NASA-CR-54911

ADVANCED REFRACTORY ALLOY CORROSION LOOP PROGRAM

Quarterly Progress Report No. 3
For Quarterly Ending January 15, 1966

By

R. W. HARRISON
and
E. E. HOFFMAN

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NAS 3-6474

SPACE POWER AND PROPULSION SECTION
MISSILE AND SPACE DIVISION
GENERAL ELECTRIC
CINCINNATI, OHIO 45215

ADVANCED REFRACTORY ALLOY CORROSION LOOP PROGRAM

QUARTERLY PROGRESS REPORT 3

Covering the Period
October 15, 1965 to January 15, 1966

Edited by

R. W. Harrison

Project Metallurgist

Approved by

E. E. Hoffman

Manager, Corrosion Technology

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Lewis Research Center

Under Contract NAS 3-6474

February 3, 1966

Technical Management
NASA - Lewis Research Center
Space Power Systems Division
R. L. Davies

SPACE POWER AND PROPULSION SECTION
MISSILE AND SPACE DIVISION
GENERAL ELECTRIC COMPANY
CINCINNATI, OHIO 45215

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ADVANCED REFRACTORY ALLOY CORROSION LOOP PROGRAM

I. INTRODUCTION

This report covers the period from October 15, 1965 to January 15, 1966 of a program to fabricate, operate for 10,000 hours, and evaluate a potassium corrosion test loop constructed of T-111 (Ta-8W-2Hf) alloy. Materials for evaluation in the turbine simulator include Mo-TZC and Cb-132M. The loop design will be similar to the Prototype Loop; a two-phase, forced convection, potassium corrosion test loop which is being developed under Contract NAS 3-2547. Lithium will be heated by direct resistance in a primary loop. Heat rejection for condensation in the secondary loop will be accomplished by radiation in a high vacuum environment to the water cooled chamber. The compatibility of the selected materials will be evaluated at conditions representative of space electric power system operating conditions, namely:

a.	Boiling temperature	$2050^{\circ}F$
b.	Superheat temperature	$2150^{\circ}F$
c.	Condensing temperature	$1400^{\circ}F$
d.	Subcooling temperature	$1000^{\circ}F$
e.	Mass flow rate	40 lb/hr
f.	Boiler exit vapor velocity	50 ft/sec
g.	Average heat flux in plug (0-18 inches) BTU/hr ft^2	240,000
h.	Average heat flux in boiler (0-250 inches) BTU/hr ft^2	23,000

II SUMMARY

During the third quarter of the program, work proceeded on the topics abstracted below:

All of the vendors are encountering difficulties in fabricating the advanced refractory alloys, and a significant part of the work during the past quarter has been concerned with the examination of processing procedures and with expediting the material procurement so as to minimize the delay to the program. Many of the difficulties are associated with the materials vendors' deviations from established processing procedures.

The initial shipment of lithium was replaced by the vendor because of its high nitrogen content; however, the second shipment was also higher in nitrogen than required. This lithium has been accepted and will be subjected to further purification at General Electric. All of the lithium purification system drawing revisions have been completed. Assembly of the argon-vacuum manifold for the lithium purification system was begun and fabrication of the hot trap has been completed.

Minor design changes have been made and specifications are being written to assure quality fabrication and performance of Corrosion Loop I (T-111).

III PROGRAM STATUS

A. MATERIALS PROCUREMENT

1. T-111 Alloy - Fansteel Metallurgical Corporation. Two T-111 alloy ingots were prepared by double EB melting at Fansteel and final vacuum arc melting at the Braeburn Alloy Steel Division, Continental-Copper and Steel Industries, Inc., Braeburn, Pennsylvania. After machining, the ingots were shipped to Canton Drop Forging Company, Canton, Ohio, and canned in Type 304SS seamless pipe. The ingots were extruded on November 15, 1965. The extrusion parameters are presented in Table I. Subsequently, the cans were removed and the billets were conditioned for forging at Anderson-Schumaker, Chicago, Illinois. Forging was to be performed at 2200°-2300°F on open face dies using a 6,000-pound hammer; however, inspection of the extrusions revealed extensive cracking along the entire length of both extrusions. A transverse slice of one of the extrusions was forwarded to General Electric for examination. Macrographs of the transverse section, shown in Figure 1, revealed three major cracks which were intergranular in nature and at approximately 120° intervals around the periphery of the extrusion. Additional metallographic examination, hardness testing, and chemical and x-ray diffraction, and fluorescence analyses are in progress at General Electric to investigate the nature and cause of the cracking of the T-111 alloy extrusions. Particular attention is being paid to the hafnium content and microstructure near the area of the cracks since Hf strips were welded to the Ta-8W electrodes at 120° intervals prior to arc melting[1].

----

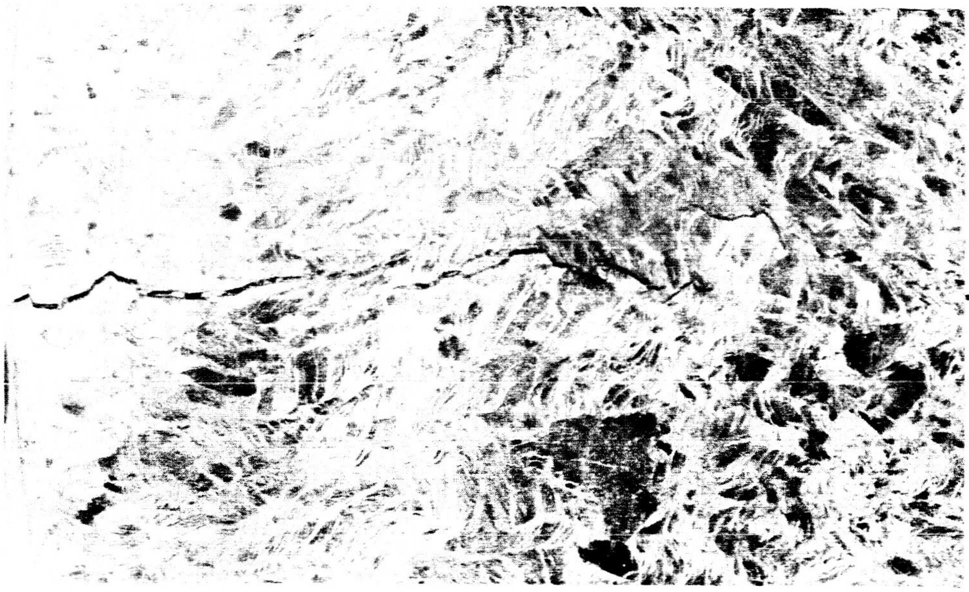
(1) Advanced Refractory Alloy Corrosion Loop Program, Quarterly Progress Report No. 2 for Period Ending 10/15/65, NASA Contract NAS 3-6474, NASA-CR-54845, p. 3.

