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**ADVANCED GAS COOLED NUCLEAR REACTOR MATERIALS
EVALUATION AND DEVELOPMENT PROGRAM**

Progress Report for April 1—June 30, 1978

August 31, 1978

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

**General Electric Company
Energy Systems Programs Department
Schenectady, New York**

**TECHNICAL INFORMATION CENTER
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PROGRESS REPORT FOR PERIOD

April 1, 1978 — June 30, 1978

BY
PROJECT STAFF

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August 31, 1978

MASTER

Prepared for

THE U.S. DEPARTMENT OF ENERGY
Under Contract No. EY-76-C-02-2975.A008

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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 Nuclear Process Heat (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 VHTR/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: 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 Nuclear Process Heat (NPH) Alloys - (S. Z. Hayden)

2.2.1.1 Materials Procurement

- ALLOYS

Mill products for twelve of the fourteen candidate alloys have been received. The two undelivered materials (centrifugally cast IN-519 and Mo-Re 2 tubes) have been fabricated by Duraloy-Blaw Knox. Two IN-519 tubes and three Mo-Re 2 tubes have been produced to date; one tube of each alloy (IN-519 Heat No. 24-18 and Mo-Re 2 Heat No. 23-73) is acceptable for evaluation in the screening program.

Due to a continuing strike (since April 1, 1978) at the vendor's plant, procurement of these two alloys have been delayed. Currently, legal steps have been taken to have the tubes removed from the vendor's plant.

● COATINGS

Arrangements have been made with Chromalloy Research and Technology Division, Orangeburg, N.W. during the past quarter to coat Incoloy 800H specimens with the Chromalloy RT 22 process. Sixty-nine (69) Incoloy 800H specimens will be coated for study in the screening program.

In addition, Walbar Metals, Inc., Peabody, Mass. was contacted regarding the CODEP-B coating of Inconel 617 alloy samples. Walbar is the CODEP coating vendor for the DCHT Alloy 713 LC. Eighty-four (84) Inconel 617 samples will be coated for evaluation in the screening phase.

Test coupons of Incoloy 800H and Inconel 617 will be sent to Chromalloy and Walbar, respectively, during the next month so that specific coating parameters can be developed prior to coating actual test specimens.

2.2.1.2 Materials Characterization

Characterization test specimen machining has been completed by Metcut Research Associates for twelve of fourteen materials. Metallography, tensile, creep-rupture and Vareststraint samples for these alloys have been received.

Characterization creep-rupture testing in air is well underway. Preliminary results are presented in Table 2.1. Stresses were selected to produce rupture in approximately 300 hours and creep data is being recorded during each test. The evaluation is being run in the 750° - 1100°C (1382° - 2012°F) temperature range. The upper test temperature (1100°C) is 50°C above the highest screening-creep test temperature [1050°C (1922°F)] and will aid in the determinations of long-time exposure stress levels. A completion date of 31 July 1978 is projected for these tests. The only problem to date has been the difficulty in estimating the proper stress levels for conducting the rupture tests of MA-956E alloy. The heat which is being evaluated has exhibited significantly higher rupture strength as compared with the Wiggin supplied rupture data (on a different product form) and has resulted in longer than anticipated testing times.

As-received room temperature tensile properties have been determined for twelve of fourteen NPH test materials. Tensile results are presented in Table 2.2, which includes the latest available results. Where available,

