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ADVANCED GAS COOLED NUCLEAR REACTOR MATERIALS
EVALUATION AND DEVELOPMENT PROGRAM

Progress Report, October 1—December 31, 1977

March 20, 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

OCTOBER 1, 1977 — DECEMBER 31, 1977

**BY
PROJECT STAFF**

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**ENERGY SYSTEMS PROGRAMS DEPARTMENT
SCHENECTADY, NEW YORK 12345**

MARCH 20, 1978

Prepared for

**THE U.S. DEPARTMENT OF ENERGY
Under Contract No. EY-76-C-02-2975.A007**

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FOREWARD

The Advanced Gas Cooled Nuclear Reactor Materials Evaluation and Development Program is being conducted for the Division of Nuclear Research and Applications, 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, 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 October 1, 1977 through December 31, 1977 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), 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 procurement of the materials for the screening test program and information from vendor certification for the materials received for the nuclear process heat candidate alloys. The design modifications to the helium purification system and the construction status of the simulated reactor helium supply system, testing equipment, and analysis instrumentation and equipment are discussed. Finally, the status and details of the data management are presented.

Section 1.0
INTRODUCTION

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 960 - 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:
 - o Surface stability ("corrosion" resistance) in 10,000 hours.
 - o Structural stability in 10,000 hours - changes in microstructure and tensile, impact and fatigue properties.
 - o Creep properties in 15,000 hours.
 - o Stress rupture properties in 10,000 hours.
 - o 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: COO-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 listing of the alloys selected for the program was presented in the last quarterly report: COO-2975-17.

2.2 TASK 2 - MATERIALS PROCUREMENT AND CHARACTERIZATION

2.2.1 Nuclear Process Heat Alloys (NPH) - (S. Z. Hayden)

2.2.1.1 Materials Procurement

In the previous Quarterly Progress Report, it was reported that the materials procurement specifications had been issued and purchase orders had been placed for all the candidate alloys for NPH applications. During this past quarter, mill products for ten of the fourteen candidate alloys for the NPH Program have been received. Table 2.1 presents the applicable specification, material producer, form and quantity ordered or received and the status of each of the NPH alloys. As indicated in Table 2.1, the alloys which are currently in-house include the Huntington Alloys, Inc. fabricated materials Incoloy 800H, Incoloy 802, Inconel 617 and Inconel 618E, the Henry Wiggin & Co., Ltd. produced materials Incoloy 807, Incoloy DS and MA-956E, the Aciéries Manoir Pompey centrifugally cast tubes* of Manaurite 900 and Manaurite 36XS alloys, and the Stellite Div., Cabot Corp. produced alloy Hastelloy X.

*Obtained from General Atomic Co.