TABLE I. EXTRUSION PARAMETERS FOR THE 8.44-INCH DIAMETER MACHINED T-111 ALLOY INGOTS*

Machined Ingot Size	-	8.44-inch diameter
Ingot Nose Geometry	-	90° angle
Can Size	-	9-1/16-inch OD x 1/4-inch thick wall Type 304SS seamless pipe with 2-inch thick Type 304SS nose block and 1/2-inch thick Type 304SS back-up block contained within the can with argon purge tubes attached
Leader Block/ Follow-up Block	-	9-1/16-inch diameter x 6-inch long mild steel
Container Size	-	9-1/4-inch ID
Die Size/Design	-	5-1/8-inch ID/conical
Die Coating	-	None
Extrusion Ratio	-	3.2/1
Lubricant	-	Hot die grease similar to Fiske 604
Furnace Temperature/ Soak Time in Salt Bath	-	2200°F/1 hour
Handling Time	-	90 seconds
Extrusion Pressure (Hydraulic)	-	2900 psi peak, average 2700 psi, runout, average
Maximum Allowable Pressure	-	Approximately 3850 psi
Cooling Procedure	-	Air cooled

----

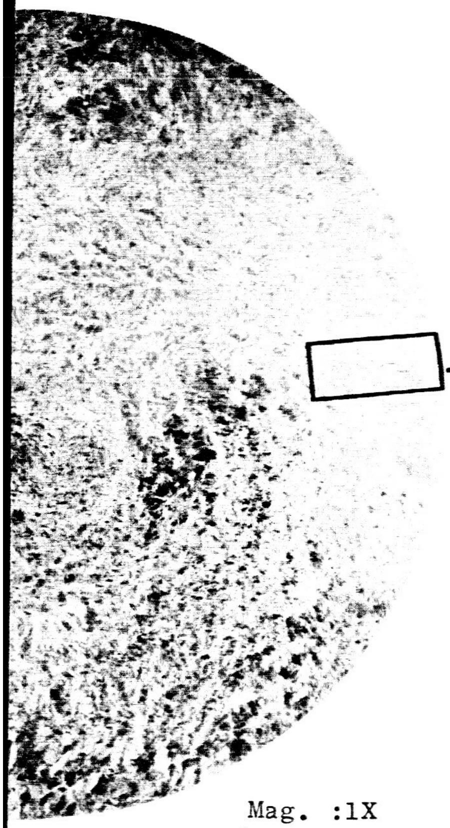
* Extruded at Canton Drop Forging Company, Canton, Ohio, on November 15, 1965.



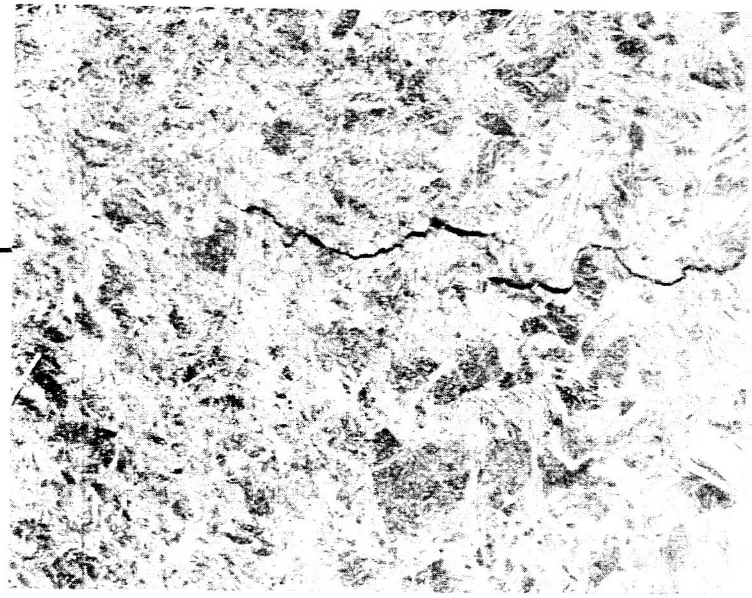
(C66010611) Mag. :6X

(C66010610) Mag. :6X

Figure 1. Macrographs of t
Showing Intergra
Intervals.
Etchant: 30HD-3



Mag. :1X
(C66010608)



(C66010609)

Mag. :6X

he T-111 Alloy Extension From Heat 111-D-1632
nular Cracks at Surface at Approximately 120°

0HF-15HNO_3

2

Fansteel has reported that the extrusions cleaned-up at 2-1/4-inch diameter and 3 3/4-inch diameter and that 13 items of the 28 items on order can be produced from this material. These items include small diameter bar from 1/8-inch diameter to 1-1/2-inch diameter, and 0.094-inch diameter wire, 0.005- and 0.009-inch thick foil, 0.040-inch thick sheet and 0.500-inch thick plate; delivery is expected early in February.

A third T-111 alloy ingot was vacuum arc melted by the Universal Cyclops Steel Corporation from available Ta-8W electron-beam melted electrode stock at Fansteel's Muskogee, Oklahoma plant. The ingot was shipped to Canton Drop Forging Company, canned in Type 304SS seamless pipe by heliarc welding, and extruded on January 10, 1966. The extrusion parameters are presented in Table II.

After extrusion, the can was removed and the billet was conditioned for forging. No cracks were found on the surface of the extrusion as determined by dye penetrant inspection techniques. The 2-1/2-inch diameter bar, 3/8-inch OD tubing and 1-inch OD tubing will be produced from this material, and delivery is expected by March 30, 1966. All of the remaining items will be produced from material currently being prepared for EB melting. Delivery of these items also is expected by March 30, 1966.