TABLE 2.1

SHORT TIME CREEP-RUPTURE DATA FOR AS-RECEIVED NPH TEST MATERIALS

ALLOY	SPECIMEN NUMBER	CONDITION FOR TESTS	TEMP (°C)	TEST STRESS		RUPTURE LIFE (HOURS)	ELONGATION (%)	REDUCTION IN-AREA- (%)
				(MPa)	(Ksi)			
Incoloy 800H	1000CR01	S.A. 1232°C	750	97	14.0	286.9	35.6	41.0
	1000CR02		850	45	6.5	333.8		
	1000CR03		950	21	3.1	464.5	39.6	36.0
	1000CR04		1050	10	1.5	594.1 Running		
Incoloy 802	1100CR01	S.A. 1271 - 1282°C	750	152	22.0	480.6	2.7	8.5
	1100CR02		850	86	12.5	433.7	3.7	5.6
	1100CR03		950	38	5.5	767.6	3.7	11.0
	1100CR05		1050	21	3.0	To Be Run		
	1100CR04		1100	12	1.8	573.3 Running		
Incoloy 807	1200CR01	S.T. 1230°C/ 5 min., W.Q.	750	145	21.0	100.2	85.8	73.0
	1200CR02		850	55	8.0	To Be Run		
	1200CR03		950	19	2.7	905.7 Running		
	1200CR04		1050	7	1.0	570.0 Running		
	1200CR05		1100			To Be Run		
Incoloy DS	1300CR01	S.T. 1150°C/ 5 min., A.C.	750	62	9.0	299.4	34.2	37.0
	1300CR02		850	32	4.7	495.1		
	1300CR03		950	17	2.5	445.1	24.2	34.0
	1300CR04		1050	10	1.4	67.8 Running		
HD-556	1400CR02	S.T. 1177°C/ 30 min., W.Q.	750	165	24.0	535	Discontinued	
	1400CR03		850	103	15.0	To Be Run		
	1400CR04		950	35	5.1	332.2 Running		
	1400CR05		1050	17	2.5	To Be Run		
	1400CR06		1100			To Be Run		
HK-40	1700CR02	As-Cast	750	103	15.0	569.9 Running		
	1700CR03		850	62	9.0	To Be Run		
	1700CR04		950	28	4.0	428.1 Running		
	1700CR05		1050			To Be Run		
	1700CR06		1100			To Be Run		

TABLE 2.1 (Continued)

ALLOY	SPECIMEN NUMBER	CONDITION FOR TESTS	TEMP (°C)	TEST STRESS		RUPTURE LIFE (HOURS)	ELONGATION (%)	REDUCTION IN-AREA- (%)
				(MPa)	(Ksi)			
Manaurite 36XS	1500CR01	As-Cast	750	110	16.0	127	32.8	34.0
	1500CR02		850	97	9.0	234.2 Running		41.1
	1500CR03		950	36	5.2	346.1		
	1500CR04		1050	21	3.0	171.9		
	1500CR05		1100	14	2.0	258.8		
Inconel 617	1A00CR01	S.A. 1204°C	750	200	29.0	625.4	19.6	24.8
	1A00CR02		850	72	10.5	401.8 Running	46.9	46.9
	1A00CR03		950	48	7.0	285.9		
	1A00CR04		1050	21	3.0	473.2 Running		
	1A00CR05		1100	15	2.2	67.7 Running		
Hastelloy X	1900CR02	S.T. 1177°C/ 31 min., W.Q.	750	138	20.0	279.1	93.4	87.0
	1900CR03		850	69	10.0	417.3	65.8	67.0
	1900CR04		950	29	4.2	547.6		
	1900CR05		1050	12	1.8	287.4		
	1900CR06		1100	6	0.9	234.3 Running	59.0	56.0
MA-956E	1D00CR02	S.T. 1330°C 1 hr., A.C.	750	90	13.0	2733.2 Discontinued	2.3	3.2
	1D00CR03		950	69	10.0	761.5 Running		
	1D00CR04		950	69	10.0	20.(a)		
	1D00CR05		1050	69	10.0	To Be Run		
	1D00CR06		850			To Be Run		
	1D00CR07		1100			To Be Run		

