COO-2975-25

ADVANCED GAS COOLED NUCLEAR REACTOR MATERIALS
EVALUATION AND DEVELOPMENT PROGRAM

Progress Report for July 1—September 30, 1978

MASTER

November 24, 1978

Work Performed Under Contract No. EY-76-C-02-2975

General Electric Company
Energy Systems Programs Department
Schenectady, New York

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PROGRESS REPORT FOR PERIOD

July 1, 1978 — September 30, 1978

BY
PROJECT STAFF

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GENERAL ELECTRIC
ENERGY SYSTEMS PROGRAMS DEPARTMENT
SCHENECTADY, NEW YORK 12345

November 24, 1978

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FOREWORD

The Advanced Gas Cooled Nuclear Reactor Materials Evaluation and Development Program is being conducted for the Nuclear Power Development Division, U. S. Department of Energy, by the Energy Systems Programs Department, General Electric Company, Schenectady, New York 12345. The Program is under the direction of Mr. J. E. Fox, DOE Program Manager, and is being managed for the General Electric Company by Mr. R. G. Frank, Manager, Materials Technology. The Principal Investigator for the Program is Dr. O. F. Kimball, Manager, Gas Reactor Materials, (Dr. J. F. Stubbins, Gas Reactor Materials), with responsibility for overall technical coordination. Other major contributors to the Program are:

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ABSTRACT

This report presents the results of work performed from July 1, 1978 through September 30, 1978 on the Advanced Gas Cooled Nuclear Reactor Materials Evaluation and Development Program. The objectives of this program are to evaluate candidate alloys for Very High Temperature Reactor Nuclear Process Heat (NPH) and Direct Cycle Helium Turbine (DCHT) applications, in terms of the affect of simulated reactor primary coolant (Helium containing small amounts of various other gases), the high temperatures, and long time exposures, on the mechanical properties and structural and surface stability of selected candidate alloys. A second objective is to select and recommend materials for future test facilities and more extensive qualification programs.

Work covered in this report includes the activities associated with the characterization of the materials for the screening test program, i.e., test specimen preparation, information from the materials characterization tests performed by General Electric, and the status of the simulated reactor helium supply system, testing equipment, and gas chemistry analysis instrumentation and equipment. Finally, the status of the data management system is presented.

ADVANCED GAS COOLED NUCLEAR REACTOR
MATERIALS EVALUATION AND DEVELOPMENT PROGRAM

1.0 INTRODUCTION

The Very High Temperature Reactor (VHTR) Nuclear Process Heat (NPH) and the Direct Cycle Helium Turbine (DCHT) Systems are being developed to provide an expanded nuclear power capability. In both cases the use of high temperature helium-cooled reactors will require a knowledge of the long term properties of reactor primary coolant containment materials and of the materials used in constructing related hardware. Because of the very high temperatures required for NPH and DCHT applications, the need is evident for materials testing in the proper helium environment in the temperature range from 760 - 1093°C (1400 - 2000°F) on those alloys which might serve as materials of construction for heat exchangers, ducting, turbine buckets and vanes and other high temperature structural components.

The objectives of the Advanced Gas Cooled Nuclear Reactor Materials Evaluation and Development Program are to:

1. Evaluate candidate alloys for Very High Temperature Reactor (VHTR) Nuclear Process Heat (NPH) and Direct Cycle Helium Turbine (DCHT) applications, in terms of the effect of the primary coolant exposure and thermal exposure on:

- Surface stability ("corrosion" resistance) in 10,000 hours.
- Structural stability in 10,000 hours - changes in micro-structure and tensile, impact and fatigue properties.
- Creep properties in 15,000 hours.
- Stress rupture properties in 10,000 hours.
- Fatigue properties.

Low cycle 10^3 to 10^5 cycle

High cycle 10^5 to 10^7 cycle

2. Select and recommend materials for future test facilities and more extensive qualification programs.

The data base will permit the selection of materials of construction and should provide a reliable level of design data for the construction of various items of development hardware leading to the successful development of NPH and DCHT systems. The present lack of an accurate measure of materials capabilities under these high temperature helium environments is a factor which is currently limiting the development of the NPH/DCHT systems. This program is intended to provide such initial information.

Section 2.0

PROGRAM STATUS

2.0 PROGRAM STATUS

The Advanced Gas Cooled Reactor Materials Evaluation and Development Program is organized into nine (9) tasks which are designed to accomplish the program objectives listed in Section 1.0 of this report. The task structures (Program Work Breakdown Structure) and a brief description of each task (Program Work Statement) have been included in the first quarterly report covering the period September 23, 1976 - December 31, 1976: C00-2975-3.

2.1 TASK 1 - SELECTION OF CANDIDATE ALLOYS

The selection of alloys for the screening phase of the program has been completed. A list of the alloys selected for the program was presented in the quarterly report for the period July 1, 1977 - September 30, 1977: C00-2975-17.

2.2 TASK 2 - MATERIALS PROCUREMENT AND CHARACTERIZATION

2.2.1 Direct Cycle Helium Turbine (DCHT) Alloys - (E.W.Ross)

2.2.1.1 Materials Procurement

Alloys/Processes - All 13 alloy/process materials to be evaluated have been received by the end of March, 1978. This subtask is complete.

Surface Treatments (Coatings and Preoxidation) - Twelve alloy 713LC creep specimens and 32 structural stability pins have been coated with Codep B coating (aluminide) by Walbar Metals, Inc. and have been received. To achieve approximately 0.07 mm (0.0028 in.) thickness, the specimens were coated for 8 hours at $1050^{\circ}\text{C} \pm 14^{\circ}\text{C}$ ($1925^{\circ}\text{F} \pm 25^{\circ}\text{F}$) in a 4% Al pack. Seven TZM creep specimens and 20 structural stability pins are in the process of being coated in the W3 coating (silicide) by Chromalloy American Corp. The coated specimens will be received by October 8, 1978.

The preoxidation treatment conditions for a group of Rene' 80, M21 and coated alloy 713LC structural stability pins have been selected. The pins will be heat treated for 10 hours at 1050°C (1925°F) in hydrogen with approximately 100 ppm of water vapor {-42°C (-45°F) dew point}. This should allow Al₂O₃ and TiO₂ to form but not Cr₂O₃.

2.2.1.2 Materials Characterization

All materials characterization testing including tensile and stress-rupture acceptance testing and the 300-hour creep and rupture testing for long time stress verification has been completed during this reporting period.

Although the chemical compositions of the 13 alloys/processes (MM-0011 is to be tested in both the Conventionally Cast - CC and Directionally Solidified - DS forms) were reported previously and they are repeated in Table 2.1 for sake of completeness. The results of the tensile and short time stress-rupture materials acceptance tests are shown in Tables 2.2 and 2.3, respectively. General Electric test results, vendor-supplied data and, where applicable, materials specifications, are listed. No major deviations from the material specifications are reported.

The 300-hour rupture and 1% creep test results from verification of previously selected 3000-10,000 hour stress levels for the ten alloys/processes which will be tested in multi-specimen screening creep in controlled purity He and (except TZM) in air are shown in Tables 2.4 and 2.5 respectively. It is of interest to note that the lot of MA-754 that was procured for the program is much stronger in both creep and rupture than other previous lots of MA-754 recently tested at General Electric Aircraft Engine Business Group at Cincinnati, Ohio. The rupture tests at 950°C (1742°F) and 1050°C (1922°F) at stresses selected for rupture in 300 hours were discontinued after over 1000 hours. A 850°C (1562°F) test was conducted at 31 MPa (4.5 ksi) above the average stress rupture curve and it failed in only 10 hours. In the creep testing, the 950°C (1742°F) test at 10 MPa (1.5 ksi) above the previously run rupture test reached 1% total strain in 35 hours and had only 2.4% total strain when discontinued at 384 hours. The 1050°C (1922°F) creep test also was

TABLE 2.1
CHEMICAL COMPOSITION(a) OF DCHT ALLOYS

Alloy	Heat No.	Element (Weight-%)														
		Cr	Ni	W	Fe	Co	Mo	Al	Ti	Cb	Ta	Zr	B	C	Other	NV ₃₈
Rene' 80	7-11029	14.0	Bal	4.10	0.09	9.30	3.9	3.00	5.00	-	-	0.03	0.01	0.15	-	2.31
NX-188	6-9266	-	Bal	-	0.14	-	18.00	7.90	-	-	-	-	-	0.04	-	-
MM-0011 (CC+DS)	7-10768	8.20	Bal	9.80	0.02	10.00	0.64	5.45	0.99	-	2.91	0.07	0.015	0.14	1.41Hf	-
Rene' 100	7-11047	9.85	Bal	-	0.20	15.18	3.03	5.46	4.19	-	-	0.07	0.015	0.18	1.05V	2.46
IN-738	141C6869	15.82	Bal	2.50	0.11	8.10	1.76	3.30	3.32	.65	1.60	0.03	0.011	0.10	-	2.24
Alloy 713 LC	66B6965	12.00	Bal	-	0.15	0.10	4.10	5.95	0.71	2.04	-	0.06	0.007	0.06	-	-
TZM	TZM10834	-	<0.001	-	0.002	-	Bal	-	0.43	-	-	0.093	-	0.022	-	-
M-21	B620	5.9	Bal	10.5	0.18	0.23	2.05	6.00	-	1.3	-	0.14	0.022	0.10	-	-
MA-754	DT0110B	20.2	77.03	-	1.04	-	-	0.29	0.41	-	-	-	-	0.07	0.58Y ₂ O ₃ 0.38 O ₂	- -
Udimet 720	7-10753	18.0	Bal	1.29	0.10	14.8	3.10	2.54	4.94	-	-	0.03	0.035	0.034	-	-
YD-NiCrAl	X-173	16.1	78.33	-	-	-	-	4.50	-	-	-	-	-	-	1.1Y ₂ O ₃	-
YD-Ni	X-309	-	97.7	-	-	0.91	-	-	-	-	-	-	-	-	1.28Y ₂ O ₃	-

(a) Values from vendor certifications.

