°R and an I.D. temperature of 4750°R. Previously the O.D. was to be held at 3000°R.

(2) Inclusion of twelve pre-formed Z-type liners per wrapper layer as opposed to two formed-in-place wrappers per layer.

(3) Extension of the test duration at full power from 60 to 75 minutes with 10 recycles.

(C-RD) To determine the feasibility of performing these tests, a thermal analysis was performed on the model using the updated computer code. At a reasonable and practically attainable heater temperature and heat flux of 5553°R and 60,000 BTU/hr-ft^2, the following design limits were calculated for the 37 inch core station:

Case	Outside Wrapper Temperature °R	Inside Wrapper Temperatures °R	Lateral Support Spring Temperatures °R	Hard Pyrotile Thickness Inches	Wrapper Thickness Inches
1	2165	4750	2047	0	0.305
2	2555	4750	1710	0.065	0.240
(C-RD) 3	2689	4750	1600	0.085	0.220
4	2989	4750	1407	0.125	0.180
5	2500	4750	1166	0.125	0.240

(C-RD) Case 4 represents the current design for TFL-2.a.0004 prior to the design modifications and shows an O.D. temperature of 3000°R with a combined tile and wrapper thickness of 0.305 inches. In order to reduce the O.D. to 2555°R (Case 2) at the same total thickness of pyrolytic graphite foil and tile, the spring temperature must be increased to 1710°R. The design limit for these springs is about 1450°R; therefore, Case 2 is not feasible. Case 1 and 3 show other operating points which are not feasible.

(C-RD) Case 5 was calculated on the basis of 2500°R and 4750°R on the wrapper O.D. and I.D. at the same heater conditions. The spring operating temperature can be held well within the design limits (thus insuring adequate cyclic testing) if the wrapper thickness is increased to 0.240 inches. This increases the total wrapper plus tile thickness to 0.365 inches and requires a modification to existing filler strips in order to provide for the additional 0.060 inches of pyrolytic graphite.

(C-RD) Based on the above study, the following recommendations were made to the Reactor Design and Thermal Nuclear Design Departments.

(1) Test TFL-2.a.0004 to be a test of the wrapper O.D. at 2500°R with a wrapper I.D. below 4750°R (off-design) using the existing configuration (0.125 inch hard pyrotile and 0.180 inch thick wrapper).

(C-RD) (2) Test TFL-2.a.0005 to be a test of the wrapper I.D. at 4750°R with a wrapper O.D. of about 3000°R (off-design) using the existing configuration.

(3) Test TFL-2.a.0006 to be a test which attempts to simulate both I.D. and O.D. at 4750°R and 2500°R by increasing the wrapper thickness to 0.240 inches.

These recommendations are being reviewed and final designs for builds TFL-2.a. 0004 and TFL-2.a.0005 are being specified.

(U) Hardware for TFL-2.a.0004 is being received. Coating of the inner core and simulated elements was completed. Filler strip assemblies were also fabricated and final machined. Many items of equipment are being inspected dimensionally. The Z-liner design was completed and submitted to the vendor for trial forming. Based on his experience the drawing will be modified, as required, to reflect practical tolerance limits for the pre-formed foil.

GENERAL DEVELOPMENT TESTS

TFL-1.b Single Element Process Development and Evaluation Tests

(U) Fifty-seven single element corrosion tests were conducted during this period.

(C-RD) Ten tests of Phase II-Fb elements were conducted at R1.05, R1.06, or R1.07 test conditions. Eighteen tests were conducted employing GP-72 elements at R1.06 or R1.07 test conditions for single cycles of 60, 80, or 100 minutes. Thirteen Phase IV-B elements were tested at A6.02, A6.03, or R1.05 test conditions, and one high void element with a 2 inch long hot end carbide tip was evaluated in a corrosion test.

(U) Twelve tests were conducted for Test and Chuck Development at A6.03 or R1.06 test conditions, and three tests were completed for checkout of the WANL single element furnace.

(U) Tests planned for the next period include evaluation of elements from Phase II-Fb and GP-72.

TFL-2.a Core Periphery Test

(U) The FS-1 furnace was being assembled in preparation for its insertion into the test cell. The test model which will be used in the facility checkout was about 90 percent complete. This model, TFL-2.a.0003b, is a duplicate of the NRX-A6 model used in TFL-2.a.0003. Many of the parts from the previous test are being utilized. The checkout model will be used to establish control points for the flow systems, power supply, and coolant systems as well as to functionally check all data acquisition equipment.

FACILITIES

Liquid Hydrogen Facility at WANL

Bids were received on the dikes, foundations, and deluge system for the WANL liquid hydrogen facility. The low bidder has been selected and the procurement package has been forwarded to AGC and SNPO for approval.

WANL Cell 1 and 2 Reactivation

The single element furnace and cell (SE-1) was checked-out on March 13, 1968 and, shortly thereafter, was on a full, operational test schedule. All systems are functioning normally following the repair and reconstruction of systems damaged by the fire.

The reconstruction of the cluster test furnace and auxiliary systems continued on a crash basis to insure that PEWEE cluster corrosion tests can be completed by June 24. Filler strip furnace, flow system, and control installations also are proceeding at a somewhat lower level of effort. At present, the piping for the flow systems are complete. Pneumatic instruments and lines are being installed. The thermocouple systems for both furnaces are complete. Work continues on the remaining instrumentation of the two flow loops and on the wiring of flow loop controls.

SECTION B

MONTHLY REVIEW OF ENGINEERING MECHANICS TESTS

TABLE I

ENGINEERING MECHANICS LABORATORY

PERFORMED THIS PERIOD (March 1, 1968 - March 28, 1968)		PLANNED NEXT PERIOD (March 29, 1968 - April 30, 1968	
TESTS IN SUPPORT OF R-1			
REFLECTOR SYSTEM TESTS		**REFLECTOR SYSTEM TESTS**	
A.4	Band Spot Weld Tests	A.4	Conduct Preliminary Three Drum System Tests
		A.4	Conduct Actuator Decoupler Shear Pin Tests
FUEL ELEMENT TESTS		**FUEL ELEMENT TESTS**	
B.1	Transition Tip Axial Creep Tests	B.1	Fuel Element Bend Tests
AXIAL SUPPORT SYSTEM TESTS		**AXIAL SUPPORT SYSTEM TESTS**	
C.1	High Temperature Load Tests		
C.1	High Temperature Creep Tests		
C.1	Thermal Cycle Tests		
C.1	Room Temperature Load Tests		
C.2	Pedestal Thermal Shock Tests	C.2	Continue Thermal Shock
		C.3	Conduct Interface Friction Tests
CORE PERIPHERY		**CORE PERIPHERY**	
		E.1	Wrapper Pyrofoil Expansion Test
CORE ASSEMBLY TESTING		**CORE ASSEMBLY TESTING**	
G.2	Static Tests of an R-1 Flat Seal Design	G.2	Dynamic Tests of R-1 Flat Seal Design
		D.2	Conduct Lateral Support System Component Tests

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TABLE I (continued)

PERFORMED THIS PERIOD (March 1, 1968 - March 28, 1968)	PLANNED NEXT PERIOD (March 29, 1968 - April 30, 1968)
TESTS IN SUPPORT OF R-1	
FACILITY, LAUNCH & FLIGHT TESTING	FACILITY, LAUNCH & FLIGHT TESTING
H.1 XECF Resonance Survey Data Review	H.1 Issue Draft Report
ANTICRITICALITY POISON SYSTEM	ANTICRITICALITY POISON SYSTEM
J.1 Poison Wire Elongation Tests	J.1 Poison Wire Pull Tests
SUPPORT STEM TESTS	SUPPORT STEM TESTS
L.1 Grafoil Seal Expansion Tests	L.1 Liner Tube Pressure Test
L.2 Stem Aft End Weld Evaluation Tests (Metallographic Examination)	
CENTRAL & EXTENSION SHIELD	CENTRAL & EXTENSION SHIELD
	M.1 Fixture Checkout and Conduct Shield Thermal Shock Test
TESTS IN SUPPORT OF NRX & XE	
REFLECTOR SYSTEM TESTS	REFLECTOR SYSTEM TESTS
DCB Fracture Toughness	Conduct WOL Fracture Toughness
Bi Axial Specimen Design	Fabricate Bi Axial Specimen
CORE PERIPHERY	CORE PERIPHERY
Statis Key Tests at Cryogenic Temperature	
XE-1 READINESS REVIEW PREPARATION	
FACILITIES	
Tinius Olsen Test Machine Received & Installed	

TESTS IN SUPPORT OF R-1

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REFLECTOR SYSTEM TESTS

EML-A.4 Band Spot Weld Tests

(U) Three titanium bands were tested to failure at ambient temperature. The bands were made from the initial lot of material supplied by the WANL Materials Department and were fabricated by forming and spot welding an integral loop at each end of the band. The objective of the test was to evaluate the structural adequacy of a proposed R-1 spot welded end configuration.

(U) The bands were wrapped around a simulated R-1 drum lubricated with molybdenum disulfide and the ends were loaded by fixture which simulated the band loading of the R-1 configuration. The test setup of the band and loading fixture is shown in Figure 1. In the first test, the free ends of the spot welded configuration were located away from the drum while in the other two tests, the ends of the loop were adjacent to the drum as proposed in the R-1 design concept.

(U) Test results, tabulated below, show that the strength of the spot welded end configuration is at least equivalent to the strength of a single thickness tension area of the band.

Test No.	Failure Load, lbs	Location of Failure
1	1200	First row of spot welds
2	1050	In single tension area
3	985	In single tension area

A photograph of the failed bands is shown in Figure 2.

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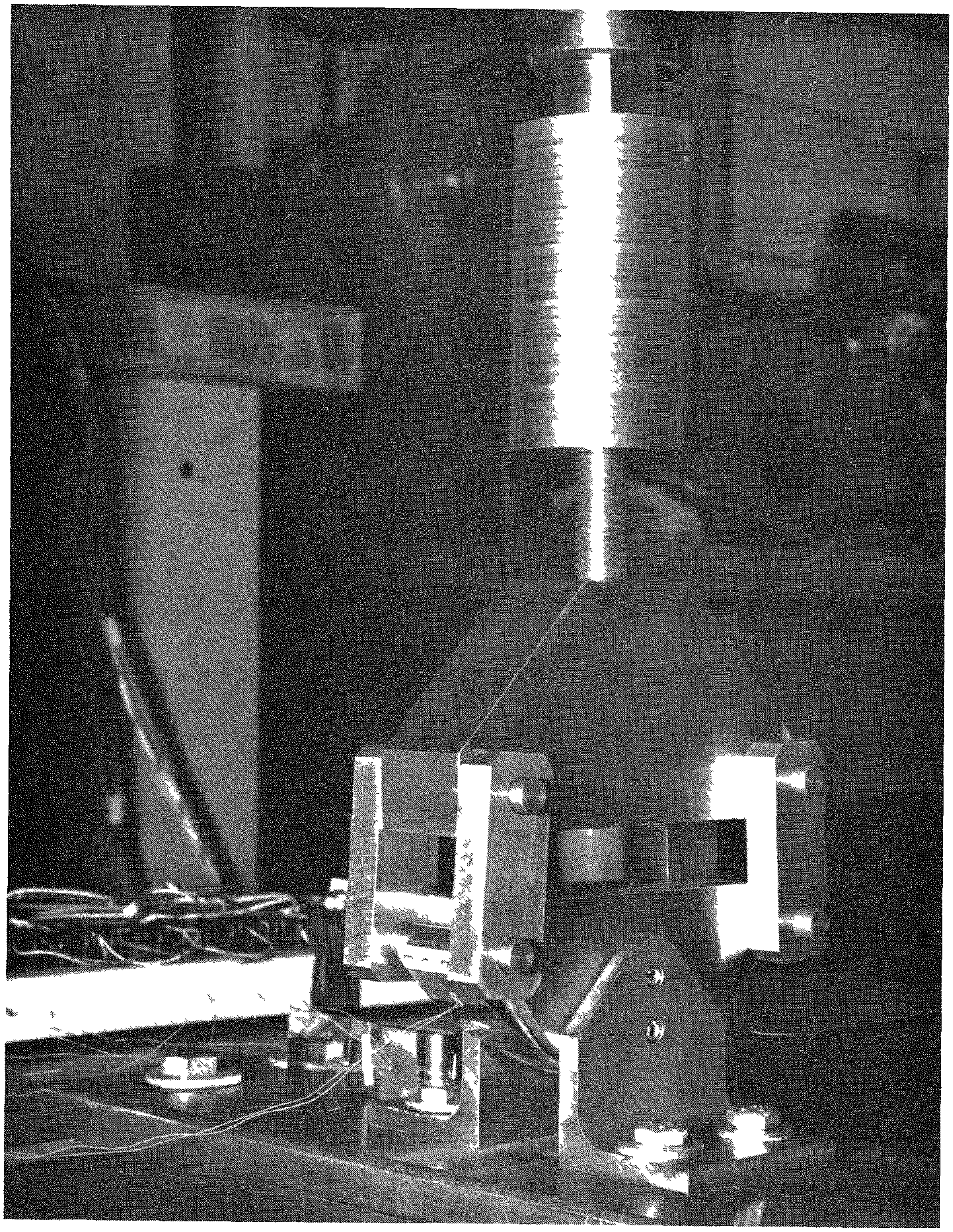