TABLE 2.2

TENSILE PROPERTY DATA FOR AS-RECEIVED NPH TEST MATERIALS

ALLOY	SPECIMEN NUMBER	CONDITION FOR TESTS	TEMP (°C)	0.2% OFFSET YIELD STRENGTH (MPa)	0.2% OFFSET YIELD STRENGTH (Ksi)	ULTIMATE TENSILE STRENGTH (MPa)	ULTIMATE TENSILE STRENGTH (Ksi)	ELONGATION (% IN 1 INCH GAGE LENGTH)	REDUCTION -IN-AREA (%)
Incoloy 802	1100TN02	S.A. 1271-	R.T.	221	32.0	610	88.5	47.0	58.0
Incoloy 802	1100TN03	1282°C	R.T.	221	32.0	613	88.9	49.0	59.0
Incoloy 807	1200TN02	S.T. 1230°C/	R.T.	255	37.0	662	96.1	53.0	61.0
Incoloy 807	1200TN03	5 min., WQ	R.T.	255	37.0	662	96.0	53.0	61.4
Incoloy DS	1300TN02	S.T. 1150°C/	R.T.	221	32.0	600	87.0	54.0	73.1
Incoloy DS	1300TN03	5 min., AC	R.T.	221	32.0	600	87.0	53.0	73.1
Manuarite 900	1600TN03	As Cast	R.T.	190	28.0	541	78.5	42.0	43.4
Manaurite 900	1600TN04	As Cast	R.T.	190	28.0	543	78.7	39.0	43.4
Manaurite 36XS	1500TN02	As Cast	R.T.	269	39.0	569	82.5	15.3	15.4
Manaurite 36XS	1500TN03	As Cast	R.T.	268	38.8	585	84.8	16.0	16.2
Hastelloy X	1900TN02	S.T. 1177°C/	R.T.	358	52.0	776	112.5	49.0	61.0
Hastelloy X	1900TN03	31 min., WQ	R.T.	357	51.8	772	112.0	49.0	60.5
Inconel 618E	1B00TN02	S.T. 1232°C/	R.T.	269	39.0	633	91.8	60.0	67.1
Inconel 618E	1B00TN03	1 hr., WQ	R.T.	248	36.0	633	91.8	63.0	73.1
MA-956E	1D00TN01	S.T. 1330°C/	R.T.	786	114.0	796	115.5	13.0	41.6
MA-956E	1D00TN02	1 hr., AC	R.T.	786	114.0	800	116.0	12.0	39.1
Incoloy 800H	1000TN02	S.A. 1232°C	R.T.	153	22.2	515	74.8	52.0	69.3
Incoloy 800H	1000TN03	S.A. 1232°C	R.T.	158	22.9	531	77.0	59.0	65.4
Inconel 617	1A00TN02	S.A. 1204°C	R.T.	318	46.0	781	113.3	67.0	58.4
Inconel 617	1A00TN03	S.A. 1204°C	R.T.	318	46.0	780	113.1	64.0	56.4
HD-556	1400TN02	S.T. 1177°C/	R.T.	371	53.9	810	117.6	57.0	64.2
HD-556	1400TN03	30 min., WQ	R.T.	373	54.2	808	117.2	61.0	70.7
HK-40	1700TN02	As Cast	R.T.	309	44.8	667	96.8	23.0	22.4
HK-40	1700TN03	As Cast	R.T.	309	44.8	643	93.3	23.0	22.4

manufacturers tensile data compare well with the tensile results obtained by G.E.

Dirats Testing Laboratories, Westfield, Mass., will conduct an independent chemical analysis on as-received alloys to check for conformance to the material specification and the vendor's certification. The samples required for chemical analysis are currently in machining.

As-received longitudinal and transverse sections of all alloys received to date have been metallographically evaluated with all structures examined to date being acceptable. A summary of grain size and hardness measurements for as-received NPH alloys is presented in Table 2.3.

2.2.1.3 Materials Joining Studies

Varestraint tests now have been completed on nine (9) of the eleven (11) alloys included in joining studies programs. The Varestraint test is being performed to evaluate the tendency for hot cracking in the weld metal, heat-affected zone, and base metal of an autogeneous welded specimen (gas tungsten arc welded). Preliminary results indicate that in order of decreasing resistance to hot cracking, the ranking of the alloys is as follows:

- Inconel 617 (best)
- Incoloy 802
- Incoloy 807
- Manaurite 36XS } comparable
- Incoloy 800H } comparable
- Hastelloy X }
- HK - 40
- HD - 556
- Incoloy DS (worst)

During this quarter most of the welding filler wire and electrodes required for the program have been received. Table 2.4 lists the filler metals recommended by the alloy producers, the filler metals chosen, and the welding method to be used for each alloy.