2. Mo-TZC Alloy - Climax Molybdenum Company. A 6-15/16-inch diameter vacuum arc melted and machined Mo-TZC alloy ingot was canned in unalloyed molybdenum by heliarc welding and shipped to Allegheny Ludlum, Watervliet, New York, for extrusion; the diameter of the canned ingot was 7-1/8 inches. The ingot was heated by induction to 3200°F (optical) in an argon atmosphere. An attempt to extrude the Mo-TZC alloy ingot in a

TABLE II. EXTRUSION PARAMETERS FOR THE 8.44-INCH DIAMETER MACHINED T-111 ALLOY INGOT*

Machined Ingot Size -	8.44-inch diameter
Can Size -	9-1/16-inch OD x 1/4-inch thick wall Type 304SS seamless pipe with a 2-inch thick Type 304SS nose block and a 1/2-inch thick Type 304SS back-up block contained within the can
Leader Block/ Follow-up Block -	9-1/16-inch diameter x 6-inch long mild steel
Container Size -	9-1/4-inch ID
Die Size/Design -	5-1/8-inch ID/conical
Die Coating -	None
Extrusion Ratio -	3.2/1
Lubricant -	Hot die grease similar to Fiske 604
Furnace Temperature/ Soak Time in Salt Bath -	2200°F/45 minute 2300°F/75 minute
Extrusion Pressure (Hydraulic) -	2500 psi peak 2400 psi runout
Maximum Allowable Pressure -	3850 psi
Cooling Procedure -	Air cooled
Extrusion Direction of Ingot -	Top of ingot was extruded through die first with hot top remaining on ingot

NOTE: The ingot was 3 inches too long for the container and the pressure had to be stopped before the extrusion was completed. The stem was withdrawn, a pusher block inserted in the container and subsequently the extrusion was completed (approximately 10-second delay). The tail of the extrusion showed cracks similar to those in the first extrusions.

---

* Extruded at Canton Drop Forging Company, Canton, Ohio, on January 10, 1966.

7-3/8-inch ID container was unsuccessful as failure of a valve to the accumulator resulted in a loss of pressure. Severe cracking of the ingot occurred as a result of the upsetting action in the container.

Two additional ingots of Mo-TZC alloy, machined from the same heat, were shipped to Allegheny Ludlum for extrusion. Prior to shipment, both ingots were vacuum annealed for one hour at 2800°F. The ingot sizes were:

Diameter, Inch	Length, Inch	Weight, lbs
5.4	12	102
6.0	21	233

The 5.4-inch diameter ingot was machined from the bottom of the original ingot and required more clean-up of the surface. The 21-inch length is a limiting dimension because of the length of the induction coil used for heating the ingots.

A second attempt to extrude at Allegheny Ludlum with the 5.4-inch ingot also was unsuccessful. The ingot failed to extrude at the full capacity of the press for the type and size of stem that was used. The extrusion parameters that were employed are presented in Table III.

Examination of the billet showed that about 2 inches had extruded before the ingot stalled in the press, and it was apparent that very little of the lubricant was on the surface. It is believed that lack of lubrication due to the possible use of too high a melting glass and/or the flat, shear-type die were responsible for the failure of the ingot to extrude. Subsequent inspection of the ingot revealed that severe cracking had occurred from the upsetting action. Extrusion of the third ingot is scheduled for the week of January 30, 1966.

TABLE III. EXTRUSION PARAMETERS FOR THE 5.4-INCH DIAMETER MACHINED CLIMAX Mo-TZC INGOT*

Machined Ingot Size -	5.4-inch diameter
Ingot Nose Geometry -	90° included angle; 3/4-inch radius
Leader Block -	None used
Follow-up Block -	2-inch thick mild steel at 1400°F
Container Size -	5.625-inch ID
Die Size/Design -	2.25-inch ID/flat shear-type
Die Coating -	ZrO_2
Extrusion Ratio -	6.25/1
Lubricant -	Proprietary glass + Fiske grease; 2 thicknesses of glass are placed in front of die; ingot is wrapped in blanket of glass.

Heat-Up Cycle (180 Cycle Induction Coil)

1. 75 KW 10 minutes to 2100°F
2. Power off 2 minutes to equalize temperature - 2000°F
3. 110 KW 15 minutes to 3200°F (optical), 3300°F (Ir/Rh thermocouple)

Extrusion Pressure on Stem -	Maximum allowable pressure, approximately 2000 ton
Cooling Procedure -	Air cooled

----

* Extruded at Allegheny Ludlum, Watervliet, New York, on January 4, 1966.

3. Mo-TZC Alloy - General Electric Company, LMCD. Four six-inch diameter Mo-TZC alloy ingots have been vacuum arc melted by the Lamp Metals and Components Department of General Electric Company. The ingots were machined to a nominal 5-1/16-inch diameter. The extrusion parameters that were employed are shown in Table IV.

Ultrasonic inspection of all of the extrusions revealed no internal defects. One ingot (Heat No. 4454) stuck during extrusion but it was possible to re-machine the surface and successfully reextrude to bar.

Two extrusions (4451 and 4453) were cross rolled to 1-3/8-inch thick plate for subsequent machining into nozzles for the turbine simulator. Attempts made to roll the first extrusion (4451) at a temperature of 2390°F (1300°C) resulted in severe cracking. The rolling cycle was modified for the second extrusion (4453) to provide for a 20% reduction to be made at 2912°F (1600°C) and a 20% reduction to be made at 2390°F (1300°C). The material was rolled to this schedule without difficulty.

The third extrusion (4454) was successfully cross rolled to 3/4-inch thick plate with approximately 40% reduction being made at a temperature of 2912°F (1600°C) and approximately 40% reduction being made at a temperature 2390°F (1300°C). This material is to be utilized for the machining of turbine blades.

Receipt of the 3/4-inch thick plate and the 1-3/8-inch thick plate is expected early in February.

TABLE IV. EXTRUSION PARAMETERS FOR 5.06-INCH DIAMETER MACHINED Mo-TZC ALLOY INGOTS*

Machined Ingot Size - 5.06-inch diameter

Leader Block - None

Follow-up Block - Graphite

Container Size - 5-3/16-inch ID

Die Size/Design - 2.1-inch x 4.1-inch/conical

Die Coating - ZrO_2

Lubricant - Proprietary - Ugine-Sejournet processed not used

	Heat No.		
	4451	4454	4453
Extrusion Ratio -	2.29/1	2.41/1	--
Furnace Temperature, °C -	1710	1710	1700
Soak Time, Hours/Minutes in Hydrogen	3:25	3:58	3:54
Handling Time, Seconds -	22.7	24.3	22.1

----

* Extruded at General Electric Research and Development Center, Schenectady, New York.