FIGURE 1
BAND LOADING FIXTURE
EML-A.4

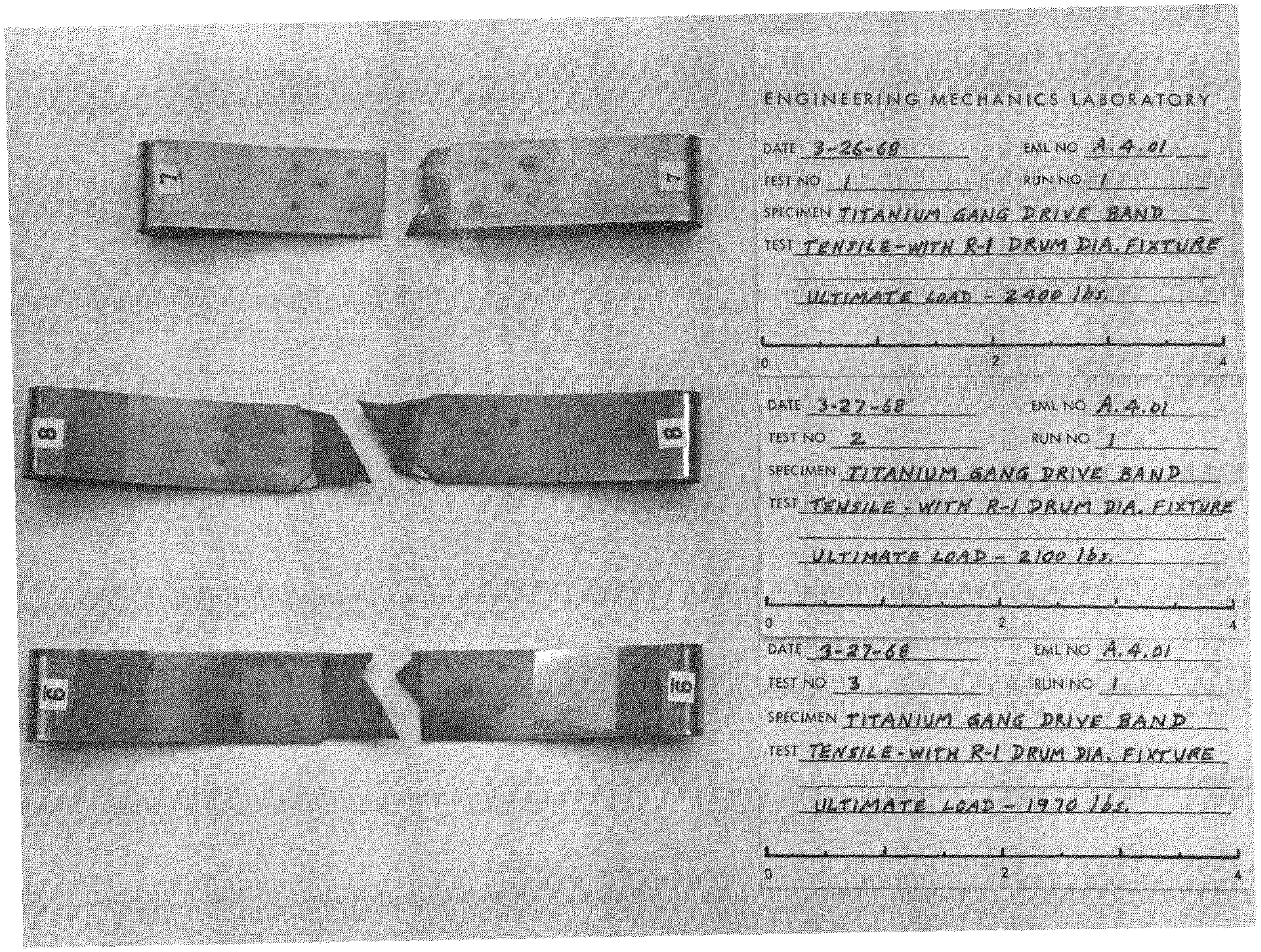

FIGURE 2
FAILED BANDS
EML-A.4

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FUEL ELEMENT TESTS

EML-B.1 Transition Tip Axial Creep Tests

(U) The final transition tip axial creep test of PEWEE I hardware was completed. In this test two new transition tips which were displaced .020 inches longitudinally, were tested at 4900°R and a 900 lb load. This test simulated an extreme condition in which one of the elements was considerably longer thereby causing the pedestal to cock and bear more on the higher tip.

(U) The test specimen was installed in the EML 6 x 10 furnace and brought to temperature with a nominal axial load of 100 lbs on the assembly. When the specimen had stabilized at the 4900°R test temperature, the load was rapidly increased (three to five seconds) to the test load level of 900 lbs and maintained for the specified period. The load was then reduced (at the same rate) to 100 lbs for cooldown. The test was comprised of three cycles of ten, twenty, and forty-five minutes for a total test time of 75 minutes at load and temperature. After each test cycle, the specimen was disassembled and all pertinent dimensions were measured and recorded. The test setup and test results are shown in Figure 3.

(U) The conclusion which may be drawn from these tests is that creep deformation in the fuel element transition tips can be tolerated without experiencing a tip or pedestal failure. At normally expected operating conditions, the pedestal and fuel element tips would survive with little creep deformation the severe loading condition resulting from uneven expansion of the elements. At extreme operating conditions, the creep would be greater, but this would bring the pedestal in contact with the other fuel element tips, thus reducing the load and limiting further creep deformation.

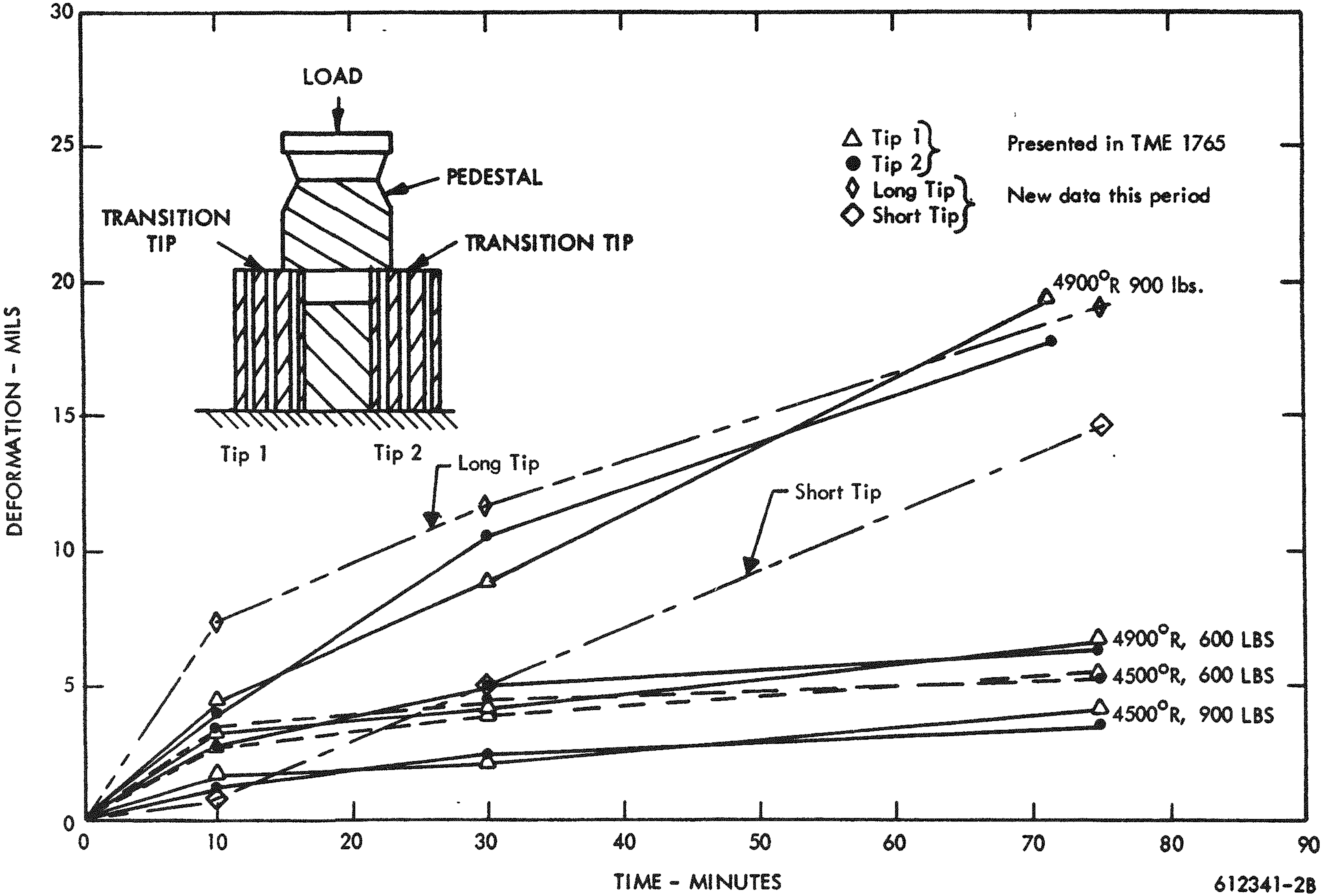

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FIGURE 3
RESULTS OF TRANSITION TIP CREEP TESTS
EML-B.1

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AXIAL SUPPORT SYSTEM TESTS

(U) During the last period the tests in support of PEWEE I were completed. Measurements and metallography data are still being compiled and are not yet complete.

(U) Four major tests have been completed; namely, High Temperature Load Capability, High Temperature Creep, Thermal Cycle Capability and Room Temperature Load Capability. All of the high temperature tests were conducted in the EML Bundling Furnace in a fixture similar to that shown in Figure 4. The assembly shown is bundled laterally by graphite load rods that bear directly against the filler strips shown in the photo.

EML-C.1 High Temperature Load Tests

(U) The purpose of the High Temperature Load Test was to determine the structural margin of the design at high temperature. This was accomplished by loading the specimen with 650 lbs axial load and nominal bundling loads, heating to 4800°R, holding for two minutes and cooling to room temperature. At the end of the cycle, the specimen was examined and then returned for the next cycle which was identical except that the axial load was increased 150 lbs. Five cycles were run with the highest axial load being 1250 lbs.

(U) Results indicated no damage to the fuel elements. However, after the 950 lb load cycle, a possible crack was observed running in a radial direction near the inner axial and horizontal surfaces of the protection cup. The suspected crack could not be seen during inspection conducted after subsequent tests and metallography is underway to further investigate this suspected area.

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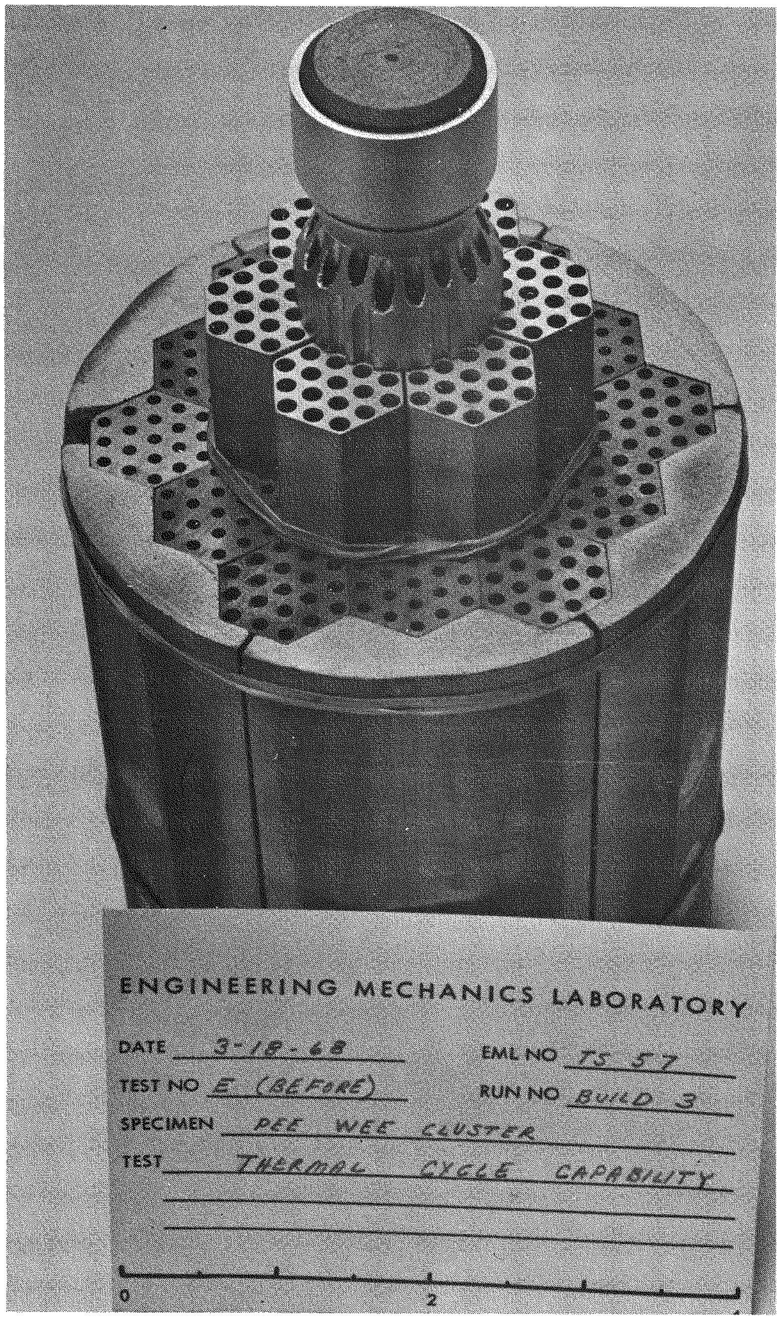

FIGURE 4
BUNDLING FURNACE FIXTURE
EML-C.1

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(U) Creep of the fuel elements during the five test cycles varied from 1.7 to 7.0 mils with the longer elements contracting the greatest amount. This is probably typical of the type of deformation and load sharing that could be expected in a reactor core, although the loads used in this test were considerably higher than the reactor.

EML-C.1 <u>High Temperature Creep Tests</u>

(U) The purpose of the Creep Tests was to determine the creep endurance margin for the case where the center element carries the entire cluster load. Tests were run under two sets of conditions; 1 hour at 4630°R, 900 lb axial load and 500 lb bundling load (R-1 conditions) and 1 hour at 4580°R, 650 lb axial load and 500 lb bundling load (PEWEE conditions).