The next activity planned is to develop welding procedures required to produce sound welds with the weld products and methods selected. The

TABLE 2.3

SUMMARY OF GRAIN SIZE AND HARDNESS MEASUREMENTS
FOR AS-RECEIVED NPH ALLOYS

Alloy	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	0-5.5	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	N/F	96	N/F	(c)

(a) N/F = None Furnished

(b) % Columnarity, hot end/cold end

(c) High grain aspect ratio, greater than $l/d = 10$

TABLE 2.4

SELECTED WELDING METHOD AND FILLER WIRES FOR WELDING STUDIES

Vendor Recommendation			Weld Metal Chosen		
Alloy	Filler Metal	Covered Electrode	Filler Metal	Covered Electrode	Welding Method
Incoloy 800H	Inconel 82	Inco weld A	Inconel 82		Gas Tungsten Arc Welding (GTAW)
Incoloy 802	Inconel 625 Inconel 617	Inconel 112		Inco Weld A	Gas Metal Arc Welding (GMAW)
Incoloy 807	Inconel 625	Inconel 112	Inconel 617		GTAW
Incoloy DS	NC 80/20	Inco Weld A	NC 80/20		GTAW
HD-556	HD-556 Matching Composition		HD-556		GTAW
Manaurite 36XS(a)		Manaurite 36X Matching Composition		Manaurite 36X	GMAW
HK-40(a)		HK-40 Matching Composition		HK-40	GMAW
IN-519(a)		IN-519 Matching Composition		IN-519	GMAW
Hastelloy X	Hastelloy X Matching Composition		Hastelloy X		GTAW
Inconel 617	Inconel 617 Matching Composition		Inconel 617		GTAW
Mo-Re 2		22H		22H	GMAW

(a) Incorrectly reported as GTAW process in previous quarterly report C00-2975-21.

geometrics to be welded for wrought plate and centrifugally cast tube materials were presented in the last quarterly report (C00-2975-21). Machined samples for nine (9) alloys have been received from Metcut Research Associates. Welding trials will be initiated during the month of July.

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

2.2.2.1 Materials Procurement

All 13 alloy/process materials to be evaluated have been received and the machining of test specimens for materials characterization testing is complete.

2.2.2.2 Materials Characterization

The chemical composition of all alloys are listed in Table 2.5. All analyses are within the required specifications.

Metallographic examination of all alloys has been completed and the evaluation has shown that the structures of all the materials are acceptable.

The status of other characterization tests of the 13 alloy/process materials is shown in Table 2.6. Acceptance tests (short time rupture and/or tensile) are nearly completed and the results are shown in Tables 2.7 and 2.8. These tables list the applicable specification requirement, the vendor test results where available, and the General Electric test results from the received material. Note that for the seven cast alloys, the vendor results are "heat acceptance" values and the results are from test bars cast when the heat is initially received and used by the vendor to accept/reject the heat. The GE results are from subsequent molds of test bars. The casting vendor guarantees the capability of the heat to meet the specification. The GE test results to date show that the materials received meet or nearly meet the specifications in all tests.

The heat treatments utilized for the DCHT materials are listed in Table 2.7. In general, the heat treatments used have been developed by prior experience and are part of the established material specifications. In the case of NX-188, MM-0011CC and MM-0011DS alloys, there are no established heat treatments and the heat treatments selected for these three materials were based on published information and discussions with the alloys' inventors.

TABLE 2.5

CHEMICAL COMPOSITION^(a) OF DCHT ALLOYS

Alloy	Heat No.	Cr	Ni	W	Fe	Co	Mo	Al	Ti	Cb	Ta	Zr	B	C	Other	NV _{3B}
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	5.85	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 2.6

STATUS OF DCHT BLADE & VANE MATERIALS
CHARACTERIZATION TESTS

ALLOY

TZM	In Rupture(a) and Tensile Test
MA-754	In Rupture(a) and Tensile Test
MM-0011 CC	Testing Complete
MM-0011 DS	In Rupture(a) and Tensile Test
Rene' 80	Testing Complete
Rene' 100	Testing Complete
Alloy 713 LC	Testing Complete(b)
IN-738	In Rupture(a) and Tensile Test
NX-188	Testing Complete
Udimet 720	In Rupture(a) and Tensile Test
M-21	Testing Complete
YD-Ni	In Rupture and Tensile Test
YD-NiCrAl	In Rupture and Tensile Test

(a) Rupture Tests include acceptance testing and 300-hour creep and rupture tests for long time stress verification.