4. Cb-132M Alloy - Universal Cyclops Steel Corporation. A 5-3/8 inch diameter x 10.09-inch long Cb-132M alloy ingot was arc cast from an EB melted ingot by the Wah Chang Corporation and jacketed in a 5-7/8-inch OD, pressed and sintered molybdenum can. The canned ingot was successfully extruded by DuPont through a 3-3/4-inch ID die at a temperature of 3100°F. The extrusion parameters employed are presented in Table V. The dimensions of the Cb-132M alloy extrusion were approximately 3-1/2 inches in diameter x 24 inches long. Subsequently, the extrusion was stress-relieved at 2200°F. During press straightening, at approximately 2200°F, the extrusion cracked in the center throughout the entire length. A new ingot is to be melted by the Wah Chang Corporation.

A revised delivery schedule for this material has not been received to date.

B. ALKALI METAL PURIFICATION AND HANDLING

Fifty pounds of LCA High-Purity lithium were received from the Lithium Corporation of America. The vendor's typical and guaranteed analysis of this lithium is presented in Table VI.

Analyses of this material by General Electric indicated a nitrogen content of 600-1200 ppm, an oxygen content of 335 ppm, and metallic impurities near or below the limits of detection (5-25 ppm)*. The vendor indicated that this original batch of lithium had been contaminated with lithium amide ($LiNH_2$) which accounted for the high nitrogen content, and the shipment was returned for replacement.

---

* Ag, Al, B, Be, Ca, Cb, Co, Cs, Cu, Fe, Mg, Mn, Mo, Na, Ni, Pb, Si, Sn, Ti, V, Zr

TABLE V. EXTRUSION PARAMETERS FOR 5.375-INCH DIAMETER MACHINED Cb-132M ALLOY INGOT*

Machined Ingot Size - 5.375-inch diameter

Ingot Nose Geometry - 135° included angle

Can Size - 5-7/8-inch OD pressed and sintered molybdenum

Leader Block - None

Follow-up Block - Graphite

Container Size - 6.00-inch ID

Die Size/Design - 3-3/4-inch ID/conical

Die Coating - ZrO_2

Extrusion Ratio - 2.55/1

Lubricant - Proprietary glass; 1-inch thick pad in front of die

Handling Time, Seconds - 35

Ingot Temperature (Corrected, Optical), °F - Top, 3090
Middle, 3050
Bottom, 3050

Soak Time in Argon, Minutes - 45

Extrusion Pressure on Stem - 1075 ton peak

Cooling Procedures - Buried in insulation, slow cool

---

* Extruded at E. I. DuPont de Nemours, November 17, 1965.

TABLE VI. INFORMATION ON THE PURITY OF LITHIUM PRESENTED BY THE LITHIUM CORPORATION OF AMERICA

Chemical Analysis	Maximum Content (ppm in Li)	
	Typical	Guaranteed
Nitrogen	20	50
Chlorine	10	30
Sodium	10	30
Calcium	50	50
Iron	10	20
Silicon	40	40
Lithium	99.9 + %	--

The lithium shipping container was emptied, cleaned by flushing with water, emptied, dried by purging with argon at 300°F for two days, and refilled with a new charge of lithium. Analyses of the new charge by the vendor and General Electric are presented in Table VII.

This lot of lithium was accepted as being representative of the vendor's present capabilities, and hot trapping, filtration, and distillation of the lithium will be used to reduce the nitrogen and calcium concentrations to acceptable levels. A sample of the lithium was filtered through a 5-micron pore size, sintered stainless steel filter (area - 0.5 square feet) at 400°F. This filtration resulted in significant reductions in carbon and calcium as shown in Table VII. Again, the other metallic impurities were at or below the detection limits. It is believed that filtration could be performed at a temperature below 400°F since the pressure drop across the filter at 400°F was only 15-17 psi, thereby accruing further reductions in carbon and calcium (and possibly oxygen). Lower temperature filtration will therefore be employed in filling the lithium hot trap. Samples taken before and after filtration have been sent to General Atomic, San Diego, California for oxygen analyses by fast neutron activation.

All lithium purification system drawings were completed during the past quarter and will be submitted to the NASA Program Manager for approval.

The lithium purification system dolly frame and various component support structures were received. Installation of the electrical outlets and other structures on the dolly frame was initiated. Fabrication and assembly of the argon-high vacuum manifold was started and essentially completed.

TABLE VII. CHEMICAL ANALYSIS OF LITHIUM

Analysis Performed by	Chemical Analysis, ppm		
	N	C	Ca
Lithium Corporation of America (Vendor)	400	-	170
	800	-	390
General Electric (As-Received)*	801	134	133
	834	158	
	871		
General Electric (Filtered at 400°F Through a 5-Micron Filter)*	755	97	53
	778	101	-
	841	-	-

---

* Metallic Impurities Near or Below the Limits of Detection (5-25 ppm).

The fabrication of the 35-pound capacity hot trap for lithium was completed. This equipment is shown in Figures 2 and 3, before and after assembly, respectively. It consists of a Type 316 stainless steel container fitted with a fill valve, dip leg valve, inert gas valve, thermocouple well, level probe well, titanium liner, and zirconium getter, The fill and dip leg valves are Hoke* HY 473A's mounted in the inverted position with the bellows toward the hot trap so that they may be easily cleaned to the valve seat. The gas valve is a Hoke TY 445. The getter foil bundle was produced from 0.012-inch thick Reactor Grade zirconium sheet. The lithium mass to getter surface area ratio is 2.5 gms lithium/ in^2 zirconium and titanium for a 35-pound charge.

The liquid metal level detection system was received from Mine Safety Appliances Research Corporation (MSAR), Callery, Pennsylvania(2). This device is basically an inductance mechanism wherein one leg of an inductance bridge is used as a sensing probe. A change in inductance occurs when the probe is in the vicinity of the liquid metal level. The system is equipped with an internal probe which is inserted in a non-magnetic well which extends to the bottom of the container, and a second probe which can be used to detect the alkali metal level by movement of the probe along the outside of the non-magnetic containers. The system is designed for austenitic stainless steel but can be used with Cb-1Zr alloy tubing where

---

* Hoke, Incorporated, Cresskill, New Jersey

(2) Advanced Refractory Alloy Corrosion Loop Program, Quarterly Progress Report No. 2 for Period Ending October 15, 1965, NASA Contract NAS 3-6474, NASA-CR-54845, p 15.