(U) Two tests were run, both with new hardware. The first simulated both PEWEE I and R-1 conditions in two cycles. This made complete measurements of all parts difficult since the center element welded firmly to the pedestal during the first cycle. The second test only simulated PEWEE I conditions and provided better measurements.

(U) At the end of the second test, it was found that the center element crept from 1.8 to 6.9 mils. This measurement varied, because the end of the center element was skewed where it contacted the pedestal. Scribe lines placed on the center element showed that a total of 0.2 to 1.0 mils occurred in the carbide tip and 1.2 to 2.5 mils occurred in the graphite transition, with the remainder in the center element itself. The diameter of the center hole was measured before and after the test and showed no change as a result of the test.

The joint between the center element and pedestal was leak tested and showed 0.9 cc/min. at 5 psig and 9.0 cc/min. at 15 psig. There was no damage found on any of the components after either of the creep tests.

EML-C.1 Thermal Cycle Tests

(U) The final thermal cycle test was completed and is currently undergoing detailed examination and measurement. Two previous tests were discussed during last month's meeting and are reported in WANL-TME-1765.

(U) In all of the tests, two elements carried the full load of the cluster. This was done by shimming or trimming the elements so that two of the elements were longer than the adjoining elements. The first two tests were made up of five cycles; the first simulating startup, the second shutdown and the third through fifth simulating both startup and shutdown. The test completed during this period used a modified procedure to obtain firm welding of the elements to the pedestal. This procedure involved bringing the assembly to 5000°R under load for the first two cycles followed by a repeat of the first four cycles of the previous tests. The increased temperature used on the first two cycles resulted in firm welding of the elements to the pedestal as shown in Figure 5. This weld did not break during the post-test inspections as had occurred during the two previous builds. However, after the third test which simulated reactor startup by heating up with full axial and bundling loads, the pedestal had crept around the longer elements and was contracting the shorter elements firmly enough to transfer pieces of coating from the elements to the pedestal. At this point, more material was removed from the upstream ends of the short elements to make the longer elements carry the load again. No damage was noted to any component except for a small chip which pulled away from the face of one of the loaded elements. Although four of the elements in the cluster were unloaded, they had contracted varying amounts (5 to 10 mils) by the end of the second test while the load bearing elements contracted approximately 10-15 mils.

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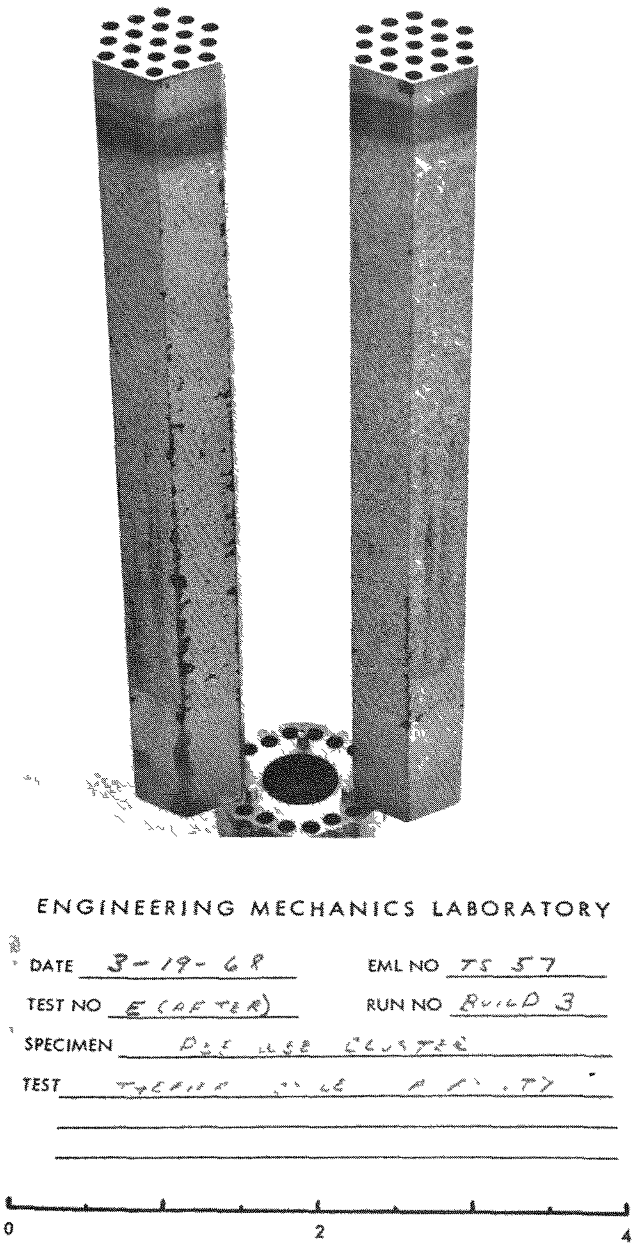

FIGURE 5
ELEMENT TO PEDESTAL WELDING
RESULTING FROM MODIFIED TEST CYCLE
EML-C.1

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(U) Detailed metallography from a study of a crack found in a carbide tip from the second Thermal Cycle Test has shown that the crack penetrates through to the nearest flow channel. This is shown in Figures 6 and 7. On the same tip, another crack of the same magnitude was confirmed in a questionable area. Both cracks appeared to terminate at the braze joint of the ATJ transition section, except on the external surface where the crack continued into the ATJ. Investigation of these cracks is continuing.

EML-C.1 Room Temperature Tests

(U) Two room temperature tests were completed on two separate cluster test assemblies similar to that shown in Figure 8. The purpose of these tests was to verify the room temperature strength of the design and to measure the leakage rate through the pyrofoils used between the insulating cup and tapered washer as a function of axial load.

(U) Leakage rates were measured on the pyrofoil seals at axial loads up to 650 lbs and pressures up to 10 psig. The results for the two cluster test assemblies varied widely because the center element of the second cluster had a non-concentric center hole and a skewed end that increased the leakage by a factor of approximately 5. Leakage data has been plotted on Figure 9 for the three load conditions. Note that despite the discrepancies found on the center element of the second test cluster, the leakage rate is still very low.

(U) Following the leakage tests, the two clusters were loaded and examined in 150 lbs increments up to 1250 lbs. No damage was found except for a thin crack in a pyro-tile washer which was used to simulate

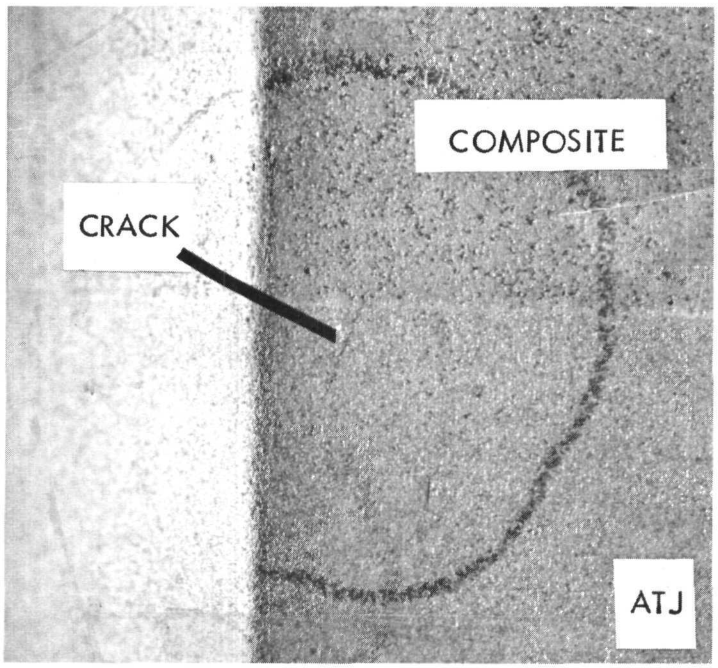
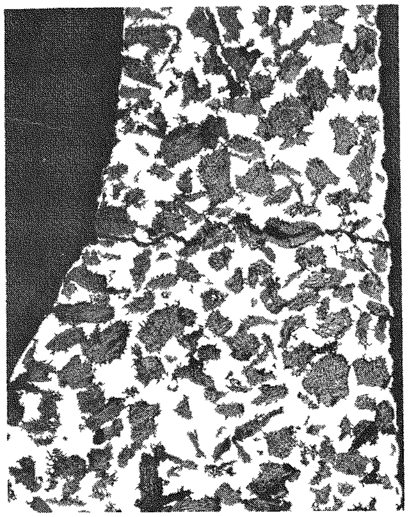
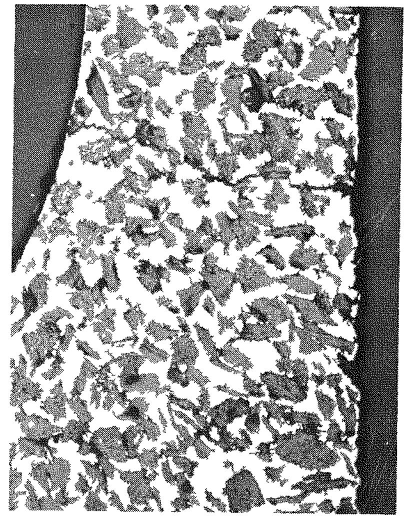


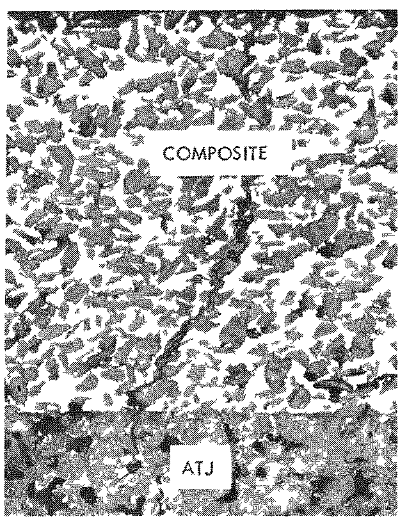
FIGURE 6
EXTERNAL VIEW OF TIP CRACK
EML-C.1



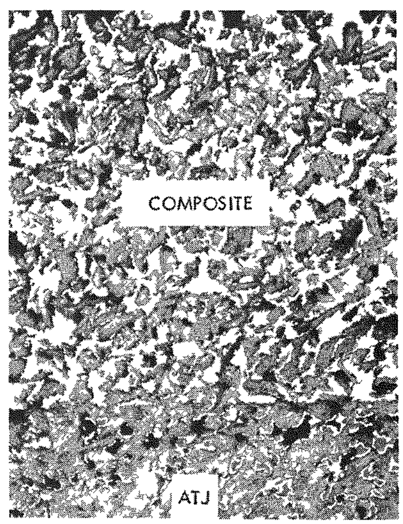
(100X) Normal to Flow Direction



Normal to Flow Direction (100X)



Axially With Flow (75X)