(b) Except for RT tensile testing after coating.

TABLE 2.7

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	
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	-	-	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	19.8	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 Dir. 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.	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-Ni	2000F/1 Hr (By Vendor)	1092	2000	51.7	7.5	-	-	.1	-	-	5.0	-	-	-	Longitudinal Dir.
YD-NiCrAl	2450F/1 Hr	1093	2000	51.7	7.5	20	-	-	5	-	-	-	-	-	Longitudinal Dir. Long Transverse
		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).

TABLE 2.8

TENSILE ACCEPTANCE TEST RESULTS FOR DCHT ALLOYS

Alloy	Temperature °C °F	ULTIMATE TENSILE STRENGTH						0.2% YIELD STRENGTH						ELONGATION, %			REDUCTION AREA, %			Remarks	
		Min. MPa	Spec. KSI	Vendor MPa		GE KSI		Min. MPa	Spec. KSI	Vendor MPa		GE KSI		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	737.8	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																			
	RT	RT																			
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	887.7	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. 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	100	780.5	113.2	768.1	111.4	18	32	37.8	-	-	-	Vendor Ran 2 Tests Coated
	RT	RT	-	-	878.4	127.4	-	-	-	-	801.9	116.3	-	-	-	-	-	-	-	-	
	RT	RT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	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 - 3x10⁻⁵ Torr).

(c) Average.

The 300-hour rupture and creep testing at 750-1050°C for verification of previously selected 3000-10,000-hour stress levels (all alloy/processes except M-21, YD-Ni and YD-NiCrAl) have been completed for Alloy 713LC, Rene' 80, MM-0011CC, Rene' 100 and NX-188 and are in progress for all the other materials. The results to date are shown in Tables 2.9 and 2.10.

2.3 TASK 3 - TESTING AND ANALYSIS FACILITIES AND EQUIPMENT - (D. H. Baldwin)

2.3.1 High Temperature Reactor Materials Testing Laboratory (HTRMTL)

2.3.1.1 Construction

The last remaining and comparatively small construction tasks were completed during this quarter:

- Fabrication and installation of the copper helium dump line system from the utility frame subassemblies and the Pumping, Purification and Analysis Unit (PP&A) No. 1 to an outdoors vent.
- Installation of piping for filtered and dried compressed air to the laboratory shop area and PP&A No. 1.
- Modification of helium lines to allow calibration gas and purging helium to be passed through the gas chromatograph independently of the controlled impurity test gas.
- Fabrication and installation of stainless steel helium lines connecting stand retorts to utility frame subassemblies.
- Removal of obstructions to provide overhead clearance for loading and unloading multi-specimen creep test stands.
- Installation of water lines to helium coolers to exit ports of copper furnaces in PP&A No. 1.
- Tie-in to domestic cold water supply and final operational checkout of water pumping system.
- Operational checkout of back-up electrical power system.
- Application of thermal insulation to cooling water distribution piping.

Laboratory construction related to Loop No. 1 is completed.

2.3.1.2 Helium Distribution System

Leak checking and repair activities on Loop No. 1 were completed during this quarter. Sections or subsystems were checked individually, and detected leaks reduced until undetectable with a helium mass-spectrometer leak detector capable of detecting leaks of 5×10^{-8} std cc/sec of air.

The system has been operated for several periods of up to ten days duration for shakedown purposes. A number of problems have been uncovered, most having to do with the tendency for leaks to develop in areas of vibration

TABLE 2.9
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	Running
	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	234			
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	Running Running
	850	1562	296.5	43	381			
	950	1742	124.1	18	379			
MA-754	850	1562	124.1	18	497			Running
	950	1742						
	1050	1922						
TZM	850	1562 ^(a)	462.0	67	996.0	21.0	91.0	Discontinued Discontinued
	950	1742 ^(a)	400.0	58	664.7			
	1050	1922 ^(a)	379.2	55	108.7			

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

TABLE 2.10
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	11	1.8	99.4	4.34
	850	1562	406.8	59	235	305	327.4	1.10
	950	1742	213.7	31				
	1050	1922						
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 ^(a)	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 ^(a)	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				
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				
	850	1562						
	950	1742						
MA-754	850	1562						
	950	1742						
	1050	1922						
TZM	850	1562 ^(b)	482.7	70				
	950	1742 ^(b)						
	1050	1922 ^(b)						

(a) Extrapolated.