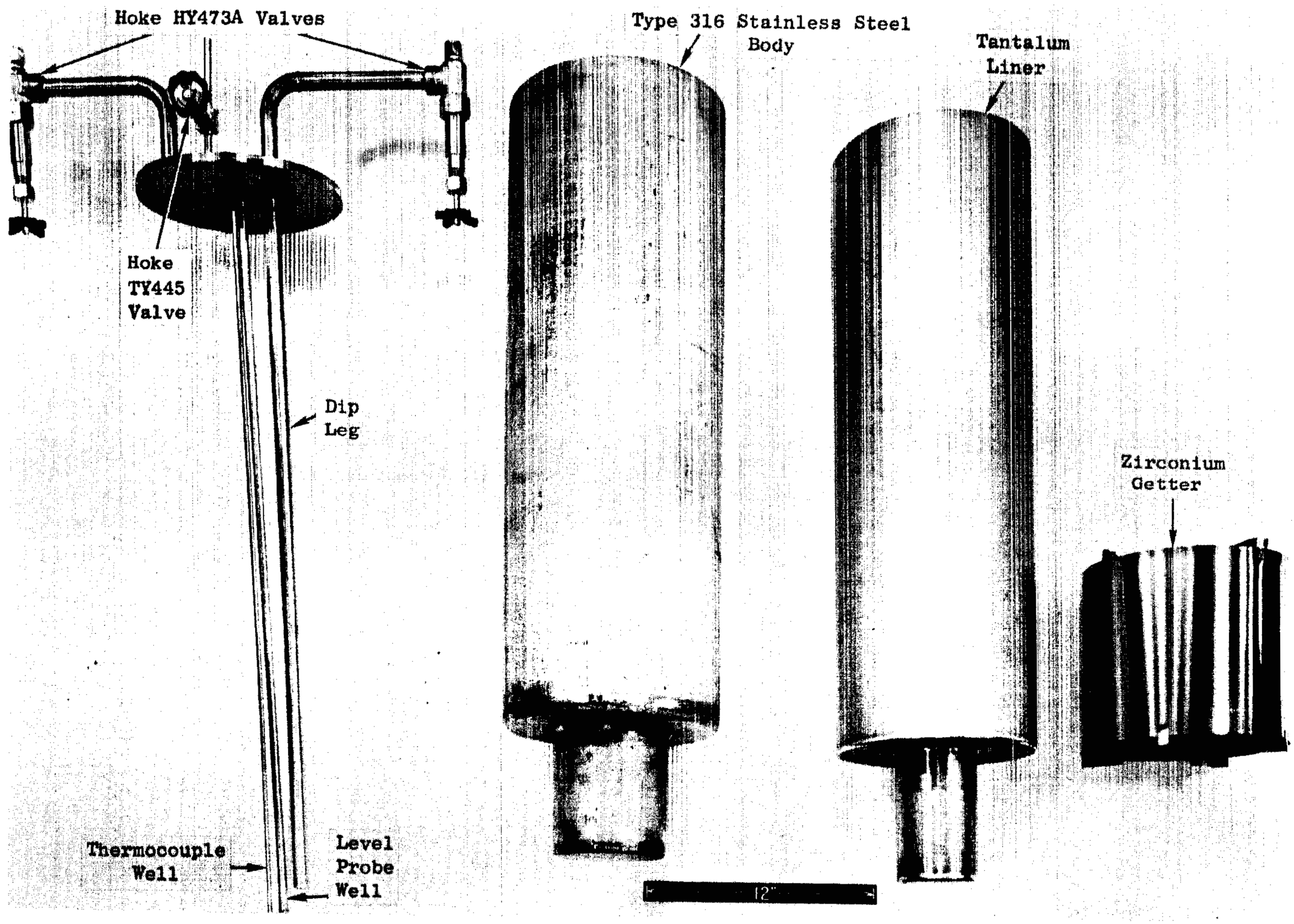


Figure 2. 35-Pound Capacity Lithium Hot Trap Before Assembly. (Orig. 65111625)