TABLE 2.2
TENSILE ACCEPTANCE TEST RESULTS FOR DCHT ALLOYS

Alloy	Temperature °C °F		ULTIMATE TENSILE STRENGTH						0.2% YIELD STRENGTH						ELONGATION, %			REDUCTION AREA, %			Remarks
			Min. Spec. MPa Ksi	Vendor		GE		Min. Spec. MPa Ksi	Vendor		GE		Min. Spec.	Vendor	GE	Min. Spec.	Vendor	GE			
MM-0011 CC	RT	RT	-	-	-	-	1033.6	149.9	-	-	-	-	797.7	115.7	-	-	10.3	-	-	13.2	
	RT	RT	-	-	-	-	1052.9	152.7	-	-	-	-	780.5	113.2	-	-	12.2	-	-	13.8	
MM-0011 DS	RT	RT	-	-	-	-	1077.0	156.2	-	-	-	-	881.2	127.8	-	-	11.1	-	-	12.8	Failed in Radius
	RT	RT	-	-	-	-	981.2	142.3	-	-	-	-	877.7	127.3	-	-	4.6	-	-	3.2	
Rene' 100	704	1300	827.4	120	958.4 ^(c)	139 ^{(c)(a)}	1011.5	146.7	689.5	100	703.2 ^(c)	102 ^(c)	780.5	113.2	-	13.3-14.7	16.0	8	13.1-20.4	18.2	Vendor Ran 3 Tests
	RT	RT	-	-	-	-	1003.2	145.5	-	-	717.1	104	808.1	117.2	-	-	11.1	-	-	13.9	
	RT	RT	-	-	-	-	1023.2	148.4	-	-	-	-	821.2	119.1	-	-	12.7	-	-	14.9	
Rene' 80	871	1600	620.6	90	772-793	112-115 ^(a)	696.4	101.0	482.6	70	544/565	79/82	529.5	76.8	-	-	14.9	15	15.4/21.1	18.2	Vendor Ran 2 Tests
	RT	RT	-	-	-	-	947.4	137.4	-	-	-	-	870.8	126.3	-	-	2.0	-	-	3.2	
	RT	RT	-	-	-	-	975.6	141.5	-	-	-	-	879.1	127.5	-	-	3.3	-	-	2.8	
IN-738	RT	RT	930.8	135	-	-	1066.0	154.6	792.9	115	-	-	826.7	119.9	5	-	8.4	5	-	9.7	
	RT	RT	930.8	135	-	-	1086.6	157.6	792.9	115	-	-	836.4	121.3	5	-	9.5	5	-	10.1	
	619	1200	930.8	135	-	-	1134.2	164.5	689.5	100	-	-	713.6	103.5	5	-	12.7	5	-	13.6	
Alloy 713LC	RT	RT	758.4	110	903.2	131 ^(a)	1012.9	146.9	689.5	100	727.8	107	786.7	114.1	3	12.4	11.8	-	19.0	11.4	GE - Fine Grain GE - Coarse Grain Coated
	RT	RT	758.4	110	-	-	958.4	139.0	689.5	100	-	-	786.0	114.1	3	-	10.6	-	-	11.5	
	RT	RT	-	-	-	-	837.1	121.4	-	-	-	-	699.8	101.5	-	-	75.0	-	-	9.5	
	RT	RT	-	-	-	-	802.6	116.4	-	-	-	-	689.5	100.0	-	-	54.0	-	-	9.6	
NX-188	RT	RT	-	-	-	-	1112.9	161.4	-	-	-	-	999.1	144.9	-	-	4.2	-	-	5.3	
	RT	RT	-	-	-	-	1078.4	156.4	-	-	-	-	1000.5	145.1	-	-	2.6	-	0	5.5	
Udimet 720	RT	RT	861.9	125	1060.5	153.8	1097.0	159.1	758.5	110	867.7	127.3	797.1	115.6	-	3.8	7.7	6	5.1	7.9	
	RT	RT	861.9	125	-	-	1109.4	160.9	758.5	110	-	-	794.3	115.2	-	-	8.2	6	-	9.3	
	871	1600	586.1	85	684.7	99.3	607.4	88.1	517.1	75	546.8	79.3	493.7	71.6	-	24.8	25.2	12	34.2	44.6	
MA-754	RT	RT	-	-	-	-	948.8	137.6	-	-	-	-	557.1	80.8	-	-	21.4	-	-	54.7	Longitudinal Dir.
	RT	RT	-	-	-	-	950.1	137.8	-	-	-	-	571.6	82.9	-	-	21.1	-	-	51.3	
TZM	RT	RT	792.9	115	826.7	119.8	812.2	117.8	689.5	101	780.5	113.2	768.1	111.4	18	32-33	37.8	-	-	N.A.	Vendor Ran 2 Tests
	RT	RT	-	-	878.4	127.4	824.0	110.5	-	-	801.9	116.3	-	-	-	-	35.5	-	-	24.1	
	850	1562 ^(b)	-	-	-	-	502.8	72.8	-	-	-	-	482.7	70.0	-	-	18.9	-	-	89.0	
M-21	RT	RT	-	-	-	-	826.7	119.9	-	-	-	-	788.1	114.3	-	-	2.4	-	-	5.6	
YD-Ni	RT	RT	-	-	-	-	597.1	86.6	-	-	-	-	462.0	68.7	-	-	15.8	-	-	46.7	Longitudinal Dir.
YD-NiCrAl	RT	RT	-	-	-	-	1193.5	173.1	-	-	-	-	732.2	106.2	-	-	10.1	-	-	14.4	Longitudinal Dir.

(a) Vendor results are heat qualification tests and not from the molds cast from this program.

(b) Test in vacuum ($0.3 - 3 \times 10^{-5}$ Torr).

(c) Average.

(d) Two reduced areas; 24.1% at fracture, higher value away from fracture.

N.A. - not available

TABLE 2.3

STRESS-RUPTURE ACCEPTANCE TEST RESULTS FOR DCHT ALLOYS

Alloy	Heat Treatment	Temperature °C °F		Stress MPa Ksi		Life, Hours			Elongation, %			Reduction of Area, %			Remarks
						Spec. Min.	Vendor	G.E.	Spec. Min.	Vendor	G.E.	Spec. Min.	Vendor	G.E.	
MM-0011 CC	1975F/4 Hrs-Cool To 1200F in 3/4 Hr + 1600F/20 Hrs	982	1800	200.0	29	-	26.5 ^(a)	39.7	-	11.0	11.2	-	17.5	16.8	GE Test on Fine Grained Bar
		760	1400	724.0	105	-	130.9 ^(a)	-	-	6.0	-	-	6.1	-	
MM-0011 DS	2235F/2 Hrs/He Q + 1975 F/4 Hrs/Cool to 1200F in 1 Hr + 1600F/20 Hrs	982	1800	200.0	20	-	-	138.4	-	-	26.7	-	-	51.9	Same Heat as MM-0011 CC
Rene' 100	1550F/12 Hrs	982	1800	189.6	27.5	23	27.5-37.0 ^(a)	30.5	-	12.2-15.3	8.8	5	17.5-23.2	11.6	Vendor Ran 3 Tests
Rene' 80	2200F/2 Hrs/He Q + 2000 F/4 Hrs He Q + 1925F/4 Hrs-Cool to 1200F in 20 Min. + 1550/16 Hrs.	982	1800	189.6	27.5	23	45.1 ^(a)	16.2	-	-	5.8	5	10.2	7.8	
		982	1800	189.6	27.5	23	-	35.6	-	-	5.8	5	-	6.2	
		982	1800	189.6	27.5	23	-	-	-	-	-	-	-	-	
IN-738	2050F/2 Hrs/He Q + 1550 + 24 Hrs	982	1800	151.7	22	35	35.1 ^(a)	32.2	5	12.3	5.4	10	12.3	6.3	
		982	1800	151.7	22	35	-	37.8	5	-	6.3	10	-	8.9	
		760	1400	586.1	85	-	122.7 ^(a)	-	-	5.9	-	-	8.3	-	
Alloy 713LC None.		982	1800	151.7	22	30	61.8 ^(a)	41.4	5	12.8	N.A.	-	24.6	14.6	GE Test on Fine Grained Bar
		760	1400	530.9	77	-	237.2 ^(a)	-	-	3.4	-	-	5.4	-	
NX-188	2300F/2 Hrs/He Q	982	1800	124.1	18	-	-	139.6	-	-	3.7	-	-	1.2	
Udimet 720	2135F/4 Hrs/He Q + 1975	982	1800	151.7	22	20	30.6	22.4	-	14.5	8.5	10	19.3	11.2	
		982	1800	110.3	16	-	151.2	-	-	12.4	-	-	18.0	-	
		843	1550	344.8	50	-	133.8	-	-	19.0	-	-	20.7	-	
MA-754	2400F/1 Hr (By Vendor)	1093	2000	82.7	12	20	>22.1	>137.2	-	4	21.7	-	16	54.3	Longitudinal Dir. } Long Transverse } Step-Loaded Dir. } To Fracture Short Transverse } Dir. }
		1093	2000	27.6	4	20	>22.0	-	-	2	-	-	5	-	
		1093	2000	15.6	2.3	20	>22.0	-	-	5	-	-	0.5	-	
TZM	2300F/ 3/4 Hr. (By Vendor)	927	1700 ^(b)	530.9	77	-	-	F.O.L.	-	-	17.0	-	-	92.0	Failed on Loading Step Loading; + 22.9 Hrs at 56 Ksi (386 Mpa) and 0.9 Hrs at 59 Ksi (406.8 Mpa)
		1038	1900 ^(b)	365.4	53	-	-	>130	-	-	18.0	-	-	91.0	
M-21	None	982	1800	189.6	27.5	-	-	31.2	-	-	2.2	-	-	1.6	
YD-N1	2000F/1 Hr (By Vendor)	1093	2000	51.7	7.5	-	-	1	-	-	5.0	-	-	N.A.	Longitudinal Dir. " " " " " "
		1093	2000	34.5	5	-	-	49.7 ^(c) 70.8	-	-	N.A. ^(d)	-	-	N.A. ^(d)	
YD-NiCrAl	2450F/1 Hr (By Vendor)	1093	2000	51.7	7.5	20	-	>161	5	-	36.8	-	-	69.1	Longitudinal Dir. } Long Transverse } Step-Loaded to Fracture
		1093	2000	41.4	6	-	0.5	-	-	1.9	-	-	0.6	-	

(a) Vendor results are heat qualification tests and not from the molds cast for this program.