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

or elevated temperatures. Despite these unresolved leakage problems, the system's ability to maintain desired helium pressures and flow rates was demonstrated. Further, encouraging results were obtained from the purification system. Over a period of days, the oxygen level was reduced to a measured value of 10^{-16} atm partial pressure, moisture to less than 2 vppm and all other impurities to undetectable levels (less than 1 vppm).

Other HTRMTL activities related to the helium system during the report period include assembly of the portable gas analysis station (Carle Gas Chromatograph and Shaw dew point meter) and associated plumbing.

2.3.2 Single Specimen Creep/Rupture Equipment

Ten additional test stands and furnaces have been received from the vendor. Delivery of the last five stands is scheduled for September, 1978.

2.3.3 Lubrication for Metal Couplings

The need for a lubricant to prevent specimens from diffusion welding to the couplings under a reducing chemistry environment has been identified. Because of the high temperatures involved, this material would need to be a solid in fine powder form. Most solid lubricants are unacceptable because of possible reactions with the gas chemistry or due to their low melting points. In addition, very hard lubricants may cause specimen galling. At present, MgO appears to be the most acceptable choice for a solid anti-sieze agent and will be evaluated during loop commissioning tests.

2.4 TASK 4 - SIMULATED REACTOR HELIUM ENVIRONMENT FACILITIES AND EQUIPMENT

2.4.1 Simulated Reactor Helium "Loop" System Design and Construction - (C. L. Ehde)

Fabrication of the pumping, purification and gas analysis sub-assembly plus the instrumentation and control consoles for Loop No. 2 has been completed and the sub-system is undergoing checkout tests.

Shipment of the PP&A Sub-assembly for Loop No. 2 will follow the completion of the checkout tests in July.

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

2.4.2.1 Instrumentation

The radiation materials license amendment was approved, allowing the laboratory to house two gas chromatographs with helium ionization detectors. The chromatograph calibration system was modified by adding a vent and a connection for a He gas cylinder. The vent allows calibration gas to be dumped overboard through a bubbler without contaminating the loop. A high purity He gas cylinder has been joined to the calibration system to allow the residual calibration gas in the lines to be purged out before loop gas is sampled for analysis. The chromatograph has been in use for over a month for analyzing loop gas.

The dew point probes have been calibrated using a three-cylinder stainless steel calibration manifold to insure trace moisture control. Both probes were first calibrated using a moisture standard of 6.5 ppmv. The response of the probes was subsequently checked using a moisture stand of 1.0 ppmv. The results indicated an accuracy within the manufacturer's claims (± 0.3 ppmv at 1.0 ppmv H_2O) and suggest the probes are accurate for moisture levels between 0.5 ppmv and 10 ppmv H_2O . Both probes have been operating satisfactorily for several months.

The oxygen probes have also been functioning satisfactorily for several months.

2.4.2.2 Laboratory Alarm Systems

A plan for an alarm system to notify responsible persons of an emergency laboratory situation during off-hours has been prepared. The signal(s) generated during an alarm condition would be sent to the main plant security headquarters, by means of phone lines. The signal would be manifest as an audio and visual annunciation at a console under constant supervision.

The following conditions have been chosen as criteria for signalling an alarm:

- High Dew Point
- Backup Gas On
- Low Loop Pressure
- High O₂ Main Loop
- High O₂ Analysis System
- Pump #1 Low Pressure
- Pump #2 Low Pressure
- Pump #3 Low Pressure
- Pump #4 Low Pressure
- High Fill Gas Flow
- Loss of Cooling Water
- High Laboratory Temperature

An alarm system also has been selected to monitor the level of liquid nitrogen in the purification canisters.