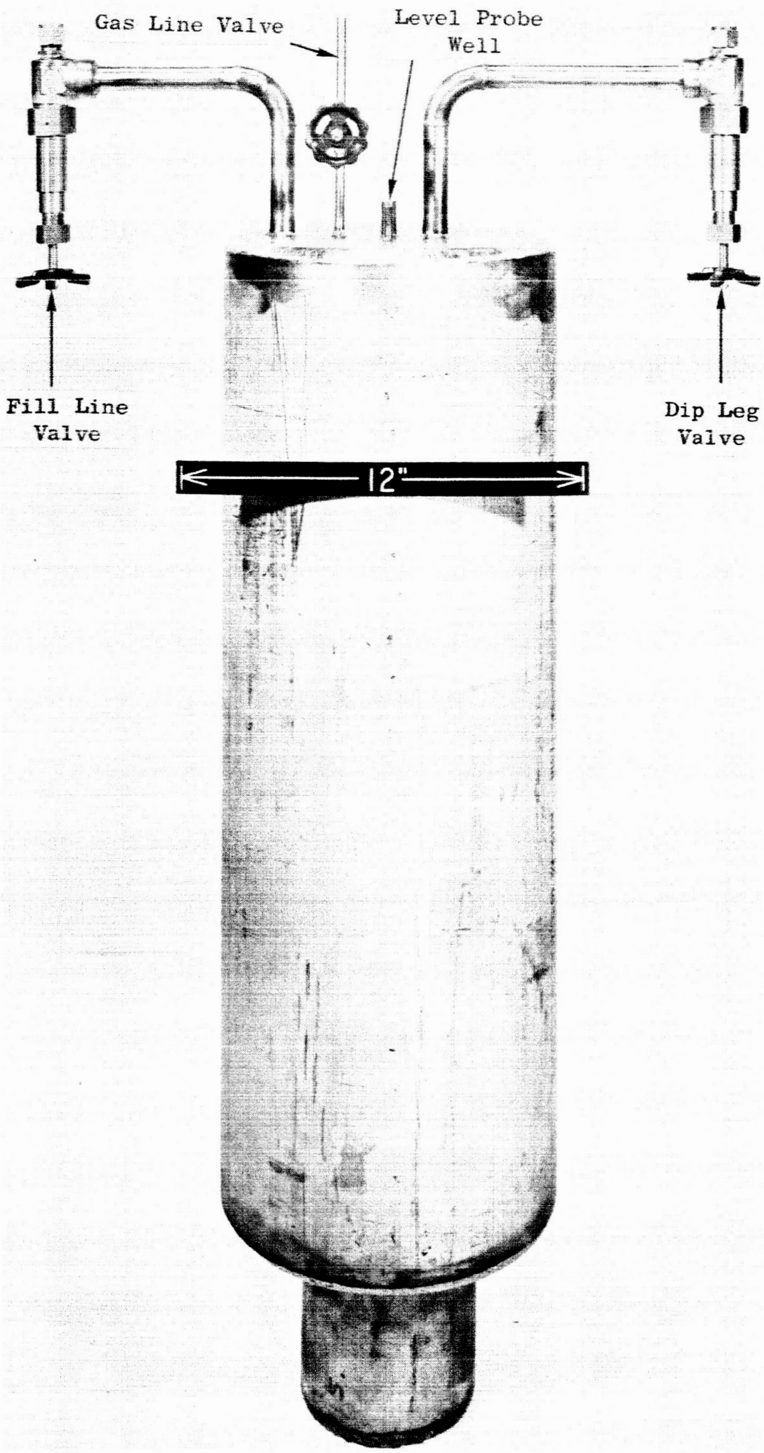


Figure 3. 35-Pound Capacity Lithium Hot Trap After Assembly. (Orig. C65111823)

the thickness does not exceed 60 mils. The internal probe has been found accurate to ± 1/8-inch in stainless steel and Cb-1Zr tubing with lead being the metal detected as a matter of convenience. The external probe accuracy is ± 1/4-inch through stainless steel to lead. The probe system can be used at temperatures up to 1200°F although the probe is removed before hot trapping.

C. QUALITY ASSURANCE

1. Specifications. Specifications were prepared for welding and postweld vacuum annealing of T-111 (Ta-8W-2Hf) alloy and submitted to the NASA Program Manager for approval. A new specification outlining the cleaning, packaging, and handling procedures to be used for Corrosion Loop I (T-111) components and assemblies is also nearing completion. These specifications constitute the major effort required to up-date process specifications for Corrosion Loop I (T-111) fabrication.

2. Bimetallic Joints. T-111 alloy to Type 316 stainless steel joints are required on the NaK lines of the slack diaphragm pressure transducers. No fabrication difficulties are anticipated since previously produced Cb-1Zr alloy to Type 316 stainless steel joints are quite similar in metallurgical properties. However, sample T-111 alloy to Type 316 stainless steel bimetallic joints have been machined and will be brazed to be certain that no unforeseen difficulties are present.

3. T-111 to Cb-1Zr Alloy Welding. Corrosion Loop I (T-111) will utilize the Cb-1Zr surge tanks presently in service on the Prototype Corrosion Loop. The transition to T-111 alloy will occur between the T-111 alloy loop fill tubes and the Cb-1Zr alloy surge tanks. Although the welding requirements for the T-111 and Cb-1Zr alloys are quite similar, the selection of weld

filler wire and postweld annealing treatment requires a brief welding study. Tungsten inert arc welds have been made between suitable sheet materials to study the weldment bend characteristics. Both as-welded and postweld annealed specimens are being tested. Postweld anneals have been performed at 2200°F and 2400°F. Aging will be performed at 1500°F for 50 hours.

4. Postweld Cleaning. Tantalum wire brushes have been obtained and employed to remove metal vapor deposits from T-111 alloy weld specimens. These brushes were produced at no cost by Pittsburgh Plate Glass from tantalum wire supplied by G.E. Although a minor consideration, employment of refractory alloy brushes of the same base metal composition as the material to be cleaned is a further example of an improvement in the state-of-the-art in fabrication of refractory alloy components.

5. Acid Pickling of T-111 Alloy. Experiments with various pickling solutions have indicated that some tend to promote hydrogen pickup in the T-111 alloy(1). A solution of 1 part H_2SO_4, 2 parts Hf, 4 parts HNO_3, and 2 parts H_2O has been used to pickle T-111 alloy sheet specimens with subsequent chemical analysis indicating no detectable hydrogen pickup. Similar tests are planned with tubing specimens.

D. LOOP DESIGN

Although the over-all loop design was essentially completed last quarter, a continuing effort to improve the detail drawings is in progress. The major effort has been in the changes to specifications and drafting practices to comply with the quality control program and the addition of new sub-assembly drawings to aid in the scheduling of the fabrication of

---

* Determination of the Weldability and Elevated Temperature Stability of Refractory Metal Alloys, Eigth Quarterly Report, NASA Contract NAS 3-2540, NAS-CR-54723.

the loop. The changes include more realistic tolerance specifications and inspection procedures developed during the fabrication of the Prototype Loop. New sub-assembly drawings were made to group connecting components, which are scheduled for simultaneous furnace heat treating in specific facilities, into convenient sub-assemblies. During the fabrication phase of the Prototype Loop this had been handled by the use of detailed process sheets, since specific processes and facilities could not be defined during the design phase of the program.

In addition, several changes were made in the loop design based on the experience gained during the operation of the Prototype Loop. The lithium heater electrodes will be lengthened by 2 inches and fixtures with Cb-1Zr bolts threaded on both ends. The longer length will lower the tantalum/copper bus bar junction temperature. The lower coefficient of thermal expansion of the Cb-1Zr bolts, as compared to the stainless steel bolts employed in the Prototype Loop, should limit the possibility of an open circuit resulting from thermally induced slack.

The number of bends in the Corrosion Loop I (T-111) design was checked and found to be adequate to accommodate the thermal expansion of various loop components. The flowmeter magnets have been re-oriented to assure that orientation between the pole pieces will be maintained after heat-up of the loop. Shields will be employed on the copper bus bars to optically shield them from radiation heat sources in the test chamber. Attachment of these Cb-1Zr alloy shields will be described in the test plan.

IV FUTURE PLANS

A. Monitoring the fabrication of refractory alloy materials for Corrosion Loop I (T-111) will continue with special emphasis placed on meeting the new schedules.