(b) Tests in vacuum (0.3 - 3 10⁻⁵ Torr).

(c) Timer did not shut off.

(d) Could not measure - excessive oxide.

N.A. - not available

TABLE 2.4

**STRESS-RUPTURE TEST RESULTS FOR LONG
TIME STRESS VERIFICATION FOR DCHT ALLOYS**

Alloy	Temperature		Stress		Life, Hours	EL, %	RA, %	Remarks
	°C	°F	MPa	Ksi				
MM-0011CC	750	1382	689.5	100	395.0	4.8	7.9	
	850	1562	379.2	55	488.1	9.5	12.3	
	950	1742	189.6	27.5	346.6	11.5	15.0	
	1050	1922	62.1	9	825.4	11.1	26.4	
MM-0011 DS	750	1382	772.2	112	138.0	6.5	5.3	
	850	1562	441.3	64	462.1	16.3	21.5	
	950	1742	227.6	33	299.6	30.4	55.5	
	1050	1922	93.1	13.5	712.1	22.6	69.2	
Rene' 100	750	1382	606.8	88	184.0	2.7	5.8	
	850	1562	351.6	51	359.7	4.1	5.6	
	950	1742	158.6	23	476.5	11.6	18.8	
	1050	1922	58.6	8.5	112.4	N.A.	N.A.	
Rene' 80	750	1382	579.2	84	450.4	6.2	7.9	
	850	1562	344.8	50	418.1	6.3	9.4	
	950	1742	158.6	23	360.0	4.1	6.3	
IN-738	750	1382	537.8	78	399.4	5.4	7.5	
	850	1562	296.4	43	403.5	6.4	8.1	
	950	1742	131.0	19	303.0	2.8	6.5	
	1050	1922	48.3	7	61.0	N.A.	N.A.	
Alloy 713 LC	750	1382	517.1	75	470.1	3.0	2.4	
	850	1562	282.7	41	530.2	5.2	7.3	
	950	1742	131.0	19	461.6	8.3	16.8	
NX-188	750	1382	551.6	80	239.7	0.8	0.4	
	850	1562	296.5	43	451.3	2.5	0.4	
	950	1742	131.0	19	440.8	1.1	0.4	
Udimet 720	750	1382	551.6	80	308.9	11.0	18.7	
	850	1562	296.5	43	450.3	11.3	13.0	
	950	1742	124.1	18	408.6	14.3	19.9	
MA-754	850	1562	193.1	28	10.2	13.4	48.3	Discontinued
	950	1742	124.1	18	1332.1	0.5	0.0	
	1050	1922	98.3	14.25	1006.3	N.A.	N.A.	
TZM	850	1562 ^(a)	462.0	67	996.0	0.7	0.0	Discontinued Discontinued
	950	1742 ^(a)	400.0	58	664.7	0.8	0.8	
	1050	1922 ^(a)	379.2	55	108.7	21.0	91.0	

(a) Tested in Vacuum ($0.3-3 \times 10^{-5}$ Torr).

N.A. - not available

TABLE 2.5
CREEP TEST RESULTS FOR LONG
TIME STRESS VERIFICATION FOR DCHT ALLOYS

Alloy	Temperature		Stress		Time, Hours to 1% Creep		Test Duration Hours	Final % Plastic Creep
	°C	°F	MPa	KSI	Total	Plastic		
MM-0011CC	750	1382	593.0	86	250	500 ^(a)	286.5	0.64
	850	1562	344.8	50	108	169	186.9	1.07
	950	1742	179.3	26	210	232	303.5	1.68
	1050	1922	55.2	8	650 ^(a)	685 ^(a)	219.1	0.40
MM-0011DS	750	1382	717.1	104	1.1	1.8	99.4	4.34
	850	1562	406.8	59	235	305	327.4	1.10
	950	1742	213.7	31	126	153	186.9	1.35
	1050	1922	86.2	12.5	1380 ^(a)	2000 ^(a)	434.0	0.51
Rene' 100	750	1382	551.6	80	55	175	209.6	1.10
	850	1562	289.6	42	510 ^(a)	670 ^(a)	405.7	0.59
	950	1742	148.2	21.5	215	264	280.3	1.05
	1050	1922	27.6	4	920 ^(a)	970 ^(a)	403.5	0.41
Rene' 80	750	1382	524.0	76	42	170	255.8	1.20
	850	1562	296.5	43	165	260	268.4	1.02
	950	1742	137.9	20	650 ^(a)	750 ^(a)	237.7	0.38
IN-738	750	1382	489.5	71	67	198	219.9	1.07
	850	1562	255.1	37	244	307	316.7	1.05
	950	1742	110.3	16	69	95	114.9	1.05
	1050	1922	13.8	2	1870 ^(a)	1910 ^(a)	619.8	0.33
Alloy 713 LC	750	1382	468.9	68	455 ^(a)	760 ^(a)	405.7	0.59
	850	1562	255.1	37	310	410	455.6	1.10
	950	1742	100.0	14.5	70	120	161.3	1.08
NX-188	750	1382	482.7	70	340	625 ^(a)	376.6	0.72
	850	1562	268.9	39	235	390	431.7	1.06
	950	1742	89.6	13	900 ^(a)	1000 ^(a)	256.1	0.38
Udimet 720	750	1382	510.2	74	13	37	42.9	1.10
	850	1562	241.3	35	95	230	265.3	1.05
	950	1742	89.6	13	275	360	400.5	1.06
MA-754	850	1562	151.7	22	TEST STOPPED - DEFECTIVE EXTENSOMETER			-
	950	1742	134.5	19.5	35	50	383.6	2.40
	1050	1922	103.4	15 ^(c)	--	--	307.8	0.09
TZM	850	1562 ^(b)	482.7	70	--	90	215.9	
	950	1742 ^(b)	420.6	61	--	24	470	Failed: 42%E1 51% RA
	1050	1922 ^(b)	365.4	53	--	5	75	Failed: 21%E1 83% RA

(a) Extrapolated.

(b) Tested in Vacuum ($0.3-3 \times 10^{-5}$ Torr).

(c) Stress increased to 17 ksi (117.2 MPa) after 307.8 hours and had a total of 1.32% plastic creep after an additional 331 hours (~ 237 hours 1% total creep, ~ 287 hours 1% plastic creep at 17 ksi (117.2 MPa)).

run at a higher stress level than the rupture test, and had essentially no movement after 308 hours. The stress was increased 14 MPa (2 ksi) and after more than 300 additional hours, the plastic strain was only 1.32%. Some attempts will be made to determine why this lot of MA-754 is more creep resistant than previous lots of MA-754 evaluated by GE.

A second material that has displayed exceptional creep properties is MM-0011 DS. In this case, the directionally solidified form of the alloy has shown improvement in creep-rupture properties on the order of approximately four times greater than for the conventionally cast form of the alloy; or approximately 28°C (50°F) improvement in temperature capability.

2.2.2 Nuclear Process Heat (NPH) Alloys - (S.Z.Hayden and R.A.Ellis)

2.2.2.1 Materials Procurement

Alloys - This task was completed during this report period with the receipt of the remaining two of the 14 candidate NPH alloys. Legal action resulted in the delivery of the required quantities of IN-519 and Mo-Re 2 from Duraloy-Blaw Knox. In addition, a second heat of MA-956E bar was received. This will provide sufficient material to cover the intensive testing phase, should that alloy be among those selected for further study.

Surface Treatments (Coatings) - Coating of 84 Inconel 617 and 69 Incoloy 800H specimens has been completed by the coating vendors, Walbar Metals, Inc. and Chromalloy American Corp., respectively, and the coated test specimens have been received.

The Inconel 617 samples were coated with Codep B (an aluminide coating applied by pack cementation) at a temperature of $1066^{\circ}\text{C} \pm 14^{\circ}\text{C}$ ($1950^{\circ}\text{F} \pm 25^{\circ}\text{F}$) for 6 hours with an 8% Al pack. A test coupon included in this run revealed a 0.069 mm (0.0037 inch) thick coating, well within the 0.038-0.076 mm (0.0015-0.003 inch) thickness specification requirement. The Incoloy 800H samples were coated with RT-22, which is essentially a platinum-chromium-aluminide type coating. Specimens were first electroplated with a layer of Pt followed by the deposition Cr and Al

by pack cementation at temperature/time conditions of 1066°C (1950°F)/ 2 hrs. plus 982°C (1800°F)/20 hrs. with a final treatment of 1079°C (1975°F)/2 hrs. to improve the ductility of the coating. A test coupon included in this run produced a 0.089-0.102 mm (0.0035-0.0040 inch) thick coating.

2.2.2 Materials Characterization

The characterization test statuses are listed in Table 2.6 for the NPH alloys. Testing has been started on the two alloys received during this report period. All testing will be finished in October.

The chemical compositions of all the as-received alloys are presented in Table 2.7. For the most part, the values are the result of material vendor certifications. Chemical analyses of the Manaurite 900 and Manaurite 36XS alloys also were conducted by the International Nickel Company (INCO) Research Laboratories for General Atomic Company (GAC). The chemical compositions of all NPH alloys are presently being determined independently as a check on the vendor certifications with respect to the program materials specifications.

Longitudinal and transverse sections of all alloys have been metallographically examined in the as-received condition. In all cases the microstructures appear acceptable, and no abnormalities have been observed. A summary of grain size and hardness measurements for as-received NPH alloys is presented in Table 2.8.