2.4.2.3 Gas Chemistry Experiments

To gain system operating experience, several preliminary gas chemistry experiments have been performed during leak checking operations. A typical experiment involves the following steps:

1. The loop is evacuated.
2. Vacuum pumps are disconnected and the rise in pressure of the loop is plotted for several hours. This data is translated into an overall leak rate for the system.
3. The loop is filled with high purity helium and the pumps are activated.
4. The impurity gas levels are measured using the appropriate instrumentation.
5. The loop gas is circulated through all purification canisters required to remove the impurity gases. The decrease in levels of these gases is monitored.
6. When all gases except H₂O and O₂ have been removed to levels below chromatographic detectability, all purification components are closed off. The rise in any impurity levels, particularly H₂O and O₂ is observed.

2.4.2.5 Fatigue Test Gas Supply System

Three preliminary designs for delivery controlled-impurity helium to the fatigue test chamber are being evaluated. These systems are summarized as follows:

System I - A once through system where welding grade helium is purified over a 77°K activated charcoal bed, followed by a heated copper canister.

Impurities are added through micrometering valves. CH_4 and H_2 are added upstream of the copper bed, and a mixture of 0.5% CO_2 in CO is purified over a small, heated Pt chamber, and added downstream through a micrometering valve. H_2O is added by diverting some of the flow over a chamber containing oxalic acid dihydrate at 273°K .

System II - This system is very similar to System I except that only H_2 would be added upstream of the heated Cu canister, and that CH_4 and the mixture of CO_2 in CO would be added downstream directly without any catalytic purification.

System III - A configuration where helium test gas which is mixed in one of the main loops is circulated through the fatigue test stand. This system requires the addition of a large tank to the main loop gas line to absorb fluctuations in gas chemistry upon test initiation.

A decision on the helium supply system will be made during the next quarter.

2.5 TASK 5 - MECHANICAL PROPERTIES EVALUATION

2.5.1 Test Specimen Machining

The chosen machining vendor, Metcut Research Associates, Cincinnati, Ohio, is continuing specimen machining for both the NPH and the DCHT alloys.

The number of specimens being machined for the DCHT alloys include 111 tensile bars, 409 screening creep bars and 376 corrosion pins. The machining of these specimens should be completed by mid-August, 1978.

Table 2.11 shows the required and received specimens for the NPH alloys. Top machining priority has been given for Incoloy 800H and Inconel 617 test specimens, since a number of these samples will have to be coated.

All machined specimens, both NPH and DCHT alloys, will be fluorescent penetrant inspected. In addition, NPH alloys machined from centrifugally cast tubes will be radiographically inspected.

TABLE 2.11

STATUS OF NPH TEST SPECIMENS

Alloy	TEST SPECIMEN													
	Varestraint		Creep Rupt.		Tensile		Screening Creep		Structural Stability		Impact		Screening Weld	
	Rec. (a)	Req. (b)	Rec.	Req.	Rec.	Req.	Rec.	Req.	Rec.	Req.	Rec.	Req.	Rec.	Req.
Incoloy 800H	6	6	12	12	26	26	25	48	25	42	10	20	1	1
Incoloy 802	6	6	6	6	13	13	8	23	15	26	5	10	1	1
Incoloy 807	6	6	6	6	16	16	8	33	15	26	6	12	1	1
Incoloy DS	6	6	6	6	13	13	8	23	15	26	5	10	1	1
HD-556	6	6	6	6	16	16	11	33	15	26	6	12	1	1
Manaurite 36XS	6	6	6	6	16	16	10	34	15	26	6	12	1	1
Manaurite 900	-	-	-	-	2	2	-	-	15	26	-	-	-	-
HK-40	6	6	6	6	16	16	11	31	13	26	6	12	1	1
IN-519	0	6	0	6	0	16	0	30	0	26	0	12	0	1
Hastelloy X	6	6	6	6	16	16	8	28	15	26	6	12	1	1
Inconel 617	6	6	12	12	32	32	19	64	21	42	12	24	1	1
Inconel 618E	-	-	-	-	2	2	-	-	15	26	-	-	-	-
MO-Re 2	0	6	0	6	0	16	0	43	0	26	0	12	0	1
MA-956E	-	-	6	6	13	13	18	35	15	26	5	10	-	-
TOTAL	54	66	72	84	181	213	126	425	194	396	67	158	9	11

(a) Rec. - Received.