B. Thirty-five pounds of lithium will be filtered and hot trapped to reduce the nitrogen concentration to acceptable levels.

C. A complete set of drawings on the Alkali Metal Purification and Handling System for Corrosion Loop I (T-111) will be submitted to the NASA Program Manager for approval.

D. All Corrosion Loop I (T-111) design drawings will be completed and submitted to the NASA Program Manager for approval.

DISTRIBUTION LIST
QUARTERLY AND FINAL PROGRESS REPORTS

Contract NAS3-6474

NASA
Washington, D.C. 20546
Attention: Arvin Smith (RNW)

NASA
Washington, D.C. 20546
Attention: James J. Lynch (RNP)

NASA
Washington, D.C. 20546
Attention: George C. Deutsch (RR)

NASA
Washington, D.C. 20546
Attention: Dr. Fred Schulman (RNP)

NASA
Scientific & Technical Information Facility
P.O. Box 33
College Park, Maryland 20740
Attention: Acquisitions Branch (SQT-34054)(2+repro.)

NASA
Ames Research Center
Moffett Field, California 94035
Attention: Librarian

NASA
Goddard Space Flight Center
Greenbelt, Maryland 20771
Attention: Librarian

NASA
Langley Research Center
Hampton, Virginia 23365
Attention; Librarian

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: Librarian, MS 3-7

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: Dr. Bernard Lubarsky (SPSD), MS 500-201

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: Roger Mather (NPTB), MS 500-309

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: G. M. Ault, MS 105-1

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: R. L. Davies (NPTB), MS 500-309 (2)

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: John E. Dilley (SPSPS), MS 500-309

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: John Weber, MS 3-19

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: T. A. Moss, MS 500-309

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: Dr. Louis Rosenblum (MSD), MS 106-1

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: Report Control Office, MS 5-5

NASA
Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
Attention: V. Hlavin, MS 3-14 (Final only)

NASA
Manned Spacecraft Center
Houston, Texas 77001
Attention: Librarian

NASA
George C. Marshall Space Flight Center
Huntsville, Alabama 38512
Attention: Librarian

NASA
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 99103
Attention: Librarian

NASA
Western Operations Office
150 Pico Boulevard
Santa Monica, California 90400
Attention: John Keeler

National Bureau of Standards
Washington, D.C. 20225
Attention: Librarian

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio
Attention: Charles Armbruster,
ASRPP-10

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio
Attention: T. Cooper

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio
Attention: AFAPL (APIP)

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio
Attention: George E. Thompson,
APIP-1

Flight Vehicle Power Branch
Air Force Aero-Propulsion Lab
Wright-Patterson Air Force Base, Ohio
Attention: George Glenn

Army Ordnance Frankford Arsenal
Bridesburg Station
Philadelphia, Pennsylvania 19137
Attention: Librarian

Bureau of Mines
Albany, Oregon
Attention: Librarian

Bureau of Ships
Department of the Navy
Washington, D.C. 20225
Attention: Librarian

Bureau of Weapons
Research & Engineering
Materials Division
Washington, D.C. 20225
Attention: Librarian

U.S. Atomic Energy Commission
Technical Reports Library
Washington, D.C. 20545
Attention: J. M. O'Leary (2)

U.S. Atomic Energy Commission
Germantown, Maryland 20767
Attention: H. Finger

U.S. Atomic Energy Commission
Germantown, Maryland 20767
Attention: H. Rochen,
SNAP 50/SPUR Project Office

U.S. Atomic Energy Commission
Germantown, Maryland 20767
Attention: Col. Gordon Dicker,
SNAP 50/SPUR Project Office

U.S. Atomic Energy Commission
Germantown, Maryland 20767
Attention: K. E. Horton

U.S. Atomic Energy Commission
Technical Information Service Extension
P.O. Box 62
Oak Ridge, Tennessee 27831 (3)

U.S. Atomic Energy Commission
Washington, D.C. 20545
Attention: M. J. Whitman

Office of Naval Research
Power Division
Washington, D.C. 20225
Attention: Librarian

U.S. Naval Research Laboratory
Washington, D.C. 20225
Attention: Librarian

American Machine and Foundry Company
Alexandria Division
1025 North Royal Street
Alexandria, Virginia
Attention: Librarian

Aerojet-General Corporation
P.O. Box 296
Azusa, California 91702
Attention: Librarian

Aerojet-General Corporation
P.O. Box 296
Azusa, California 91702
Attention: R. S. Carey

Aerojet-General Nucleonics
P.O. Box 77
San Ramon, California 94583
Attention: Librarian

AiResearch Manufacturing Company
Sky Harbor Airport
402 South 36th Street
Phoenix, Arizona 85034
Attention: Librarian

AiResearch Manufacturing Company
Sky Harbor Airport
402 South 36th Street
Phoenix, Arizona 85034
Attention: E. A. Kovacevich

AiResearch Manufacturing Company
Sky Harbor Airport
402 South 36th Street
Phoenix, Arizona 85034
Attention: John Dannan

AiResearch Manufacturing Company
9851-9951 Sepulveda Boulevard
Los Angeles, California 90045
Attention: Librarian

Argonne National Laboratory
9700 South Cross Avenue
Argonne, Illinois 60440
Attention: Librarian

Atomics International
8900 DeSoto Avenue
Canoga Park, California 91303
Attention: Librarian

Atomics International
8900 DeSoto Avenue
Canoga Park, California 91303
Attention: Harry Pearlman

Avco
Research and Advanced Development Department
201 Lowell Street
Wilmington, Massachusetts 01800
Attention: Librarian

Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201
Attention: Librarian

Battelle Memorial Institute
505 King Avenue
Columbus, Ohio 43201
Attention: Dr. E. M. Simmons

Battelle-Northwest Labs.
P.O. Box 999
Richland, Washington 99352

The Bendix Corporation
Research Laboratories Division
Southfield, Michigan 48200
Attention: Librarian

The Boeing Company
Seattle, Washington 98100
Attention: Librarian

Brookhaven National Laboratory
Upton Long Island, New York 11973
Attention: Librarian

Chance Vought Aircraft, Incorporated
P.O. Box 5907
Dallas, Texas 75222
Attention: Librarian