(75X) Axially With Flow

FIGURE 7
PHOTOMICROGRAPHS OF TIP CRACK
EML-C.1

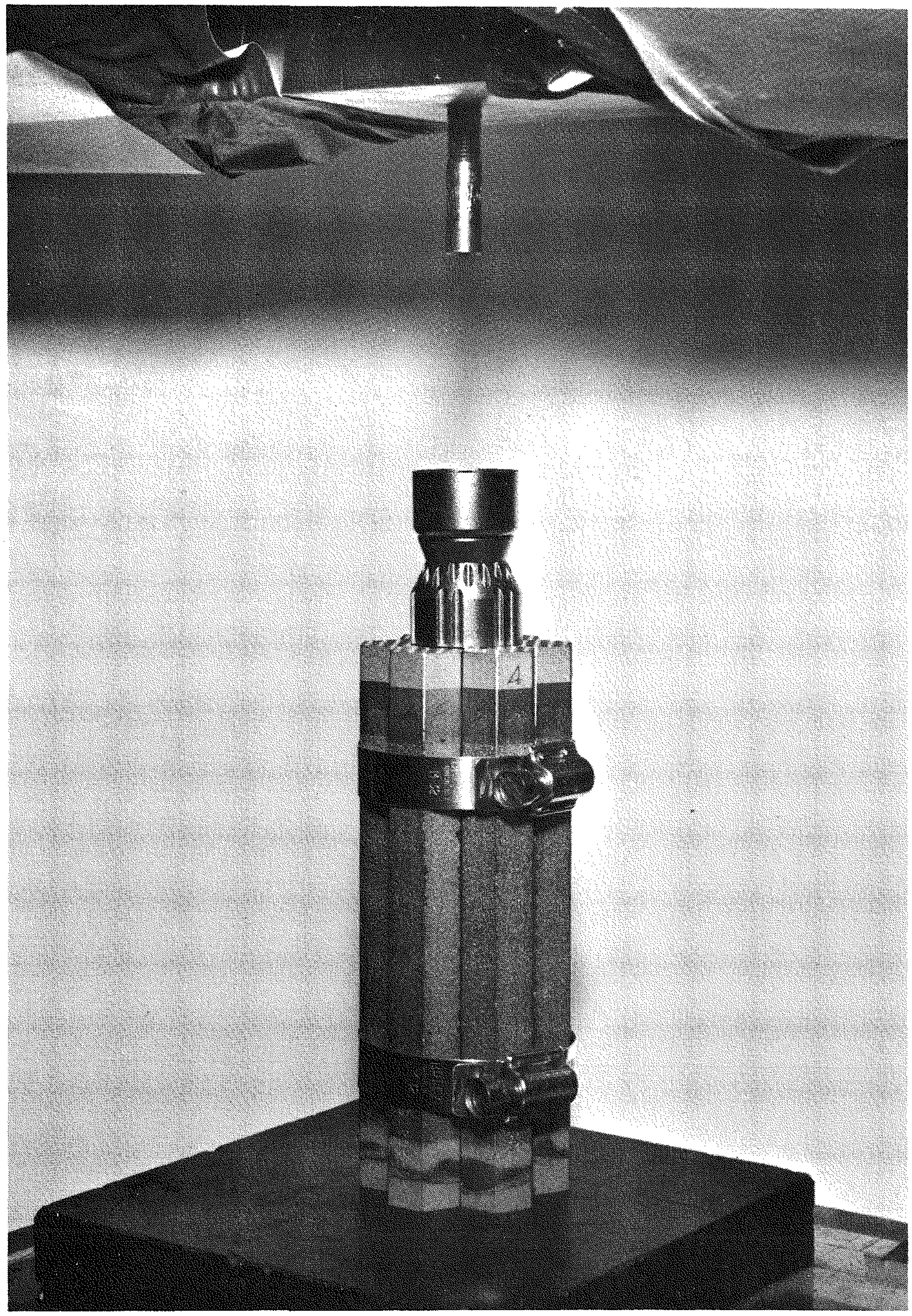


FIGURE 8
ROOM TEMPERATURE LOAD TEST SET-UP
EML-C.1

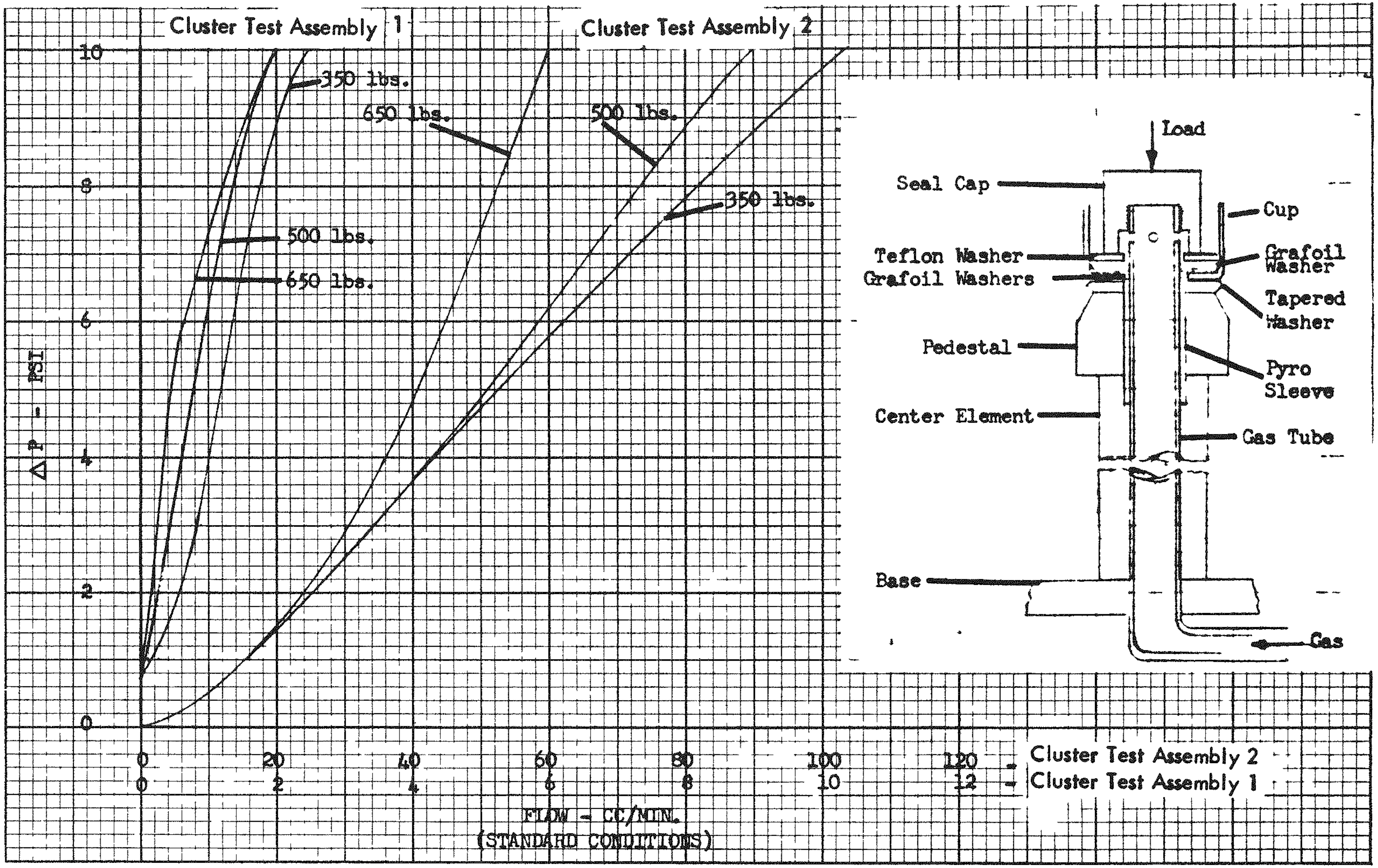


FIGURE 9
LEAKAGE BETWEEN INSULATING CUP AND WASHER
EML-C.1

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(U) the insulating cups which were not available for test. The second cluster assembly was taken to ultimate failure which occurred at 2900 lbs. The failure originated in the pyrographite insulating washer, and the resulting shock cracked the composite protection cup and simulated insulating washer. These parts are shown in Figure 10.

(U) The face of one fuel element was crushed slightly from the impact but no yielding of any of the components was observed before ultimate failure. The 2900 lbs ultimate load for this assembly is comparable to previous designs and indicates adequate strength well in excess of the tie rod ultimate.

EML-C.2 Pedestal Thermal Shock Tests

(U) Development of a thermal shock technique for pedestal assemblies continued. The purpose of these tests is to simulate the reactor thermal stresses sustained by the pedestal during startup and cooldown. To satisfy this requirement, reliable data on thermal gradients must be obtained as a function of time. Recent efforts have been concentrating on obtaining reliable thermocouple data to determine the gradients that cause thermal stresses during startup and shutdown.

(U) A suitable means for measuring the temperature change of the composite on the outer diameter of the pedestal, continues to be a major problem. Thermocouples have been located on the O.D. and in one of the flowholes by cementing them in place with C-14 cement. Data obtained follows the gas temperature too closely and indicates gradients as high as 700°R during startup. This is above the 300°R maximum gradient calculated for the reactor startup condition and indicates that the thermo-

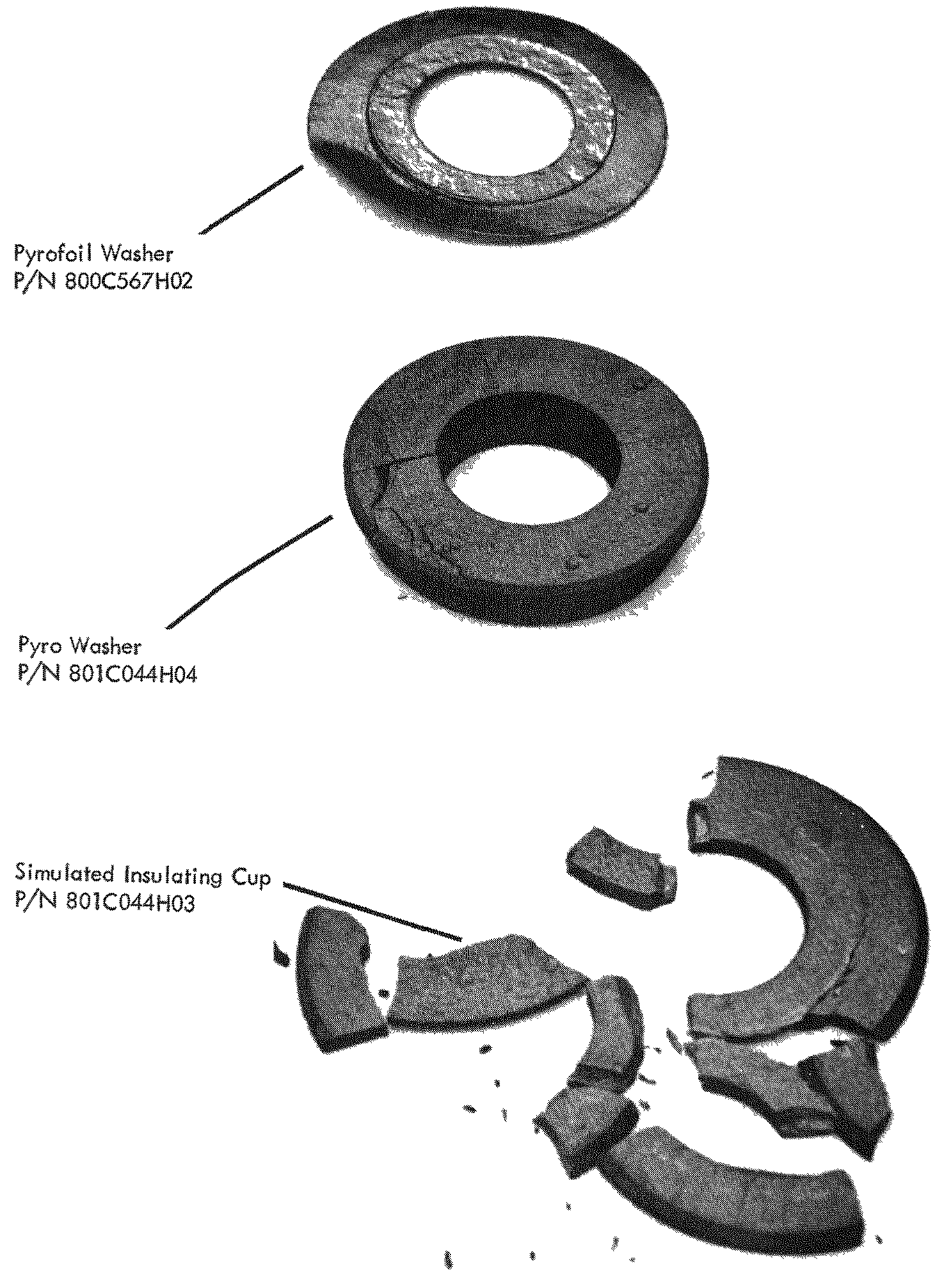


FIGURE 10
SIMULATED INSULATING CUP FAILURE
EML-C.2

(U) couple is being affected by the gas temperature and is not measuring the true temperature change of the composite material. Recent efforts have attempted to measure the O.D. temperature by working with cylindrical composite specimens of the same envelope as the pedestal. These specimens did not include any flowholes, but incorporated three blind holes to allow temperature measurements without gas flow or radiation corrections during both heatup and cooldown ramps.

One of these was subjected to six thermal shock cycles with the following results:

(U)

1. The maximum measured thermal gradient achieved in the composite material was approximately 1300°R/inch.
2. Specimen transients of 150°R/sec were accomplished during cooldown bulk gas transients of 2000°R/sec.
3. Phase relationship of the thermocouples was as predicted i.e., the O.D. thermocouple indicated hotter on heatup and cooler on cooldown than other specimen thermocouple.
4. The mass of the load block and flow guide directly influenced the lowest temperature achievable during cooldown.
5. The flow guide material also influenced the O.D. and exhaust gas thermocouple indications as radiation during cooldown causes higher specimen temperature at the lower temperatures.

(U) Several more cylinder tests will be conducted to confirm the above results and to evaluate fixture improvements evolving from these tests. This configuration will be thermally analyzed by classical methods to obtain a better correlation between analytical and experimental data.

(U) During development of the test fixturing and experimentation with thermocouple installation, a pedestal has been subjected to a total of eleven heatup tests and seventeen cooldown transients. During each of these tests, the pedestal was loaded mechanically to a nominal load of 150 lbs and inspections conducted after each test showed no damage as a result of the testing.

(U) Figure 11 diagrammatically shows the pedestal installation and the location of thermocouples in the assembly.

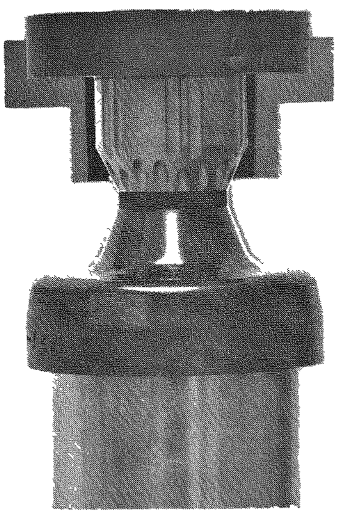
CORE ASSEMBLY TESTING

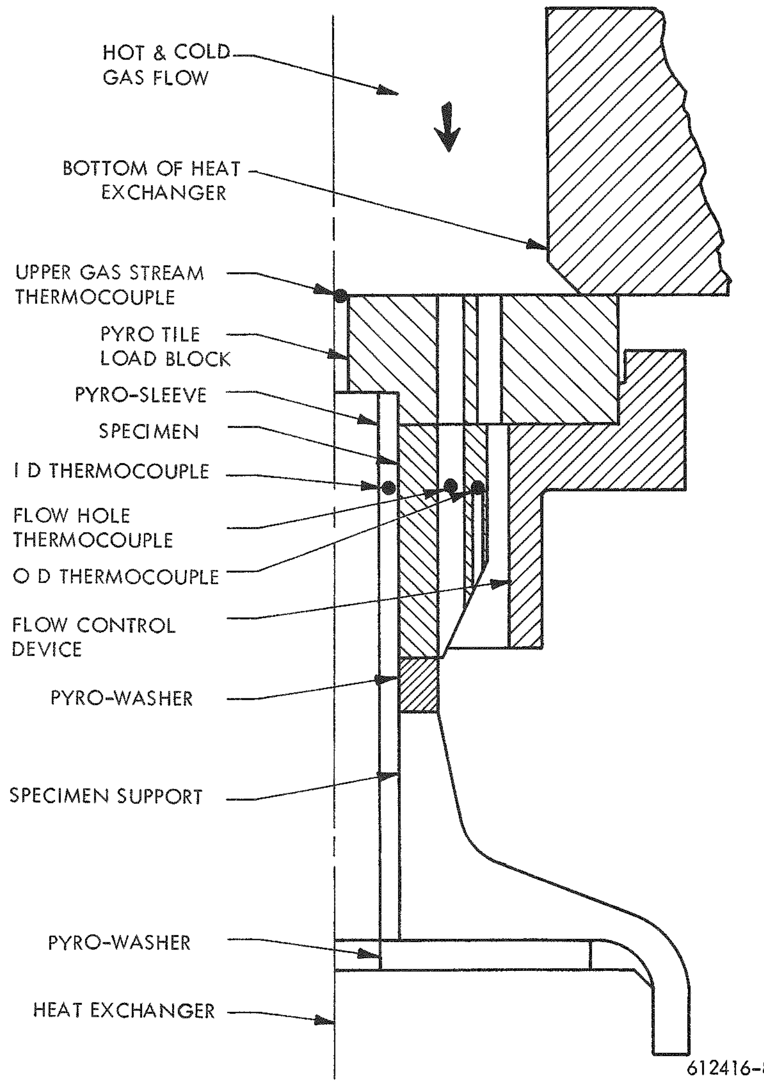
EML-G.2 Static Tests of an R-1 Flat Seal Design

(CRD) Static tests were performed to evaluate a candidate flat seal lateral support system design for the R-1 reactor. The partial length core was supported in the outer reflector ring by two rows of flat seals with each row containing a one-piece outer seal and twelve 30° inner seal segments. A cross-section of the lateral support system is shown in Figure 12.