The room temperature tensile results obtained at GE are shown in Table 2.9 along with the available vendor values and the materials specifications minimum value. Results for coated Inconel 617 also are given. Vendor stress-rupture acceptance test data and minimum values from the applicable specifications are shown in Table 2.10.

TABLE 2.6

NUCLEAR PROCESS HEAT MATERIALS CHARACTERIZATION
TEST STATUS

<u>Alloy</u>	<u>Test Status</u>
Incoloy 800H	Testing Complete
Incoloy 800H (Coated)	In Test (Tensile)
Incoloy 802	Testing Complete
Incoloy 807	In Test (Creep-Rupture)
Incoloy DS	Testing Complete
HD 556	Testing Complete
HK 40	Testing Complete
Manaurite 900	Testing Complete
Manaurite 36XS	Testing Complete
Inconel 617	Testing Complete
Inconel 617 (Coated)	Testing Complete
Inconel 618E	Testing Complete
Hastelloy X	Testing Complete
MA 956E	Testing Complete
IN-519	In Test
Mo-Re 2	In Test

TABLE 2.7

CHEMICAL COMPOSITION OF NUCLEAR PROCESS HEAT ALLOYS

GE Code No(a)	Alloy	Element (Weight-%)																				
		C	Ni	Fe	Cr	Mn	Si	Mo	Co	W	Nb	Ta	Al	Ti	Cu	V	Zr	Y	B	P	S	Other
1000	Incoloy 800H(b)	0.07	32.03	Bal	19.79	1.00	0.18	--	--	--	--	--	0.38	0.45	0.60	--	--	--	--	--	0.003	--
1100	Incoloy 802(b)	0.27	30.78	Bal	20.10	0.71	0.08	--	--	--	--	--	--	--	0.43	--	--	--	--	--	0.004	--
1200	Incoloy 807(b)	0.065	39.4	Bal	20.6	0.78	0.49	--	8.1	5.08	1.03 (Nb+Ta)	--	--	--	0.06	--	--	--	--	--	0.003	Nb+Ta 1.03
1300	Incoloy DS (b)	0.065	35.3	Bal	18.35	1.08	2.30	--	0.07	--	--	--	--	0.05	0.07	--	--	--	--	--	0.005	--
1400	HD-556(b)	0.11	22.45	Bal	21.83	0.87	0.50	3.51	18.10	2.31	0.12	0.65	0.13	--	--	--	0.040	--	0.022	0.021	<0.002	N 0.136 La 0.011
1500	Manaurite 36XS(c)	0.39	36.0	32.1(c)	24.8	1.30	1.92	<0.10	0.18	1.5	1.05	<0.10	<0.1	<0.1	<0.05	<0.10	<0.10	<0.10	--	0.026(b)	0.018(b)	--
	Manaurite 36XS(b)	0.38	34.05	Bal	25.56	1.28	1.68	--	--	1.50	1.12	--	--	--	--	--	--	--	--	0.026	0.018	--
1600	Manaurite 900(c)	0.12	34.8	40.1(c)	22.4	0.99	0.74	<0.10	<0.10	<0.1	--	--	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	--	0.024(b)	0.018(b)	--
	Manaurite 900(b)	0.105	32.65	Bal	21.62	1.06	0.66	0.01	--	--	1.09	--	--	--	--	--	--	--	--	0.024	0.018	--
1700	HK-4C(b)	0.42	19.50	Bal	25.45	0.86	1.56	<0.04	--	--	--	--	--	--	0.15	--	--	--	--	0.022	0.015	Pb<0.005 Sn<0.010
1800	IN-519(b)	0.30	23.60	Bal	24.60	0.80	0.94	<0.04	--	--	1.58	--	--	--	0.15	--	--	--	--	0.022	0.015	Pb<0.005 Sn<0.010
1900	Hastelloy X(b)	0.080	Bal	18.86	21.38	0.64	0.47	8.94	1.79	0.70	--	--	--	--	--	--	--	--	0.004	0.017	0.002	--
1A00	Inconel 617(b)	0.06	Bal	0.53	21.74	0.02	0.18	8.91	12.32	--	--	--	1.11	0.30	0.11	--	--	--	0.003	--	0.002	--
1B00	Inconel 618E(b)	0.05	Bal	14.79	22.50	0.09	0.21	--	0.25	5.85	--	--	0.01	--	0.04	--	--	--	--	--	0.005	--
1C00	Mo-Re 2(b)	0.22	50.2	0.18	32.70	0.28	0.30	<0.04	--	15.3	--	--	<0.05	--	--	--	--	--	--	0.015	0.010	Pb<0.005 Sn<0.010
1D00	MA-956E (b)	--	--	Bal	19.04	--	--	--	--	--	--	--	4.63	0.31	--	--	--	--	--	--	--	Y ₂ O ₃ .46, 0.20, N .044
1D10	MA-956E (b)	--	--	Bal	18.7	--	--	--	--	--	--	--	4.58	0.32	--	--	--	--	--	--	--	Y ₂ O ₃ .50, 0.020, N 0.46

(a) All test specimen numbers will refer to the alloy identification numbers shown in this column.

(b) Values from producer certifications.

(c) Values determined by International Nickel Research Laboratories for General Atomic Co.

(d) Balance of alloy content obtained by difference.

TABLE 2.8

SUMMARY OF GRAIN SIZE AND HARDNESS MEASUREMENTS
FOR NPH ALLOYS

	Hardness		Grain Size	
	Vendor (R _B)	GE (R _B)	Vendor ASTM #	GE ASTM #
Incoloy 800H	67	60	1	00
Incoloy 802	75	70	1	00
Incoloy 807	86	79	3	2
Incoloy DS	86	74	0.0- 5.5	2.5
HD-556	N/F ^(a)	88	3.5	3.5
HK-40	N/F	86	70/50 ^(b)	65/40 ^(b)
Manaurite 900	N/F	72	N/F	55/40 ^(b)
Manaurite 36XS	N/F	84	N/F	40/20 ^(b)
Inconel 617	84	83	00	0.5
Inconel 618E	N/F	76	N/F	0
Hastelloy X	N/F	89	6	5
MA-956E (1st Heat)	N/F	96	N/F	(c)
MA-956E (2nd Heat)	N/F	99	N/F	(c)
IN-519	N/F	88	40/0 ^(b)	35/0 ^(b)
Mo-Re 2	N/F	93	100/100 ^(b)	100/100 ^(b)

(a) N/F = None Furnished.

(b) % Columnarity, hot end/cold end.

(c) High grain aspect ratio, greater than 1/d=10.

TABLE 2.9

TENSILE ACCEPTANCE TEST RESULTS FOR NPH ALLOYS

Material	Condition For Test	Test Temp	ULTIMATE TENSILE STRENGTH						0.2% OFFSET YIELD STRENGTH						ELONGATION			REDUCTION OF AREA	
			Min. MPa	Spec. ksi	Vendor MPa	ksi	CE MPa	ksi	Min. MPa	Spec. ksi	Vendor MPa	ksi	CE MPa	ksi	Min. %	Spec. %	Vendor %	Vendor %	CE %
Incoloy 800H	S.A. 1232°C	RT	450	65.0	520	75.5	515	74.8	170	25.0	186	27.0	153	22.2	30	55	52.0	69	69.3
		RT	450	65.0	-	-	531	77.0	170	25.0	-	-	158	22.9	30	-	59.0	-	65.4
Incoloy 800H (Coated)	S.A. 1232°C	RT	-	-	-	-	*	-	-	-	-	-	*	-	-	-	*	-	*
		RT	-	-	-	-	*	-	-	-	-	-	*	-	-	-	*	-	*
Incoloy 802	S.A. 1271-1282°C	RT	517	75.0	620	90.0	610	88.5	207	30.0	252	36.5	221	32.0	18	47	47.0	52	58
		RT	517	75.0	-	-	613	88.9	207	30.0	-	-	221	32.0	18	-	49.0	-	59
Incoloy 807	S.T. 1230°C/5min. WQ	RT	620	89.9	666	96.6	662	96.1	250	36.2	286	41.5	255	37.0	30	53.1	53.0	-	61.0
		RT	620	89.9	-	-	662	96.0	250	36.2	-	-	255	37.0	30	-	53.0	-	61.4
Incoloy DS	S.A. 1150°C/5min. AC	RT	480	69.6	600	87.0	600	87.0	170	24.6	227	32.9	221	32.0	30	53.1	54.0	-	73.1
		RT	480	69.6	-	-	600	87.0	170	24.6	-	-	221	32.0	30	-	53.0	-	73.1
HIL-556	S.T. 1177°C/30min. WQ	RT	689	100.0	793	115.0	810	117.6	324	47.0	379	55.0	371	53.9	40	57.0	57.0	70	64.2
		RT	689	100.0	-	-	808	117.2	324	47.0	-	-	373	54.2	40	-	61.0	-	70.7
Manaurite 36XS	As-Cast	RT	441	64.0	534	77.5	569	82.5	245	35.6	310	44.9	269	39.0	8	15.5	15.3	-	15.4
		RT	441	64.0	-	-	585	84.8	245	35.6	-	-	268	38.8	8	-	16.0	-	16.2
Manaurite 900	As-Cast	RT	441	64.0	499	72.4	541	78.5	186	27.0	205	29.7	190	28.0	25	42.5	42.0	-	43.4
		RT	441	64.0	475	68.8	543	78.7	186	27.0	194	28.2	190	28.0	25	44	39.0	-	43.4
HK-40	As-Cast	RT	448	65.0	616	89.3	667	96.8	241	35.0	332	48.2	309	44.8	15	21	23.0	10.4	22.4
		RT	448	65.0	-	-	643	93.3	241	35.0	-	-	309	44.8	15	-	23.0	-	22.4
IN-519	As-Cast	RT	552	80.0	648	94.0	*	-	241	35.0	307	44.5	*	-	25	20	*	15.6	*
		RT	552	80.0	-	-	*	-	241	35.0	-	-	*	-	25	-	*	-	*
Hastelloy X	S.T. 1177°C/31min.	RT	689	100.0	765	111.0	776	112.5	276	40.0	345	50.0	358	52.0	35	49.0	49.0	53.0	61.0
		RT	689	100.0	-	-	772	112.0	276	40.0	-	-	357	51.8	35	-	49.0	-	60.5
Inconel 617	S.A. 982°C	RT	620	90.0	755	109.5	781	113.3	207	30.0	317	46.0	318	46.0	35	75	67.0	56.0	58.4
		RT	620	90.0	-	-	780	113.1	207	30.0	-	-	318	46.0	35	-	64.0	-	56.4
Inconel 617 (Coated)	S.A. 982°C	RT	-	-	-	-	767	111.3	-	-	-	-	324	47.0	-	-	44.8	-	45.9
		RT	-	-	-	-	776	112.6	-	-	-	-	329	47.7	-	-	41.4	-	37.4
Inconel 618E	S.T. 1232°C/1hr. WQ	RT	-	-	-	-	633	91.8	-	-	-	-	269	39.0	-	-	60.0	-	67.1
		RT	-	-	-	-	633	91.8	-	-	-	-	248	36.0	-	-	63.0	-	73.1
Mo-Re 2	As-Cast	RT	586	85.0	542	78.6	*	-	241	35.0	380	55.1	*	-	5	11.4	*	-	*
		RT	586	85.0	523	75.8	*	-	241	35.0	381	55.3	*	-	5	10.0	*	-	*
		RT	586	85.0	519	75.3	-	-	241	35.0	353	51.2	-	-	5	11.4	-	-	-
		RT	586	85.0	563	81.7	-	-	241	35.0	414	60.0	-	-	5	11.0	-	10.7	-
		RT	586	85.0	554	80.3	-	-	241	35.0	342	49.6	-	-	5	7.8	-	7.6	-
MA-956E (1st Heat)	S.A. 1330°C/1hr. AC	RT	-	-	-	-	796	115.5	-	-	-	-	786	114.0	-	-	13.0	-	41.6
		RT	-	-	-	-	800	116.0	-	-	-	-	786	114.0	-	-	12.0	-	39.1
(2nd Heat)		RT	-	-	-	-	*	-	-	-	-	-	*	-	-	-	*	-	*
		RT	-	-	-	-	*	-	-	-	-	-	*	-	-	-	*	-	*