Clevite Corporation
Mechanical Research Division
540 East 105th Street
Cleveland, Ohio 44108
Attention: N. C. Beerli, Project Administrator

Convair Astronautics
5001 Kerrny Villa Road
San Diego, California 92111
Attention: Librarian

Curtiss-Wright Corporation
Wright-Aeronautical Division
Wood-Ridge, New Jersey 07075
Attention: S. Lombardo

Ford Motor Company
Aeronutronics
Newport Beach, California 92660
Attention: Librarian

General Atomic
John Jay Hopkins Laboratory
P.O. Box 608
San Diego, California 92112
Attention: Librarian

General Atomic
John Jay Hopkins Laboratory
P.O. Box 608
San Diego, California 92112
Attention: Dr. Ling Yang

General Electric Company
Atomic Power Equipment Division
P.O. Box 1131
San Jose, California

General Electric Company
Missile and Space Division
P.O. Box 8555
Philadelphia, Pennsylvania 19114
Attention: Librarian

General Electric Company
Vallecitos Atomic Lab.
Pleasanton, California 94566
Attention: Librarian

General Dynamics/Fort Worth
P.O. Box 748
Fort Worth, Texas 76100
Attention: Librarian

General Motors Corporation
Allison Division
Indianapolis, Indiana 46206
Attention: Librarian

Hamilton Standard
Division of United Aircraft Corporation
Windsor Locks, Connecticut
Attention: Librarian

Hughes Aircraft Company
Engineering Division
Culver City, California 90230-2
Attention: Librarian

IIT Research Institute
10 West 35th Street
Chicago, Illinois 60616
Attention: Librarian

Lockheed Missiles and Space Division
Lockheed Aircraft Corporation
Sunnyvale, California
Attention: Librarian

Lockheed Missiles and Space Division
Lockheed Aircraft Corporation
Sunnyvale, California
Attention: John N. Cox, Staff Engineer

Marquardt Aircraft Company
P.O. Box 2013
Van Nuys, California
Attention: Librarian

The Martin Company
Baltimore, Maryland 21203
Attention: Librarian

The Martin Company
Nuclear Division
P.O. Box 5042
Baltimore, Maryland 21220
Attention: Librarian

Martin Marietta Corporation
Metals Technology Laboratory
Wheeling, Illinois

Materials Research and Development
Manlabls, Incorporated
21 Erie Street
Cambridge, Massachusetts 02139

Materials Research Corporation
Orangeburg, New York
Attention: Librarian

McDonnel Aircraft
St. Louis, Missouri 63100
Attention: Librarian

MSA Research Corporation
Callery, Pennsylvania 16024
Attention: Librarian

North American Aviation
Los Angeles Division
Los Angeles, California 90009
Attention: Librarian

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attention: W. H. Cook

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attention: W. O. Harms

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attention: Dr. A. J. Miller

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attention: Librarian

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attention: J. H. DeVan

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Attention: G. Goldberg

Pratt & Whitney Aircraft
400 Main Street
East Hartford, Connecticut 16108
Attention: Librarian

Republic Aviation Corporation
Farmingdale, Long Island, New York
Attention: Librarian

Rocketdyne
Canoga Park, California 91303
Attention: Librarian

Solar
2200 Pacific Highway
San Diego, California 92112
Attention: Librarian

Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78206

Superior Tube Company
Norristown, Pennsylvania
Attention: A. Bound

Sylvania Electrics Products, Incorporated
Chemical & Metallurgical
Towanda, Pennsylvania
Attention: Librarian

TRW Inc.
Caldwell Res Center
23555 Euclid Avenue
Cleveland, Ohio 44117
Attention: Librarian

Union Carbide Corporation
Stellite Division
Kokomo, Indiana
Attention: Librarian

Union Carbide Nuclear Company
P.O. Box X
Oak Ridge, Tennessee 37831
Attention: X-10 Laboratory,
Records Department (2)

Union Carbide Metals
Niagara Falls, New York 14300
Attention: Librarian

Mr. W. H. Podolny
United Aircraft Corporation
Pratt & Whitney Division
400 W. Main Street
Hartford, Connecticut 06108

United Nuclear Corporation
Five New Street
White Plains, New York 10600-5
Attention: Librarian

Union Carbide Corporation
Parma Research Center
P.O. Box 6115
Cleveland, Ohio 44101
Attention: Technical Information Services

Wah Chang Corporation
Albany, Oregon
Attention: Librarian

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

Westinghouse Electric Corporation
Astronuclear Laboratory
P.O. Box 10864
Pittsburgh, Pennsylvania 15236
Attention: R. T. Begley

Westinghouse Electric Corporation
Materials Manufacturing Division
RD #2 Box 25
Blairsville, Pennsylvania
Attention: Librarian

Westinghouse Electric Corporation
Aerospace Electrical Division
Lima, Ohio
Attention: P. E. Kueser

Westinghouse Electric Corporation
Research & Development Center
Pittsburgh, Pennsylvania 15235
Attention: Librarian

Wyman-Gordon Company
North Grafton, Massachusetts
Attention: Librarian

Grumman Aircraft
Bethpage, New York
Attention: Librarian

Lawrence Radiation Laboratory
Livermore, California
Attention: Dr. James Hadley

Lawrence Radiation Laboratory
Livermore, California
Attention: Librarian (2)

Allis Chalmers
Atomic Energy Division
Milwaukee, Wisconsin
Attention: Librarian

Allison-General Motors
Energy Conversion Division
Indianapolis, Indiana
Attention: Librarian

AMF Atomics
140 Greenwich Avenue
Attention: Librarian

Douglas Aircraft Company, Incorporated
Missile and Space Systems Division
3000 Ocean Park Boulevard
Santa Monica, California
Attention: Librarian

Climax Molybdenum Company of Michigan
1600 Huron Parkway
Ann Arbor, Michigan 48105
Attention: Librarian

Climax Molybdenum Company of Michigan
1600 Huron Parkway
Ann Arbor, Michigan 48105
Attention: Dr. M. Semchyshen

Fansteel Metallurgical Corporation
North Chicago, Illinois
Attention: Librarian

National Research Corporation
405 Industrial Place
Newton, Massachusetts
Attention: Librarian

Varian Associates
Vacuum Products Division
611 Hansen Way
Palo Alto, California
Attention: Librarian

Ultek Corporation
920 Commercial Street
Palo Alto, California
Attention: Librarian