(U) A photograph of the test setup is shown in Figure 13. A mechanical loading device was used to move the core relative to the reflector and the output signals from the load cell and displacement transducer were recorded on an X-Y plotter.

(CRD) A total of 18 cycles at displacements between 50 and 225 mils were applied to study the wear-in properties. A typical load displacement hysteresis loop is shown in Figure 14. The curve is typical of a classical spring-friction system and the parallelogram shape is the same form exhibited





SPECIMEN TEST ASSEMBLY AND THERMOCOUPLE POSITIONS

FIGURE 11

EML-C.2

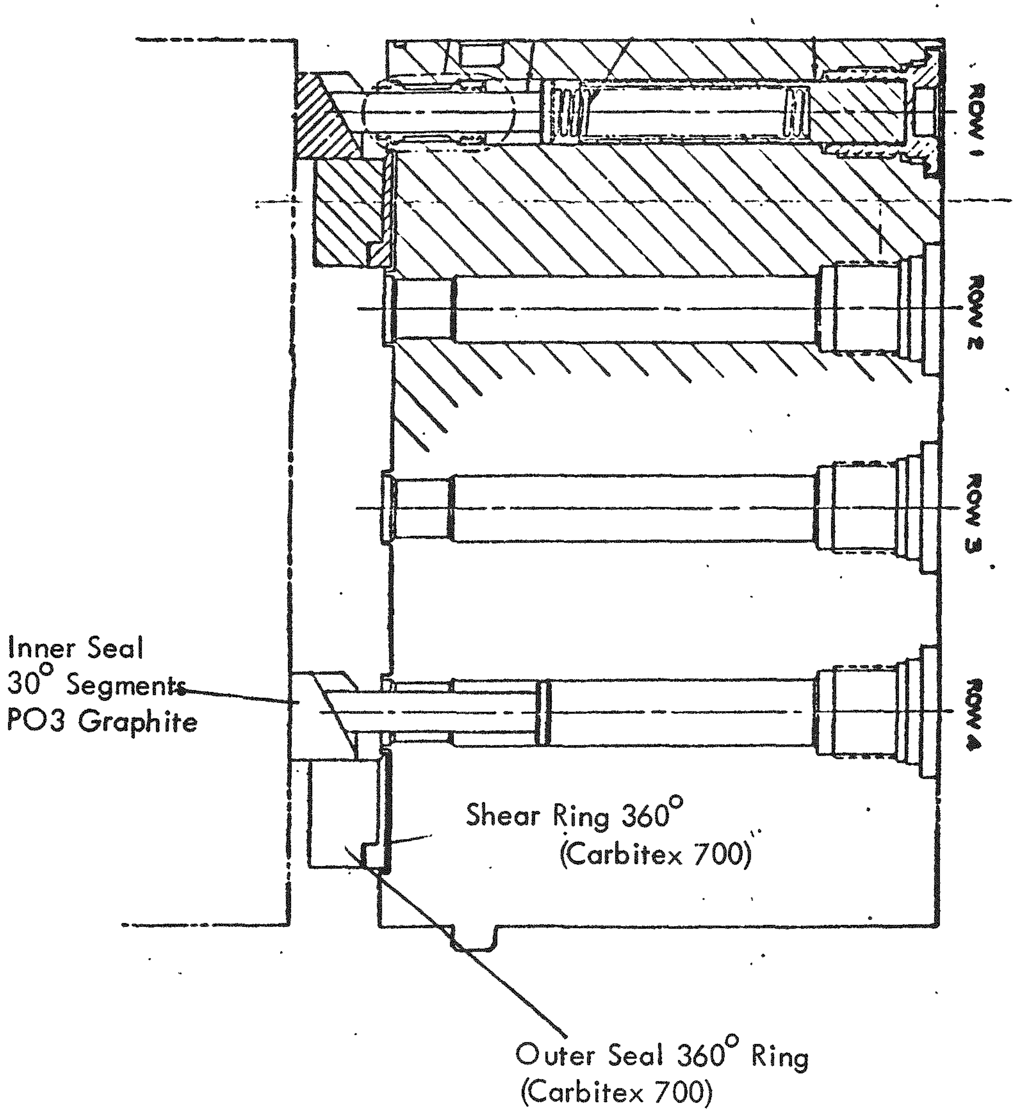


FIGURE 12
CANDIDATE FLAT SEAL DESIGN FOR
LATERAL SUPPORT SYSTEM
EML-G.2

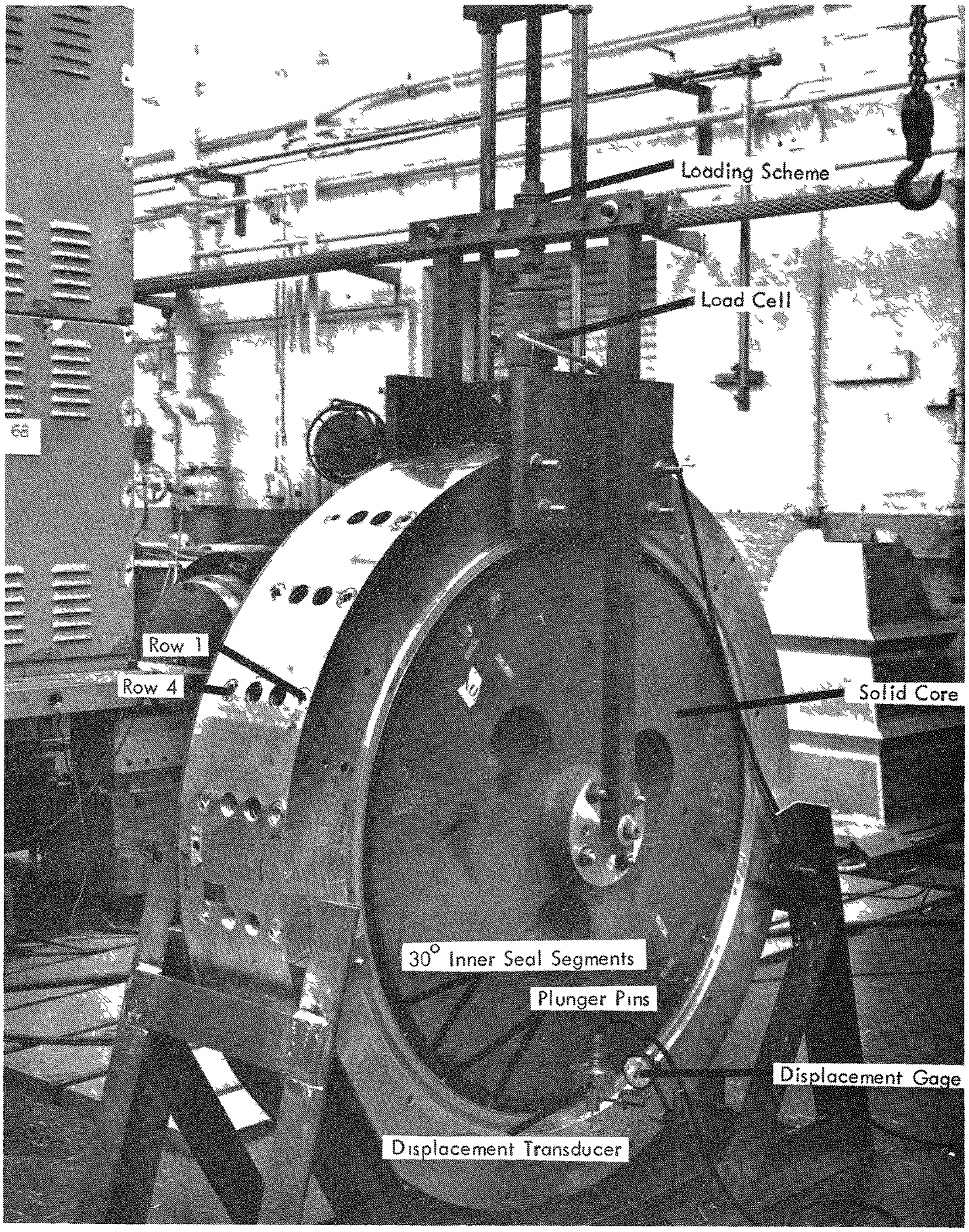


FIGURE 13
STATIC TEST SETUP FOR EVALUATION OF
FLAT SEAL LATERAL SUPPORT SYSTEM
EML-G.2

[redacted]

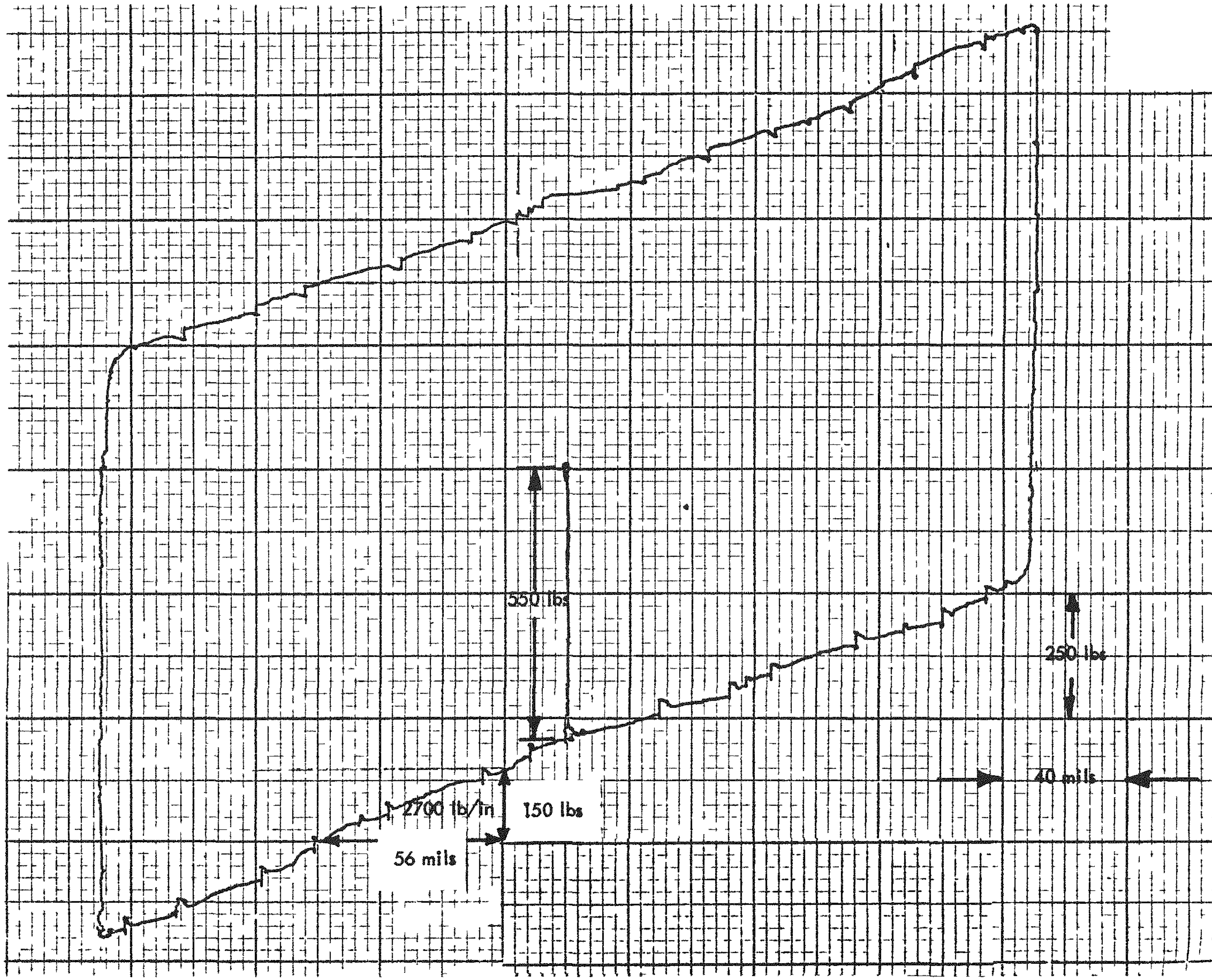


FIGURE 14
150 MIL HYSTERESIS LOOP
EML-G.2

by the A1 through A5 designs. The two row lateral support system spring rate for the lateral support springs used in this test setup is 2750 lb/in which would extrapolate to a value of 5500 lb/in for a full four row partial core system. (Figure 12). The breakaway friction is 550 lbs which would extrapolate to 1100 lbs for a full four row partial core system at a bundling pressure of 3.2 psi.