*In Test

TABLE 2.10

STRESS-RUPTURE ACCEPTANCE TEST RESULTS FOR NPH ALLOYS

Material	Condition For Qualification Tests (a)	Temp (°C)	Stress (MPa) (ksi)	Stress Rupture Properties			
				Rupture Time		Elongation	
				Actual (hr.)	Min. (hr.)	Actual (%)	Min. (%)
Incoloy 800H	S.A. 1232°C	---	---	---	---	---	---
Incoloy 802	S.A. 1271-1282°C	---	---	---	---	---	---
Incoloy 807	S.T. 1230°C/5 min., WQ	---	---	---	---	---	---
Incoloy DS	S.A. 1150°C/5 min., AC	---	---	---	---	---	---
HD-556	S.T. 1177°C/30 min., WQ	816	131 19.0	129	24	149.0 87.0%RA	25
Manaurite 36XS	As-Cast	---	---	---	---	---	---
Manaurite 900	As-Cast	---	---	---	---	---	---
HK-40	As-Cast	982	41.4 6.0	Disc 15.1 ^(b)	11	---	---
IN-519	As-Cast	982	41.4 6.0	Disc 47.7 ^(b)	35	---	---
Hastelloy X	S.T. 1177°C/31 min., WQ	816	110 16.0	72	24	165 88% RA	8
Inconel 617	S.A. 982°C	---	---	---	---	---	---
Inconel 618E	---	---	---	---	---	---	---
Mo-Re 2	As-Cast	1093	34.5 5.0	8.7	20	10	---
MA-956E	S.A. 1330°C/1 hr., AC	1100	38 5.5 + ^(c) 48 7.0 + 59 8.6	24 24 5	7.5	18% RA 10	---
MA-956E	S.A. 1330°C/hr., AC	1100	48 7.0	Disc 590 ^(b)	7.5	1.1	---

(a) S.A. Solution Annealed WQ - water quenched
 S.T. Solution Treated AC - air cooled

(b) Discontinued

(c) Step loaded.

The vendor test results show that the materials met the specifications in nearly all tests. Exceptions were: low rupture life for the Mo-Re 2 (8.7 hrs. actual vs. 20 hrs. min.); low ultimate tensile strength of Mo-Re 2 {540.2 MPa (78.3 ksi) average actual vs. 586 MPa (85.0 ksi) min.} and a slightly low RT elongation (20% actual vs. 25% min.) for the IN-519 tensile specimen. It should be noted that the Mo-Re 2 and IN-519 specifications utilized for their procurement are tentative and were established based on limited data. The Mo-Re 2 stress-rupture and ultimate tensile strength values which were used in the specification were taken from a National Alloys brochure and are now believed to have been set at unrealistically high values. With regard to IN-519, the alloy has been included as Material Number 1.4855 in a revised edition of the German Standard, Stahl Eisen Werkstoffblatt 595. This document, which was recently obtained, calls for a minimum of 5% RT tensile ($L_0 = 5 d_0$) elongation; thus, the value that was set in the material specification appears inappropriate. (The data from GE tensile tests on these two alloys is not available at the end of the report period due to late delivery of the material.)

Where available, manufacturers' tensile data compare well with the tensile results obtained by GE. GE test results of interest in Table 2.9 include the tensile ductility values for MA-956E. Tensile elongation values of 12.0 and 13.0% and reduction-in-area values of 39.1 and 41.6% are in reasonably good agreement with recent work on this ODS iron-base alloy⁽¹⁾ and suggest that the deformation leading to failure is very localized.

The effect of the Codep B coating on the tensile properties of Inconel 617 also is evident from Table 2.9. The data presented indicate that the Codep B coating did not have a significant effect on RT tensile and yield strength. The tensile ductilities of the coated bars (elongation and reduction in area), on the other hand, were significantly lowered as might be expected. The elongation dropped from approximately 66% for the uncoated specimens to approximately 43% for the coated specimens. The specification minimum for uncoated Inconel 617 is 35%. This result is not surprising in view of the relatively poor low temperature ductility of this coating. It should be noted, however, that no assessment can be made at this time of the role of the thermal cycling during coating on the degradation of tensile ductility.

(1) J.D. Whittenberger, "Tensile and Creep Properties of the Experimental Oxide Dispersion Strengthened Iron-Base Sheet Alloy MA-956E at 1365K", Met. Trans.A, Vol.9A, Jan. 1978, pg.101.

The IN-519 and Mo-Re 2 tensile bars, in addition to coated Incoloy 800H samples, will be tensile tested at RT during the next month.

Short time creep-rupture testing in air of the 12 NPH alloys to verify stresses selected for the screening creep testing is nearing completion. The available results are shown in Table 2.11, where both the time to 1% total strain and the rupture values are presented. Stresses were selected to produce rupture in approximately 300 hours and creep data is recorded during each test. The tests are being conducted in the $750^{\circ} - 1100^{\circ}\text{C}$ ($1382^{\circ} - 2012^{\circ}\text{F}$) temperature range. The upper test temperature (1100°C) is 50°C above the highest screening creep test temperature $\{1050^{\circ}\text{C}(1922^{\circ}\text{F})\}$ and will aid in the determination of long time exposure stress levels.

The only problem in this area has been the difficulties in estimating the proper stress levels for conducting the rupture tests of MA-956E. The lot of material which is being evaluated (rod) has exhibited consistently better creep-rupture strength as compared to the Wiggin supplied rupture data (sheet). This has caused longer than anticipated testing times. Creep-rupture behavior appeared consistent with previously published work⁽¹⁾ in that only very limited amounts of time-dependent deformation were observed. Specimens either ruptured in very short times (20-40 hrs.) or ran for very long times (>1000 hrs.). None of the specimens underwent noticeable creep deformation, and failed specimens (failure occurred in the radius between the gauge section and shoulder) did not experience significant deformation until just prior to failure.

The Incoloy 802 material received was found to be considerably stronger both in creep and rupture than vendor or the High Temperature Materials Programme (HTMP) published data. The heat of Incoloy 807 received also is stronger in rupture than the limited amount of data published, Henry Wiggin & Co., Ltd.⁽²⁾ The remainder of the alloys tested were either comparable to or slightly stronger than manufacturer's data.

(1) Ibid.

(2) Incoloy 802, Mechanical Property, Welding and Corrosion Resistance Data, Henry Wiggin & Company, Limited, October, 1975.