(b) Req. - Required.

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

This activity has been completed.

- Encoding Instructions

A revised edition of the encoding instructions for PAMMED will be issued by July 10, 1978.

2.6.1.2 Presentation

- Data Presentation

The first step in establishing the desired data presentation has been taken. This consists of providing the encoding form headings along with the card image retrievals, separating the data fields and placing decimal points in the proper positions. Such presentation requires 132 columns. Consequently, the batch system will be used.

- Data Plotting

A time-sharing data plotting program which operates with the Hewlett Packard Model 7202A Graphic Plotter has been obtained. The instructions for its use will be issued to program personnel. A modified program for use with the Hewlett Packard Model 7221A Graphic Plotter will be written and similarly issued later in the program.

- Curve Plotting

A time-sharing curve plotting program for plotting the average and average minus the standard deviation curves from specified equations and statistical data on either of the above indicated plotters has been obtained. The instructions will be written and issued to program personnel.

- Data Analysis

A time-sharing data analysis program has been obtained. It may be modified by the user to statistically analyze data for most material properties. It creates files which may be used with the plotting programs indicated above. Instructions for its use will be written and issued to program personnel.

2.6.2 Program Management

The report prepared by the Advanced Gas Cooled Nuclear Reactor Materials Program Advisory Review Board (edited by L. P. Jahnke, Chairman) summarizing the Review Board's recommendations from the March 1978 meeting was issued June 15, 1978 and transmitted to the DoE Program Manager for his review and consideration in regard to program scope or direction.

A number of meetings covering various aspects of HTR materials were held during the reporting period. Representatives from Huntington Alloys, Inc. visited GE, Schenectady, NY on April 20, 1978 for technical discussions of materials properties and recommended welding procedures of the alloys they have produced for the program. On April 13, 1978, Dr. K. Schneider of Brown, Boveri and CIE, Mannheim, W. Germany visited GE for a technical exchange of information pertaining to US and FRG programs directed toward Nuclear Process Heat and Direct Cycle Helium Turbine. On June 16, 1978, Dr. Buresch from the Kernforschungsanlage Institut fur Reaktor Werkstoffe, Jülich GmbH visited the GE Research and Development Center to discuss recent developments in ceramics for HTR applications. Finally, on June 29, 1978, a meeting was held with the DoE Program Manager to review FY1979 budget requests for the program.

The Program Master Schedule is presented in Figure 2.1. The major items affecting the current program schedule are the delays in receipt of the two cast tubes for the NPH screening test program due to a continued strike at the vendor's plant and the delays in the initiation of the commissioning tests of Loop No. 1 due to problems in achieving satisfactory leak tightness of various mechanical joints and connections. Legal steps

taken to remove the tubes from the vendor's plant should be finalized in July and modifications to Loop No. 1 to achieve the desired level of oxygen ingress in the system should be completed in August.

Section 3.0

WORK TO BE COMPLETED DURING THE NEXT QUARTER

3.0 WORK TO BE COMPLETED NEXT QUARTER

- Characterization testing for both DCHT and NPH alloys will be completed.
- The machining of screening test specimens for both DCHT and NPH alloys will be completed.
- The remaining two NPH alloys will be received.
- Filler materials for the joining studies will be received and welding trails will be initiated.
- The 300-hour creep-rupture results will be thoroughly reviewed and, where necessary, the recommended stress levels for the 750°C-1050°C, 3000-6000- and 10,000-hour screening creep testing will be revised.
- The Alloy 713 LC corrosion pins will be codep coated and the TZM test bars and pins silicide coated.
- Specimens of M-21, codep coated Alloy 713 LC and Rene' 80 corrosion pins will be given preoxidation treatments.
- Commissioning tests for Loop No. 1 will be initiated.
- The pumping purification and analysis console for Loop No. 2 will be received.
- A shakedown of the storage and retrieval procedures, completion of the automatic calculation and presentation programs, continuation of the development of the selective retrieval programs, and development of encoding forms and instructions for the data management system will be carried out.