(CRD)

These values are compared below to similar partial core test results obtained for the A2 lateral support system:

(CRD)

	R-1 Candidate	A2
Static Friction	1100 lbs	1205 lbs
Spring Rate	5500 lb/in	7360 lb/in

(U) The static test phase is complete.

FACILITY, LAUNCH & FLIGHT TESTING

EML-H.1 XECF Resonant Survey

(U)

The report covering the three XECF resonant survey tests is 50% complete. The data recorded from the transducers which were mounted on the core and on the forward and aft pressure vessel flanges were reviewed and important frequencies to be analyzed were selected. The motions on these three components are directly related to the input forces on the reactor.

In the longitudinal direction, the core responses to be studied are at frequencies of 27, 50, 308, 419, and 705 cps. Significant motions of

(U) the pressure vessel which can affect the reactor were noted at 14, 50, 290, 401, 458 and 1515 cps. The frequencies being studied in the lateral excitation direction are 16, 24, 58, 129, 228, 237, 382, 415, 452, 632 and 657 cps. No serious core resonances, as evidenced by response magnification, have been found.

(U) The usefulness of phase relationships recorded on the digital system and tape are in question especially when either of the two acceleration levels are below one eighth of a "g". Therefore, the phase information used to analyze motions of components has been limited.

ANTICRITICALITY POISON SYSTEM

EML-J.1 Poison Wire Elongation Tests

(U) Static tests in support of the poison wire development program were performed to determine the quantity of boron that would remain inside an element when a 5 lb load was applied at one end while the other end was held. Poison wires made by two potential fabrication techniques were investigated. The candidate poison wires were the types shown in Figure 15. Figure 15a is a section of a 52 inch poison wire made up of a 10 mil 304 SS wire on which Boron Carbide beads were strung and then encased with teflon type "TFE-R" shrinkable tubing. Figure 15b shows a section of a 52 inch poison wire which is the same except the shrinkable tubing is replaced with a spray-coated 5 mil thickness of Dupont type "S" teflon coating. Bare 10 mil 304 SS wire, annealed and cold worked was also evaluated.

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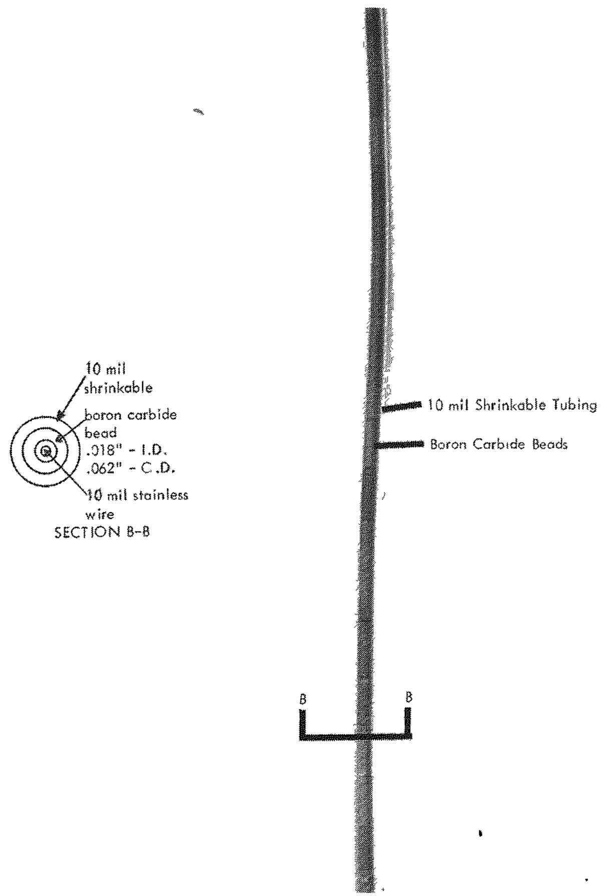

FIGURE 15a
SHRINKABLE TUBING TYPE POISON WIRE
EML-J.1

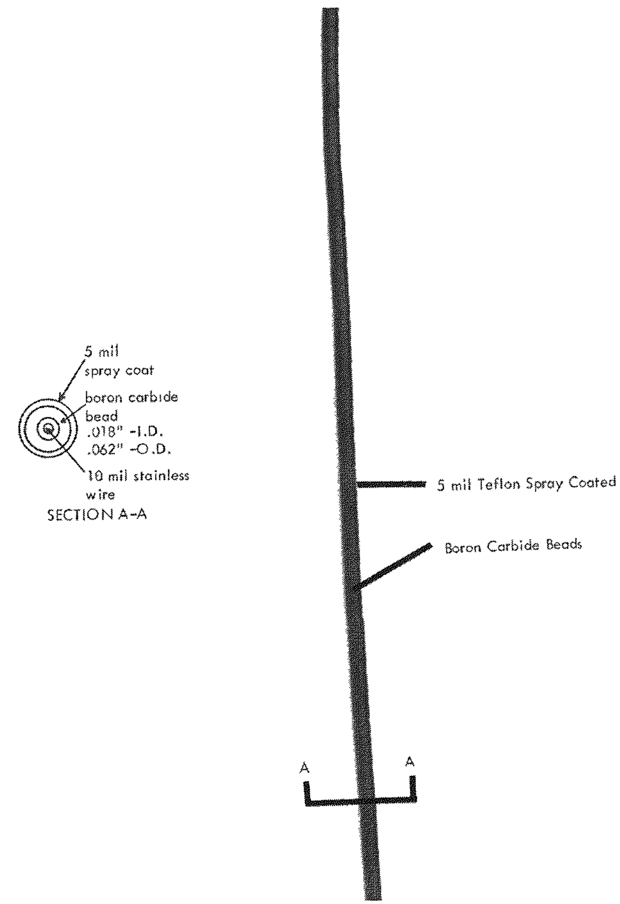

FIGURE 15b
SPRAYED TEFLON COATED POISON WIRE
EML-J.1

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(U) Fourteen tests were conducted in the test arrangement shown in Figure 16 with the output signals from the load cell and displacement transducer seen in Figure 16a monitored on an X-Y recorder.

(U) Four complete load cycles to 2, 3, 4 and 5 lb were applied to each specimen. Results of these tests are summarized in Table II and typical curves shown in Figure 17. No permanent set occurred in any of the wires tested and the spring rate of a 53 inch length of poison wire was shown to be primarily dependent on the wire characteristics with the coating having a negligible effect.

SUPPORT STEM TESTS

EML-L.1 Grafoil Seal Expansion Tests

(U) Tests on the grafoil sealing sleeves are complete. The data recorded during the tests have been analyzed and design equations were formulated in conjunction with the Stress Analysis section. An equation for calculating strains at the mid-point on the face of a central element was developed by fitting an equation to the experimentally determined data. Figure 18 shows the equation. These test data also show (Figure 18) that the measured tangential strains in the central element specimens were approximately twice the maximum values for the graphite cylinder. These higher strains were attributed to the instrumentation hole adjacent to the strain gage location, in each of the central elements tested.

(U) An equation for determining radial pressure in a central element during the assembly of grafoil sleeves was also developed. The general equation for tangential stress in a thick walled cylinder which relates

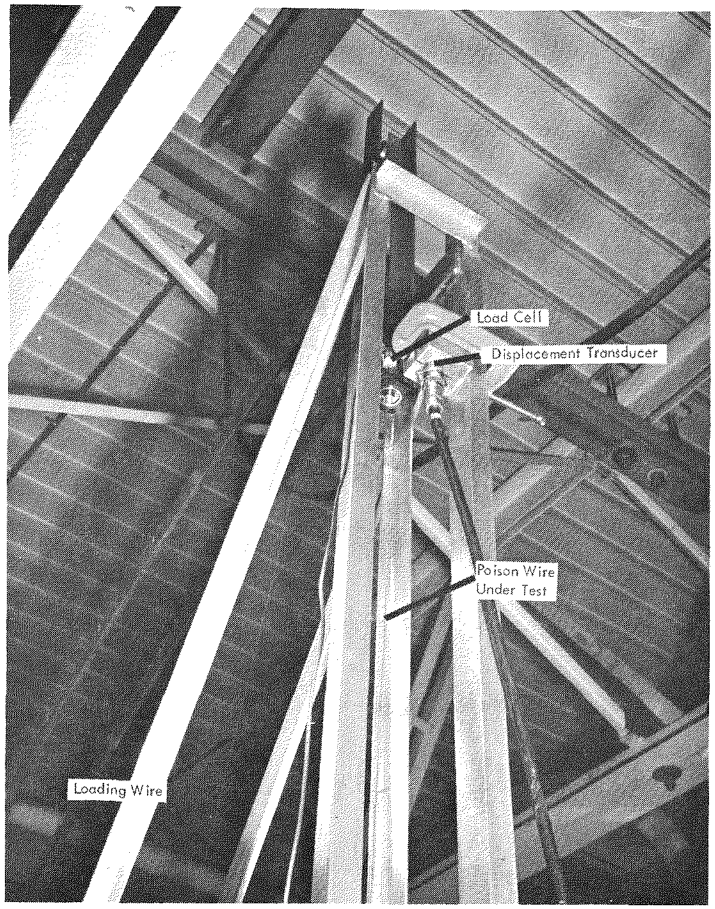

FIGURE 16a
ELONGATION TEST SETUP (UPPER VIEW)
EML-J.1

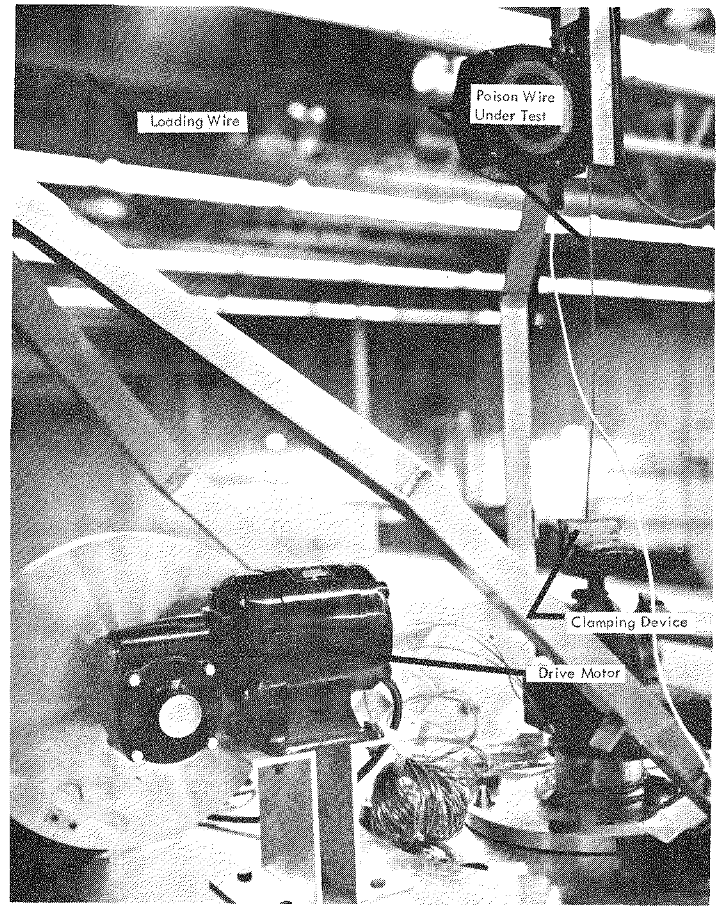

FIGURE 16b
ELONGATION TEST SETUP (LOWER VIEW)
EML-J.1

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TABLE II

SUMMARY OF ELONGATION TESTS

Specimen	Test	Wire No.	Spring Rate at Maxim Load	Load	Load Required to Strengthen Wire	Comments
TYPE I	1	6	80 lb/in	0 to 5 lb	2.25 lb	Deviation load is the load required to straighten
B_4C	2	11	93 lb/in	0 to 5 lb	2.5 lb	bending in wire
with	3	3	83 lb/in	0 to 5 lb	1.9 lb	
shrinkable	4	1	77 lb/in	0 to 5 lb	2.25 lb	
tubing	5	8	70 lb/in	0 to 5 lb	2.00	
	6	9	93 lb/in	0 to 5 lb	2.5 lb	
	7	2	86 lb/in	0 to 5 lb	2.25 lb	
	8	4	77 lb/in	0 to 5 lb	2.5 lb	
TYPE II	1	14	93 lb/in	0 to 5 lb	2.6 lb	
B_4C	2	13	100 lb/in	0 to 5 lb	3.1 lb	
with Dupont	3	12	123 lb/in	0 to 5 lb	2.75 lb	
spray on teflon	4	11	93 lb/in	0 to 5 lb	2.5 lb	
S coating						
304 A (bare) annealed	1	bare	87 lb/in	0 to 5 lb	2.25 lb	
304 B (bare) cold worked	2	bare	127 lb/in	0 to 5 lb	2.5 lb	Spring rate change to 92 lbs/in at 30 lbs