TABLE 2.11
CREEP-RUPTURE TEST RESULTS FOR LONG TIME
STRESS VERIFICATION FOR NPH ALLOYS

Alloy	Condition For Tests (a)	Temp	Test Stress		Time to 1% Total Strain	Rupture Life	Elongation (%)	Reduction In-Area (%)
		(°C)	(MPa)	(Ksi)	(Hours)	(Hours)		
Incoloy 800H	S.A. 1232°C	750	97	14.0		286.9	35.6	41.0
		850	45	6.5	3.6	333.8	62.9	64.1
		950	21	3.1	155	464.5	39.6	36.0
		1050	10	1.5	380	1005.4 Disc. (b)	7.7	5.5
		1050	14	2.1	4.6	141.3	26.5	22.9
Incoloy 802	S.A. 1271-1282°C	750	152	22.0	480	480.6	2.7	8.5
		850	86	12.5	350	433.7	3.7	5.6
		950	38	5.5	--	767.6	3.7	11.0
		1050	21	3.0	215	1493.2	13.5	15.8
		1100	12	1.8	145	820.8	11.9	40.7
		950	55	8.0		To Be Run		
Incoloy 807	S.T. 1230°C/5 min., W.Q.	750	145	21.0	2.7	100.2	85.8	73.0
		850	55	8.0		In Test		
		950	19	2.7	210	1002.7 Disc.	2.5	--
		1050	7	1.0	145	1103.3 Disc.	7.1	5.5
		1100	6	0.9	--	769.5 Disc.	--	--
		1050	12	1.8	77	409.9	10.1	9.6
Incoloy DS	S.T. 1150°C/5 min., A.C.	750	62	9.0	11.5	299.4	34.2	37.0
		850	32	4.7	97	495.1	28.9	30.6
		950	17	2.5	91	445.1	24.2	34.0
		1050	10	1.4	10.5	377.4	65.0	39.8
		850	38	5.5		To Be Run		
HD-556	S.T. 1177°C/30 min., W.Q.	750	165	24.0	19	535 Disc.	51.0	57.1
		850	103	15.0	4.0	104 Disc.	67.4	75.8
		950	35	5.1	220	1535.0	34.9	48.2
		1050	17	2.5	128	543.1	28.4	39.2
		1100	10	1.5	20.5	469.5	36.3	40.0
		850	62	9.0		To Be Run		
HK-40	As-Cast	750	103	15.0	815	1014.0	8.2	3.5
		850	62	9.0	250	296.1	2.9	4.3
		950	28	4.0	240	530.1	2.0	3.3
		1050	17	2.5	225	346.9	2.5	4.3
		1100	15	2.2	73	94.8	8.5	5.3
Maurite 36XS	As-Cast	750	110	16.0	4.8	127	32.8	34.0
		850	97	9.0	11.7	369.7	29.6	32.3
		950	36	5.2	42.5	346.1	28.9	41.1
		1050	21	3.0	38	171.9	37.3	48.4
		1100	14	2.0	38.5	258.8	35.1	48.5
Inconel 617	S.A. 1204°C	750	200	29.0	97	625.4	19.6	24.8
		850	72	10.5	20.5	1126.0	58.3	60.9
		950	48	7.0	6.7	333.6	46.9	46.9
		1050	21	3.0	125	1146.2	23.2	35.4
		1100	15	2.2	70	722.5	34.9	33.9
Hastelloy X	S.T. 1177°C/31 min., W.Q.	750	138	20.0	9.1	279.1	93.4	87.0
		850	69	10.0	22.5	417.3	84.8	91.0
		950	29	4.2	71	547.6	65.8	67.0
		1050	12	1.8	20	287.4	59.0	56.0
		1100	6	0.9		1088.7	65.4	63.1
MA-956E	S.T. 1330°C/1 hr., A.C.	750	90	13.0	0.07% @ Disc	2733.2 Disc.*	--	--
		850	79	11.5	~1000	1168.6	4.4	16.3
		950	69	10.0	130	1254.6 (c)	4.5	1.8
		950	69	10.0	0.04 @ 10.0 hrs.	20.0 (c)	2.3	3.2
		1050	69	10.0	0.36 @ 35.3 hrs.	37.5 (c)	2.1	1.2
		1050	63	9.2				
		1100	57	8.3	~900	1034.0	2.1	3.5

(a) S.A. - Solution Annealed
S.T. - Solution Treated

(b) Discontinued.

(c) Step loaded.

Creep-rupture tests have been initiated for the IN-519 and Mo-Re 2 alloys. In addition, a few coated Incoloy 800H and Inconel 617 specimens will be run during the next quarter to evaluate the effect of the coating on the creep-rupture properties of these materials.

2.2.2.3 Materials Joining Studies

The filler metals and the welding methods to be used in the preparation of the weld test specimens were reported in the previous quarterly report (C00-2975-22). The chemical compositions of the as-received welding products are presented in Table 2.12. The values were obtained from the vendor certifications; chemical compositions of all welding products were within the applicable specification. It should be noted that three (3) additional filler metals (Inconel Filler Metal 625, 310HC Filler Metal and IN-519 Filler Metal) were procured in addition to those planned for use in the screening test program. Although these products will not be employed in the screening program, they will be available if required for the intensive phase of the program.

To date, eight of eleven weldments for the preparation of test specimens have been completed including all of the GTAW welds. Figure 2.1 shows the completed Incoloy DS weldment (welded by the GTAW method with NC 80/20 filler wire) prior to sectioning. Fifteen (15) passes were required to complete this weld. After welding, plate and tube sections are inspected by radiographic techniques and machined into 1.27 cm x 1.27 cm x 5.1 cm (1/2 inch x 1/2 inch x 2 inch) specimen contains the weld metal, heat-affected-zone and base metal for evaluation. Weldment coupons machined from a plate product prior to exposure are illustrated in Figure 2.2.

2.3 TASK 3 - TESTING AND ANALYSIS FACILITIES AND EQUIPMENT - D.H.BALDWIN

2.3.1 High Temperature Reactor Materials Testing Laboratory (HTRMTL)

Laboratory construction related to Loop No. 1 was completed and reported in the last quarterly report covering the period April 1, 1978 to June 30, 1978: C00-2975-22.

TABLE 2.12

CHEMICAL COMPOSITION OF WELDING MATERIALS FOR NPH ALLOYS
ELEMENT (WEIGHT-%)

Alloy	ELEMENT (WEIGHT-%)																		
	C	Ni	Fe	Cr	Mn	Si	Mo	Co	W	Nb	Ta	Al	Ti	Cu	V	Zr	B	P	S
Inconel Filler Metal 82	0.03	Bal	1.49	19.67	3.10	0.10	0.62	0.05	--	2.48	0.01	0.05	0.33	0.08	--	--	--	0.014	0.005
Inco Weld A Covered Electrode	0.04	Bal	8.70	14.32	1.59	0.66	1.77	--	--	--	--	--	--	0.03	--	--	--	0.007	0.009
Inconel Filler Metal 617	0.09	Bal	0.38	22.07	0.02	0.14	9.27	12.53	--	--	--	1.13	0.25	0.13	--	--	0.001	--	0.002
Inconel Filler Metal 625	0.02	Bal	3.07	22.37	0.10	0.24	8.73	--	--	--	--	0.20	0.23	0.10	--	--	--	0.010	0.003
HD-556 Filler Metal	0.08	19.55	Bal	21.14	1.35	0.49	2.89	18.78	2.25	<0.05	0.87	0.34	--	--	--	0.03	0.001	0.016	<0.005
NC 80/20 Filler Metal	0.25	Bal	0.30	19.65	1.04	0.38	--	0.06	--	--	--	--	--	0.01	--	--	--	--	--
Hastelloy X Filler Metal	0.08	Bal	18.79	21.99	0.63	0.54	8.98	2.08	0.83	--	--	--	--	0.32	--	--	--	0.26	<0.002
310 HC Filler Metal	0.42	20.47	Bal	25.26	1.28	1.02	0.06	--	--	--	--	--	--	0.04	--	--	--	0.010	0.010
310 HC-15 Covered Electrode	0.43	20.50	Bal	25.94	1.86	0.63	0.10	--	--	--	--	--	--	0.030	--	--	--	0.015	0.010
IN-519 Filler Metal	0.34	24.0	Bal	24.9	1.36	1.00	--	--	--	1.50	--	--	--	--	--	--	--	--	--
IN-519-15 Covered Electrode	0.27	23.1	Bal	23.9	3.43	0.62	--	--	--	0.87	--	--	--	--	--	--	--	--	--
Manaurite 36X Covered Electrode	0.47	35.0	Bal	25.2	1.25	0.86	--	--	--	0.82	--	--	--	--	--	--	--	0.003	0.003
22H Covered Electrode	0.57	48.70	Bal	30.10	1.63	1.21	--	--	4.70	--	--	--	--	--	--	--	--	--	--

Figure 2.1. Completed GTAW Weld.

Figure 2.2. Weldment Coupons Sectioned From GTA Welded Plate.

2.3.2 Multi-Specimen Screening Creep Equipment

During July, the first attempts were made to calibrate the multi-specimen creep stands with the retorts fully assembled. It was determined that there is some degree of load train interaction; i.e., load changes on one train cause load changes of up to 5% on other trains. Accordingly, it was decided to calibrate each load train simultaneously to the specific load called for by the test matrix. Load cells, universal joints, and dummy load bars have been obtained for this purpose. The leak check on the assembled retort showed no leaks greater than 2×10^{-8} std cc of helium/sec, which is satisfactory.

Four of the six multi-specimen creep stands are shown in Figure 2.3.

2.3.3 Thermal Stability Equipment

One of the thermal stability stands has been set-up with a temporary thermocouple well installed in place of one thermocouple. This allows vertical temperature profiles to be determined. Tests are underway to determine the optimum position of the five control thermocouples relative to their respective power zones in the furnace winding, giving the desired overall temperature profile.

Figure 2.4 shows the eight thermal stability test stands installed in HTRMTL.

2.3.4 Single Specimen Creep/Rupture Equipment

The final group of 5 stands and 25 retort systems were delivered by the vendor during September. Ten stands have been set-up with retort systems and will be used for screening creep tests on the molybdenum based TZM alloy.

Figure 2.5 shows the general arrangement of single specimen creep/rupture stands in rows of five. Utility frames serving these stands are located between rows of stands such that each stand backs up to its utility frame.

Figure 2.3. Four of six multi-specimen creep tests stands in HTRMTL. The utility frame serving the stand in the foreground contains electrical power controls (small cabinet at top) helium and cooling water pressure gages, flowmeters, and control valves.

Figure 2.4. Eight thermal stability test stands. There is one utility frame serving each pair of furnaces. Electrical controls are in the small cabinet at the top, helium and water pressure gages and flowmeters face the aisle to the right of the test stand, and all valves are located between the furnaces.

Figure 2.5. Single specimen creep/rupture test stands arranged in rows of five. Utility frames are behind each row. Each stand carries an electrical controls cabinet and a helium pressure gage and flowmeter.