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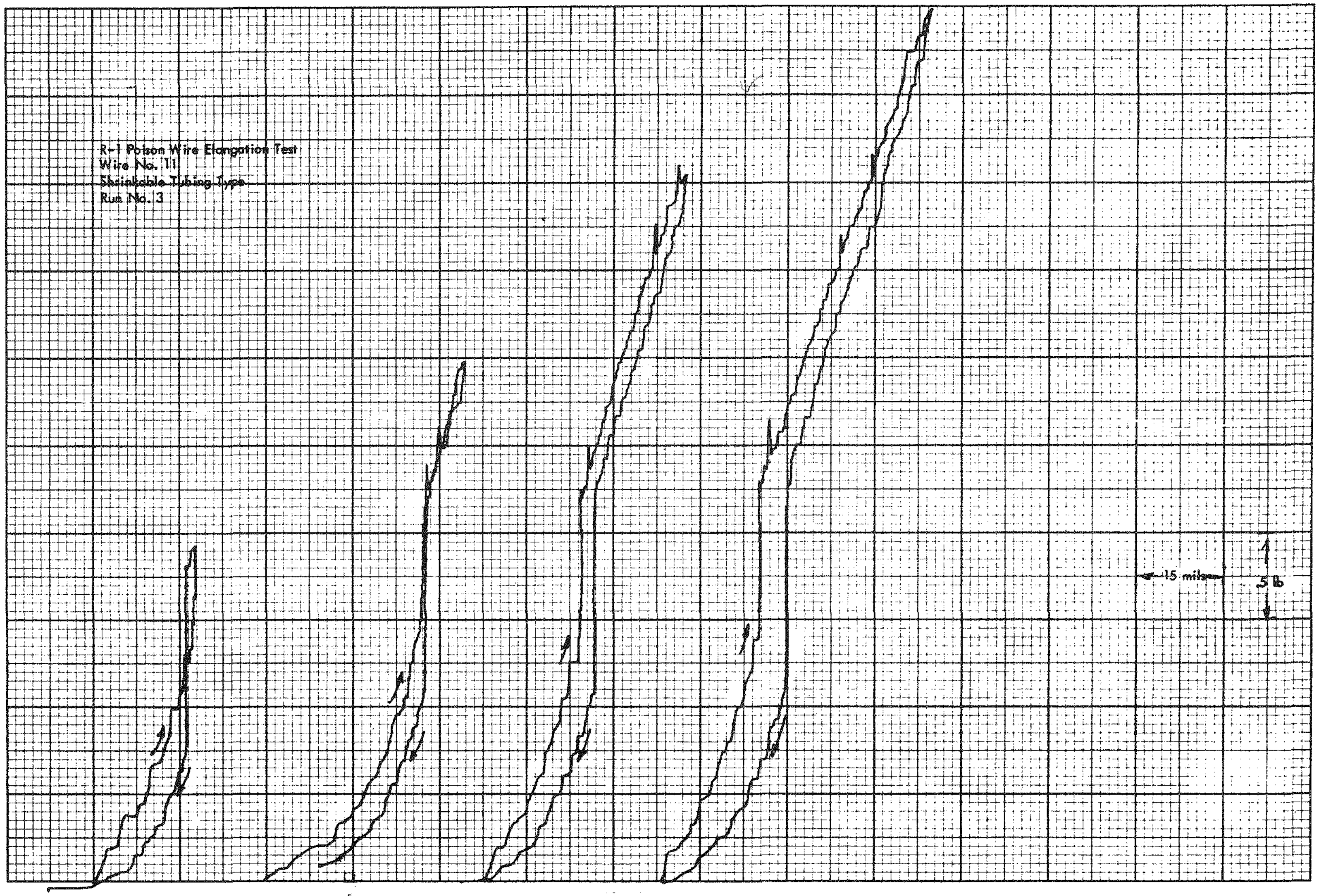

FIGURE 17
TYPICAL POISON WIRE LOAD CURVE
EML-L.1

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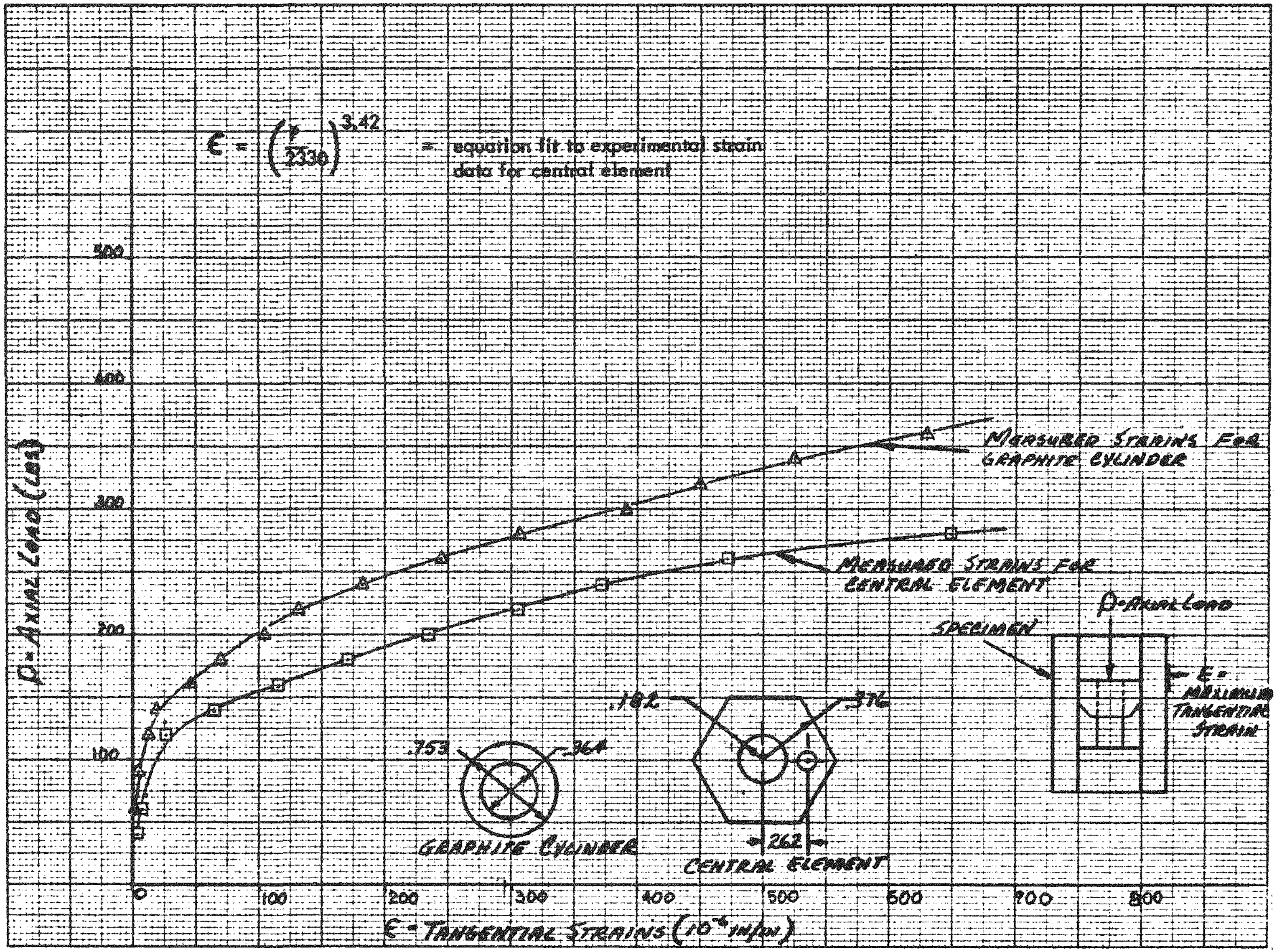

FIGURE 18
EXPERIMENTAL DATA OF MAXIMUM STRAINS MEASURED IN
GRAPHITE CYLINDER AND CENTRAL ELEMENT SPECIMENS
EML-L.1

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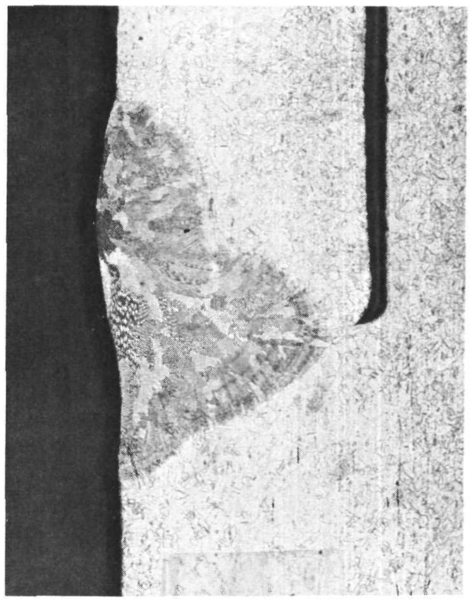
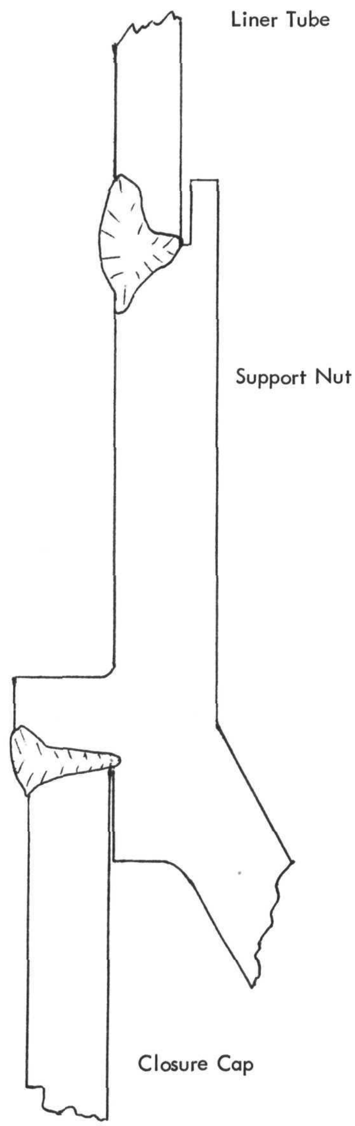
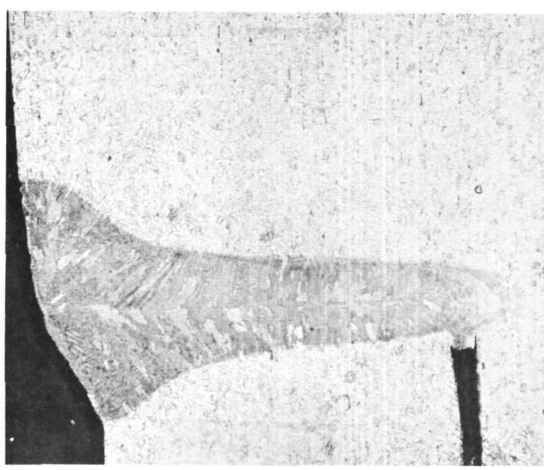


100X

LINER TUBE-SUPPORT NUT
ELECTRON BEAM WELD





75X

SUPPORT NUT-CLOSURE CAP
ELECTRON BEAM WELD

FIGURE 19
PHOTOMICROGRAPHS OF STEM CLOSURE CAP WELDS
EML-L.2

(U) tangential stress to the geometry (wall thickness and radial position) was combined with the stress-strain equation and the experimentally determined equation (Figure 18) to derive at an expression which directly relates internal pressure to axial load. This equation is shown below:

$$P = 29 P_i^{.292}$$

where

P = Axial load on grafoil seals (lbs)

P_i = Internal pressure on central element (psi)

EML-L.2 Stem Aft End Weld Evaluation Tests

(U) Metallographic examinations of the two weld joints on the aft end closure cap (Figure 19) has shown no evidence of mechanical failure. Prior to sectioning, the specimen was cycled twenty times from 0 to 900 psig. This testing has been reported previously.

(U) The study revealed that the weld joining the liner tube to support nut had less penetration than was designated on the drawing. Further development of procedures for reactor grade components will eliminate this condition.

TESTS IN SUPPORT OF NRX & XE

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REFLECTOR SYSTEM TESTS

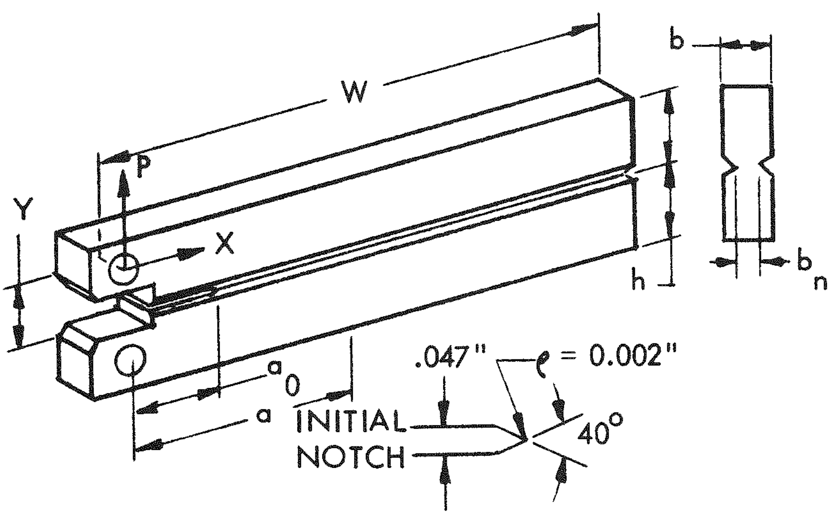
DCB Fracture Toughness Tests

Two double cantilever beam (DCB) specimens (Figure 20) fabricated from NRX-A6 ring pressing No. 4055 were tested at liquid nitrogen temperatures. The loads were applied in the transverse direction with respect to the pressing direction. The primary purpose of the test was to determine the load required to initiate cracking and whether a crack arrest would (U) occur upon release of load. A secondary test objective was conducted simultaneously by attaching two piezoelectric accelerometers to the DCB specimen to determine if incipient failure or crack initiation or growth resulting in a sudden release in elastic energy could be detected.

Results show that K_{IC} to initiate the cracks were about 50% greater than those required to initiate cracks in specimens from block pressed beryllium as reported previously in TME-1610. The K_{IC} obtained during the (U) current test series was 12.9 ksi $\sqrt{in}$ for one specimen and 14.7 ksi $\sqrt{in}$ for the other. In the previous tests on block pressed material the number of crack arrests was between 14 and 19. In this test series three crack arrests were obtained. Figure 21 shows the load-displacement curve for the second specimen tests.

Because of the time interval between the original work on block pressings and the current work in ring pressings, it is possible that the (U) apparent differences in material behavior are due to machining or experimental technique variations. Additional specimens are currently being machined from both types of material to eliminate these variables.

The current tests indicated that incipient failure could be detected (U) with piezoelectric accelerometers and this technique will be pursued in future tests.



W = 7.0"
b = 0.250"
b_n = 0.130"
h = 0.50"
a_0 = 1.0"

P = LOAD
Y = DISPLACEMENT

FIGURE 20
DCB SPECIMEN CONFIGURATION

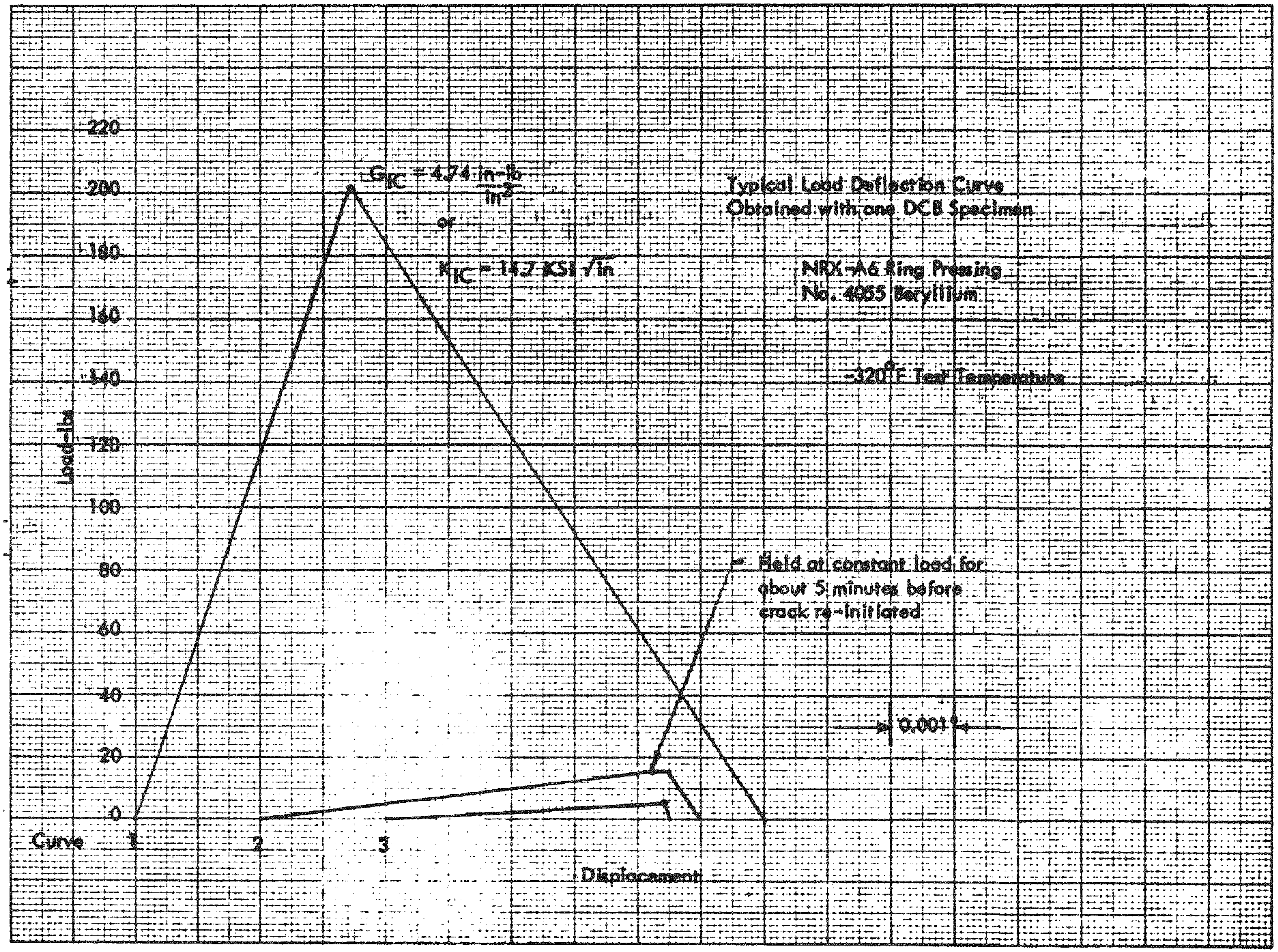


FIGURE 21
DOUBLE CANTILEVER BEAM LOAD CURVE

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CORE PERIPHERY TESTS

Static Key Tests at Cryogenic Temperature

(U) The second series of tests to investigate the failure of NRX-A6 brazed keys has been completed. These tests were conducted at cryogenic temperatures and the data are shown below:

Specimen	Serial No.	Mfg.	Failure Load	Temp
1	AC-12-39809	WNCO	286 lbs	109^{o}R
2	AC-12-39810	WNCO	322 lbs	99^{o}R
3	AC-12-39811	WNCO	377 lbs	79^{o}R

(U) The failure mode for these tests was not the same as those witnessed at the NRX-A6 disassembly.

(U) The test fixture and liquid gas supply lines are shown in Figure 22. The static loads were applied in the same manner as in the previous tests.

(U) The cryogenic temperatures were attained by directing the flow of the liquid nitrogen and liquid helium directly on the brazed key area with the specimen being prechilled with liquid nitrogen and then further reduced in temperature by using liquid helium. The temperature of the specimens were monitored with a copper-constantan thermocouple inserted into the fuel element as shown in Figure 22 and at the desired point the static load was applied to failure.

(U) Figure 23 shows the similarity of all the failures produced in the laboratory. In each case an examination of the test specimen indicated that no damage had occurred in the braze or the element.

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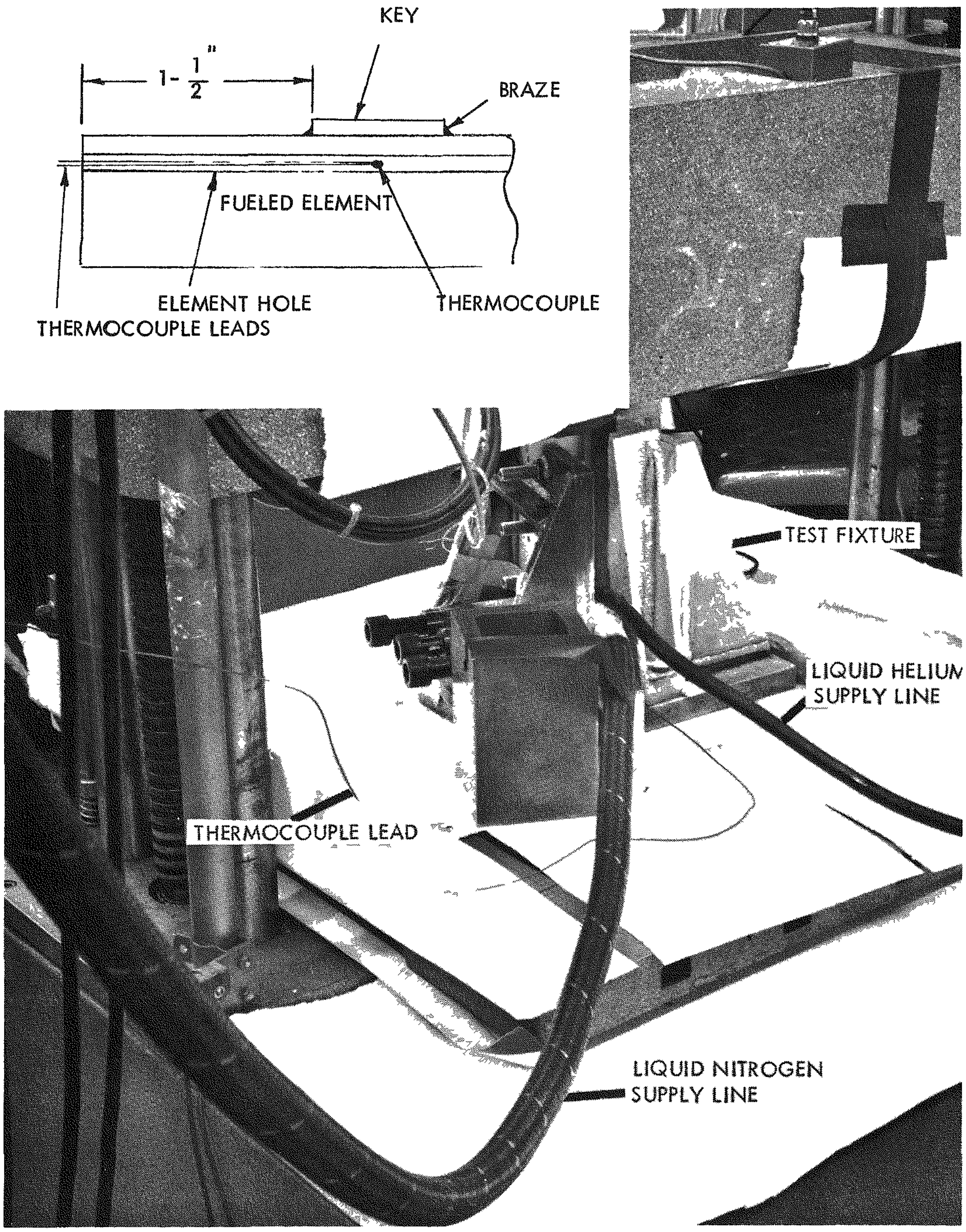

FIGURE 22
A-6 BRAZED KEY TEST SET-UP

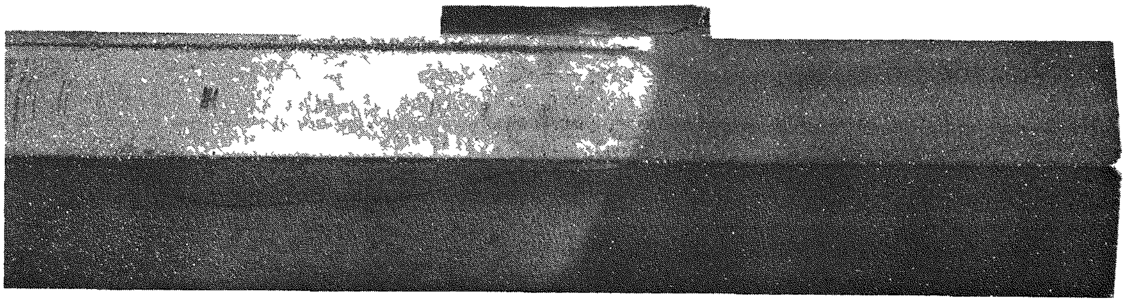

FIGURE 23a
TYPICAL FAILURE - TESTS PRIOR TO NRX-A6

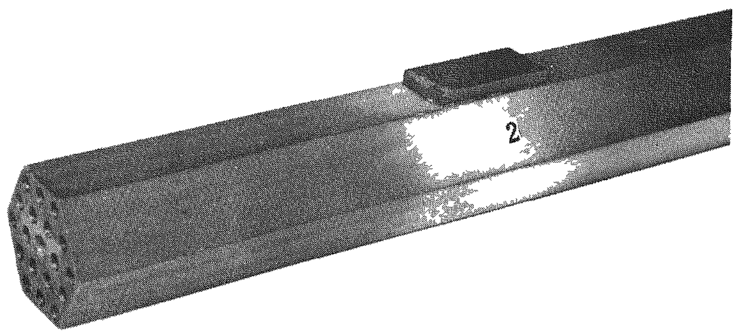

FIGURE 23b
TYPICAL FAILURE - AMBIENT CONDITIONS - AFTER NRX-A6

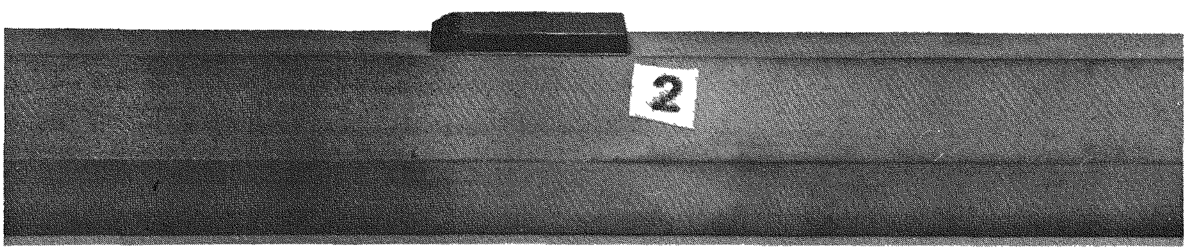

FIGURE 23c
TYPICAL FAILURE - CRYOGENIC CONDITIONS - AFTER NRX-A6

XE-1 Readiness Review Preparation

(U) Test information was gathered and summarized in tabular form for the XE-1 Readiness Review March 25, 26 and 27. All documents pertaining to control drum scram springs, tie rods, exit gas thermocouples, element twist and liner tube seals were collected. An Engineering Mechanics representative was present at the meetings to discuss any of the tests relating to these components.

FACILITIES

FACILITIES

Tinius Olsen Test Machine

(U) A universal electro-hydraulic testing machine of 60,000 lbs capacity and manufactured by Tinius Olsen was received, installed and given a preliminary checkout. This machine is a closed loop, hydraulic loading machine.

(U) One of the principal advantages of a closed loop machine is that the programmed input signals to the specimen is always constant and independent of specimen behavior. A built-in sine wave generator can be used to run low cyclic fatigue tests using either constant strain range or load range.

(U) The UEH testing machine will be load calibrated, traceable to the NBS, during the next period.