2.3.5 Temperature Control System

This system is now fully operational and is being used to establish the optimum control mode for the various types of test stand furnaces throughout the laboratory.

The temperature control system consists of a centralized digital control package and remote located analog overtemperature controllers. The digital package, shown in Figure 2.6, controls the furnace heat up from room temperature to the operating setpoint and automatically balances the temperature along the length of each furnace. The test temperatures will be monitored for alarm conditions and a printed report provided. The printer and the CRT display are seen on the table at the left of Figure 2.6.

2.4 TASK 4 - SIMULATED REACTOR HELIUM ENVIRONMENT FACILITIES AND EQUIPMENT

2.4.1 Simulated Reactor Helium "Loop" System Design and Construction

2.4.1.1 Pumping, Purification and Analysis Subsystem - (C.L.Ehde)

The Pumping, Purification and Analysis Unit (PP&A) No. 2 for Loop No. 2 was shipped from Evendale, Ohio and received and set in place in the HTRMTL, in Schenectady, New York. Installation of PP&A No. 2 will begin in the next quarter.

Figure 2.7 shows the Pumping, Purification and Analysis Units No. 1 and No. 2 in position in the High Temperature Reactor Materials Testing Laboratory. The PP&A Unit No. 1 is on the left of the figure. The gas analysis portion of PP&A Unit No. 1, including the gas chromatograph (left center) and a cabinet (right center) with annunciator, dew point meter control panel and oxygen analyzer can be seen in Figure 2.8. (Other features are listed in the figure caption.)

2.4.1.2 Helium Distribution System - (D.H.Baldwin)

A number of modifications have been made to PP&A No. 1. These changes do not alter the functions of this unit but rather were aimed at reducing or eliminating difficulties identified during shakedown operation and reducing the probability of future air leaks developing in certain critical areas. These modifications include the following:

Figure 2.6. The integrated temperature control system is shown in place in the HTRMTL.

Figure 2.7. Pumping, Purification, and Analysis packages
No. 1 (Left) and 2.

Figure 2.8. Gas analysis section of PP&A No. 1. Gas chromatograph is at left center, with strip chart recorded and peak integrator on counter in foreground. Cabinet at right center includes, from top to bottom, annunciator, dew point meter control panel, strip chart recorders for dew point and oxygen level, and oxygen analyzer. Below counter in same cabinet are purification heater temperature controllers and thermocouple vacuum gage readout.

- Leaks in three solenoid valves were corrected. Bonnet leaks (helium to air) were sealed with RTV; seat leakage (helium to helium) were corrected by using a softer elastomer for the seat material.
- The original pressure relief valves were eliminated and replaced in function by adjustable check valves plumbed into the main helium dump line.
- Valves have been added to the oxygen analytical cell supply and return lines to permit periodic flushing of the sensor with air for calibration purposes, and for subsequent evacuation.
- The No. 1 dew point sensor gas return line was routed to a lower pressure point to permit sufficient flow through the sensor.

After the PP&A No. 1 revisions were completed, the system, including overhead piping and utility frame sub-assemblies (UFSA's) was evacuated for several days and static pressure rise tests performed to assess overall leak rate. A higher than anticipated leak rate was found, and subsequent static pressure loss tests showed that air leaks had opened in several of the UFSA's. The sources of the air leaks were identified in several mechanical joints in the UFSA's; these joints were replaced by welded joints and subsequent static pressure loss tests gave a substantially improved leak rate.

Finally, a number of problems with equipment were identified during the shakedown operations. These are listed as follows:

- Hygrometer sensor developed a major helium leak and was replaced.
- Oxygen sensor developed a major helium leak and was returned to vendor for failure analysis and repair.
- A faulty helium pump starting relay was replaced.
- Defective solid state relays were found in two purification heater controllers and replaced.
- A cracked head was detected on helium pump No. 4. A replacement has been ordered.

2.4.2 Simulated Reactor Helium Instrumentation, Control Systems, Start-Up, and Commissioning Procedures - (R.K.Elton)

Difficulties with the gas chromatograph on Loop No. 1 required it to be returned to the vendor for rework and repair. The problems included leaks in the vicinity of the detector, lack of detector sensitivity, noise in the detector output and an unacceptable dead volume in the analysis lines. The vendor is currently resolving these problems by re-designing and/or replacing several fittings and seals, and replacing the active elements of the detector. These repairs are currently being completed.

During the time the gas chromatograph for Loop No. 1 is being modified, the gas chromatograph for Loop No. 2 has been installed in Loop No. 1 and currently is operational.

One of the oxygen probes developed difficulties when the heating unit apparently malfunctioned. This probe was removed from the loop, returned to the manufacturer for repairs, and replaced with a unit from Loop No. 2.

2.5 TASK 5 - MECHANICAL PROPERTIES EVALUATION

2.5.1 Test Specimen Machining

All of the creep, tensile and structural stability test specimens that are required for the screening test program have been received from the machining vendor (Metcut Research Associates). A photograph of the five steps of test specimens to be used in the screening phase of the program is shown in Figure 2.9. The "C" and "B" type screening creep specimens are numbered 1 and 5, respectively. Specimens labeled 2, 3, and 4 are the tensile, impact and structural stability specimens, respectively.

Figure 2.9. Test Specimens Included for Study in Screening Test Program; 1-Screening Creep Specimen, "C" Type; 2-Tensile Specimen; 3-Impact Specimen; 4-Structural Stability Specimen; 5-Screening Creep Specimen, "B" Type.

After machining, all the specimens were fluorescent penetrant inspected (FPI); in addition, specimens machined from centrifugally cast tubes were inspected by radiographic techniques.

2.5.2 Selection of Stresses for Screening Creep Tests

Based on the 300-hour creep and rupture test results (see Tables 2.4 and 2.5 for the DCHT alloys and Table 2.11 for the NPH alloys), stresses were selected for the following three types of screening creep tests:

1. Stress for 1% total strain in 100,000 hours; tested for 10,000 hours.
2. Stress for 1% total strain in 6,000 hours; tested for 6,000 hours.
3. 80% of the stress for rupture in 10,000 hours; tested for 3,000 hours.

The amount of creep on each sample will be measured at 1,000 hour intervals, following which the samples will be rehung at the same load unless excessive creep is occurring. In the latter case, the specimen may be replaced in the stringer.

2.5.2.1 Direct Cycle Helium Turbine (DCHT) Alloys - (E.W.Ross)

Table 2.13 lists the original estimated stresses and the finally selected stresses for the DCHT alloys for the test conditions. Selecting the 1050°C (1922°F) stresses for the cast alloys, Rene' 100, MM0011CC and DS and IN738, was particularly difficult and subjective due to the necessity of extrapolating the 1050°C (1922°F) short time results to 6,000 to 100,000 hours.

As reported previously, an unexpected surprise was the exceptional amount of improvement in stress-rupture and creep strength for the directionally solidified form of MM-0011 over the conventionally cast form. Normally only a slight improvement in strength is observed for the longitudinal DS vs. CC form of alloys due to the lack of transverse grain boundaries. Apparently, the high temperature solution treatment applied to the MM-0011 DS form resulted in the substantial strength improvement (due to more solution of $\gamma - \gamma'$ eutectic) as the CC material was given the lower temperature commercial MM-0011 treatment.

TABLE 2.13

CALCULATED STRESSES FOR DCHT SCREENING CREEP TESTS

Alloy	Temperature °C	Stress For 1% ϵ_T In 100,000 Hours				Stress for 1% ϵ_T In 6,000 Hours				Stress for 80% σ_R In 10,000 Hours			
		Original		Final		Original		Final		Original		Final	
		MPa	KSI	MPa	KSI	MPa	KSI	MPa	KSI	MPa	KSI	MPa	KSI
IN-738	750	207	30	241	35	345	50	331	48	283	41	297	43
	850	90	13	62	9	152	22	117	17	117	17	131	19
	950	28	4	7	1	83	12	21	3	55	8	21	3
	1050	7	1	.7	0.1	14	2	1.4	0.2	10	1.5	1.4	0.2
Alloy 713LC	750	186	27	262	38	310	45	365	53	248	36	303	44
	850	76	11	62	9	145	21	124	18	110	16	138	20
	950	7	1	7	1	35	5	21	3	21	3	24	3.5
NX-188	750	345	50	262	38	414	60	365	53	372	54	303	44
	850	159	23	83	12	241	35	152	22	186	27	138	20
	950	48	7	21	3	83	12	35	5	69	10	24	3.5
Udimet 720	750	186	27	200	29	310	45	276	40	248	36	303	44
	850	76	11	55	8	145	21	110	16	110	16	124	18
	950	7	1	7	1	35	5	18	2.5	21	3	18	2.5
MA-754	850	83	12	131	19	124	18	138	20	117	17	124	18
	950	55	8	103	15	97	14	117	17	83	12	97	14
	1050	35	5	76	11	76	11	90	13	55	8	69	10
TZM	850	345	50	324	47	400	58	386	56	359	52	352	51
	950	276	40	234	34	317	46	297	43	248	36	283	41
	1050	207	30	124	18	262	38	186	27	145	21	193	28
Rene' 80	750	207	30	262	38	345	50	345	50	303	44	345	50
	850	90	13	124	18	186	27	186	27	145	21	152	22
	950	21	3	24	3.5	83	12	62	9	28	4	35	5
Rene' 100	750	276	40	269	39	379	55	386	56	317	46	345	50
	850	97	14	110	16	193	28	179	26	138	20	152	22
	950	14	2	24	3.5	55	8	55	8	28	4	35	5
	1050	1.4	0.2	3.4	0.5	3.4	.5	7	1	10	1.5	7	1
MM-0011CC	750	345	50	276	40	455	66	386	56	372	54	400	58
	850	159	23	138	20	228	35	200	29	186	27	186	27
	950	48	7	45	6.5	83	12	83	12	69	10	69	10
	1050	14	2	10	1.5	21	3	14	2	21	3	14	2
MM-0011DS	750	345	50	345	50	455	66	455	66	372	54	421	61
	850	159	23	180	26	241	35	248	36	186	27	193	28
	950	48	7	62	9	83	12	110	16	69	10	76	11
	1050	14	2	21	3	21	3	28	4	21	3	21	3
TEST TIME, Hours		10,000				6,000				3,000			

The 300-hour rupture ductilities of the NX-188 alloy were very low (0.4 - 1.1% Elong. and RA). This suggests that the long time tests (1% creep in 6,000 hours particularly) could fail prior to the expected 1% creep limit. Exceptional care will have to be taken to avoid this problem when the final loading matrix is worked out.

2.5.2.2 Nuclear Process Heat (NPH) Alloys - (S.Z.Hayden and R.A.Ellis)

Table 2.14 lists the stresses originally estimated from manufacturers' data for each test condition and the revised stresses selected based on the results of the short time creep-rupture stress verification testing. Selection of the revised stresses has not been completed for the four alloys; Incoloy 800H (coated and uncoated), Incoloy 807, IN-519 and Mo-Re 2, since the creep-rupture testing has not been completed for these alloys. The test stresses for the MA-956E alloy, based on the 1% creep measurements, have not been determined since this alloy exhibits only very small amounts of deformation before rupture; the test stresses will have to be estimated as some fraction of the rupture stress at a given temperature and time.

Stress verification testing will be completed and all of the stresses for the screening creep tests will be determined by the end of October. These revised stresses, as well as those selected for the DCHT alloys, will be used to determine the loading matrix for the multi-specimen screening creep tests.

2.6 TASK 9 - DATA MANAGEMENT AND PROGRAM MANAGEMENT

2.6.1 Data Management - (R.B.Hand)

2.6.1.1 Data Acquisition Procedures

- Test Matrices Coordination

The test matrices coordination has been completed.

- Data Encoding Coordination

A revised edition of the encoding instruction for PAMMED was issued in July, 1978. The changes provided for encoding alloy compositions, gas

TABLE 2.14
CALCULATED STRESSES FOR NPH SCREENING CREEP TESTS

Alloy	Temperature °C	Stress for 1% ϵ_T in 100,000 Hours				Stress for 1% ϵ_T in 6,000 Hours				Stress for 80% ϵ_R in 10,000 Hours			
		Original		Final		Original		Final		Original		Final	
		MPa	KSI	MPa	KSI	MPa	KSI	MPa	KSI	MPa	KSI	MPa	KSI
Incoloy 800H	750	34	5	*	*	48	7	*	*	48	7	48	7
Incoloy 800H	850	21	3	*	*	28	4	*	*	21	3	21	3
Coated	950	3	0.4	*	*	7	1	*	*	7	1	7	1
Incoloy 802	750	55	8	55	8	83	12	83	12	69	10	90	13
	850	21	3	21	3	48	7	34	5	28	4	41	6
	950	7	1	7	1	14	2	14	2	14	2	14	2
Incoloy 807	750	41	6	*	*	69	10	*	*	69	10	69	10
	850	14	2	*	*	28	4	*	*	28	4	28	4
	950	5	0.7	*	*	7	1	*	*	14	2	14	2
	1050	1	0.2	*	*	3	0.4	*	*	3	0.4	4	0.6
Incoloy DS	750	14	2	21	3	28	4	34	5	28	4	34	5
	850	7	1	7	1	14	2	14	2	14	2	14	2
	950	3	0.4	3	0.4	5	0.7	5	0.7	7	1	7	1
HD-556	750	48	7	41	6	33	12	62	9	76	11	96	14
	850	14	2	21	3	34	5	28	4	34	5	48	7
	950	5	0.7	6	0.9	14	2	14	2	14	2	21	3
	1050	1	0.2	1	0.2	3	0.4	4	0.6	4	0.6	6	0.8
Manaurite 36XS	750	41	6	41	6	62	9	55	8	62	9	55	8
	850	21	3	21	3	28	4	34	5	34	5	34	5
	950	7	1	7	1	14	2	14	2	14	2	14	2
	1050	2	0.3	3	0.4	6	0.8	6	0.9	7	1	7	1
HK-40	750	55	8	48	7	90	13	69	10	48	7	62	9
	850	21	3	21	3	34	5	34	5	28	4	34	5
	950	7	1	7	1	14	2	14	2	14	2	14	2
	1050	3	0.4	3	0.4	5	0.7	6	0.9	7	1	7	1
IN-519	750	48	7	*	*	69	10	*	*	62	9	*	*
	850	21	3	*	*	41	6	*	*	34	5	*	*
	950	7	1	*	*	21	3	*	*	14	2	*	*
	1050	3	0.4	*	*	7	1	*	*	7	1	*	*
Hastelloy X	750	34	5	34	5	55	8	55	8	62	9	69	10
	850	14	2	14	2	21	3	28	4	28	4	28	4
	950	4	0.6	4	0.6	7	1	7	1	14	2	14	2
	1050	1	0.1	1	0.1	2	0.3	3	0.4	3	0.4	3	0.5
Inconel 617	750	55	8	62	9	83	12	90	13	96	14	96	14
Inconel 617	850	21	3	28	4	34	5	41	6	41	6	48	7
Coated	950	7	1	14	2	14	2	21	3	21	3	21	3
	1050	4	0.6	3	0.4	7	1	7	1	7	1	7	1
Mo-Re2	750	34	5	*	*	48	7	*	*	131	19	*	*
	850	21	3	*	*	28	4	*	*	55	8	*	*
	950	14	2	*	*	21	3	*	*	21	3	*	*
	1050	7	1	*	*	14	2	*	*	7	1	*	*
MA-956E	850	55	8	**	**	62	9	**	**	69	10	62	9
	950	48	7	**	**	55	8	**	**	55	8	55	8
	1050	34	5	**	**	41	6	**	**	48	7	48	7
TEST TIME, Hours		10,000				6,000				3,000			

*Stress not determined; testing still in progress.

**Stress not determined due to low ductility exhibited during testing.

flow rates, automatic calculation and encoding of time weighed averages and standard deviations for gas chemistries, flow rates and temperatures of test environments, future system expansion, improved material identification and traceability and additional specimen descriptions.

2.6.1.2 Data Storage and Retrieval Procedures

- Data Integrity and Safety

The program to copy the entire data base to magnetic tape for purposes of safety and security has been written and tested. The reverse procedure also has been tested.

- Retrieval Procedures

The Index Sequential Processing (ISP) file structure will have to be changed to incorporate the specimen machine history, gas composition history, gas composition history, and Vareststraint weld information. The storage program will have to be modified to reflect these changes. This will be done during the next report period.

The program to retrieve and present the contents of the data base as an intelligible card image format has had the following features added and tested:

1. Data selectable by Materials Identity Number (MINO)
2. Data selectable by data set
3. Data selectable by test property; i.e., File Identity Code (FI).

This program will also require modification during the next report period to reflect the changes indicated above.

Report formats for more complicated retrievals have been discussed and programming will begin when they have been finalized.

2.6.1.3 Presentation

- Data Presentation

Some examples of status report forms were presented for critical review. In general, the proposed formats and information were acceptable,

but some changes were suggested to improve applicability and clarity. These changes will be made. The forms will show the status of specimens, test equipment, test environment and testing.

- System Operation and Data Presentation

The storage system is ready to accept and store data. The computer data bank will be updated on a weekly basis. Initial storage will be in a temporary file. After checking a retrieval of the data, it will be transferred to the permanent data bank.

Card image retrievals will be made weekly of recently stored data prior to transfer to the permanent data bank. Specific retrievals for the purpose of determining status will be made monthly.

Status will be reported once a month using predetermined formats suitable for use by program management and principal investigators.

These computer generated reports will be initially aimed at program status; i.e., specimen, machine and testing. Later, test results and data plots will be available. Finally, after sufficient data is accrued, analytical results and curve fits will be presented.

2.6.2 Program Management

Project leadership for DCHT Materials was transferred from Dr. R. V. Hillery to Mr. T. K. Redden on July 11, 1978 due to changes in Dr. Hillery's responsibilities. A program review was held for Mr. Redden on August 1, 1978. Project leadership for the NPH Materials was assigned to Dr. S. Yukawa on July 24, 1978 due to the unfortunate death of Dr. R. M. Goldhoff. A review Meeting was held with Dr. Yukawa on July 31, 1978.

Four meetings were held with the High Temperature Reactor Materials Laboratory personnel during the month of July, four meetings were held in the month of August and two meetings were held in September. In addition, a two day meeting governing details of the data management procedures (Task 9.1) was held with program personnel in Schenectady, NY

on September 20, 1978. Finally, GE Program Management participated in the DOE Thermal Gas Reactor FY1979 planning meeting in Washington, DC on September 25 and 26, 1978.

With the receipt of the last two NPH alloys (IN-519 and Mo-Re 2) in July and the completion of the characterization tests in early October, 1978, Task 2 - Material Procurement and Characterization, will have been completed for the initial phase of the screening test program.

Technical problems encountered in the final checkout and commissioning of the controlled purity helium supply system (Loop No. 1) has continued to cause delays in the initiation of the screening test program. This has necessitated a revision to the Program Master Schedule (Revision No. 4) which is presented in Figure 2.10.

3.0 WORK TO BE COMPLETED NEXT QUARTER

- Characterization testing for the remaining two NPH alloys will be completed.
- Welding trials will be completed for the joining studies.
- The 300-hour creep-rupture test results and recommended stress levels for screening creep tests will be reviewed. Modification of the screening creep loading matrix will be completed.
- TZM test bars and pins will be silicide coated.
- M-21, Rene' 80 and coated alloy 713LC will receive the pre-oxidation treatment.
- Installation of Loop No. 2 will be initiated.
- Commissioning tests for Loop No. 1 will be completed.
- Revise computer storage and retrieval programs to incorporate the new and revised data input items.
- Finalize procedures for inter-site data transmission procedures.
- The screening creep and structural stability test program will be initiated.