Table 2.1
STATUS OF NUCLEAR PROCESS HEAT TEST MATERIALS

<u>Alloy</u>	<u>Applicable Specification</u>	<u>Material Vendor</u>	<u>Form and Quantity Ordered or Received</u>	<u>Expected Shipping Schedule</u>
Incoloy 800H	EPD 01-0001-00-0	Huntington Alloys, Inc.	1.59-cm plate, 280.3 Kg	Received
Incoloy 802	EPD 01-0002-00-0	Huntington Alloys, Inc.	1.59-cm plate, 137.0 Kg	Received
Incoloy 807	EPD 01-0003-00-0	Henry Wiggin & Co., Ltd.	1.59-cm plate, 147.0 Kg	Received
Incoloy DS	EPD 01-0004-00-0	Henry Wiggin & Co., Ltd.	1.59-cm plate, 145.0 Kg	Received
HD-556	EPD 01-0008-00-1	Stellite Div., Cabot Corp.	1.59-cm plate, 136.1 Kg	2/20/78
Manaurite 900*		Aciéries Manoir Pompey	15.6-cm O.D.x11.9-cm I.D. ~160 Kg	Received
Manaurite 36XS*		Aciéries Manoir Pompey	15.6-cm O.D.x11.9-cm I.D. ~160 Kg	Received
HK-40	EPD 01-0009-00-1	Duraloy Blaw-Knox, Inc.	14.3-cm O.D.x10.5-cm I.D. ~136 Kg	1/31/78
IN-519	EPD 01-0011-00-0	Duraloy Blaw-Knox, Inc.	14.3-cm O.D.x10.5-cm I.D. ~136 Kg	1/31/78
Hastelloy X	EPD 01-0007-00-1	Stellite Div., Cabot Corp.	1.59-cm plate, 136.1 Kg	Received
Inconel 617	EPD 01-0003-00-0	Huntington Alloys, Inc.	1.59-cm plate, 276.7 Kg	Received
Inconel 618E		Huntington Alloys, Inc.	1.90-cm plate, ~45 Kg	Received
Mo-Re 2	EPD 01-0010-00-1	Duraloy Blaw-Knox, Inc.	14.3-cm O.D.x10.5-cm I.D. ~136 Kg	1/31/78
MA-956	EPD 01-0006-00-1	Henry Wiggin & Co., Ltd.	2.54-cm dia. bar, ~28 Kg 1.91-cm dia. bar, 45.4 Kg	Received 3/31/78

*Received from General Atomic Co., San Diego, CA

It should be noted that two purchase orders have been placed for the Henry Wiggin & Co., Ltd. supplied ODS alloy, MA-956E. This is a result of the extremely long production schedule (~18-22 weeks) for a new lot of MA-956E quoted by Wiggin. The first order (~28 Kg, on hand at Wiggin when ordered) which has already been received, will provide enough material to complete the screening portion of the program. The second shipment of MA-956E 45.4 Kg (100 lb.) is scheduled for March 31, 1978.

With regard to three of the centrifugally cast reformer tube materials, a shipping delay of about one month is expected because the mill has experienced difficulty meeting the 75% columnar grain structure specification requirement for the HK-40 and IN-519 alloys. In addition, although the Mo-Re 2 alloy exhibited at least 75% columnar grain structure, the vendor has had problems maintaining I.D. porosity levels below specification requirements, 2.4 mm (3/32 in.) . New melting trials have been scheduled for 1978 fiscal week 1 to meet these requirements; the melt pouring temperature for the three subject materials will be optimized to improve structure. Both macrostructure and I.D. porosity are a function of superheat (and other variables). It is anticipated that these materials will be shipped in February 1978.

The Haynes Developmental Alloy No. 556 (HD-556) plate failed to meet vendor qualification oxidation resistance requirements and was subsequently scrapped. The vendor has agreed to remake the plate from another heat they have in inventory. A revised shipping date of February 20, 1978 is scheduled.

Since the delivery of four candidate program alloys (HK-40, IN-519, Mo-Re 2 and HD-556) has been delayed, as discussed in the preceding paragraphs, it is planned to have these materials shipped from the mill directly to the machining vendor in order to expedite specimen machining and alloy characterization. Since there are no in-house inspection requirements specified for the three as-received centrifugally cast reformer tube products, direct shipment to the machining vendor will cause no programmatic problems.

Nondestructive inspection of the Hastelloy X material was completed by the vendor using both the ultrasonic straight beam and angle beam techniques (immersion method) in accordance with ASME Boiler and Pressure Vessel Code requirements; the same inspections will be performed for the HD-556 alloy. Cognizant GE non-destructive testing personnel have reviewed and approved the vendor's inspection procedures.

2.2.1.2 Materials Characterization

Ultrasonic inspection of the as-received mill products has been completed at GE. The plates were inspected by the ultrasonic angle beam (shear wave) method, and the 2.54-cm (1-inch) diameter MA-956E bars were inspected by the ultrasonic straight beam technique. Preliminary results have indicated that no subsurface indications were revealed for the plate materials. Two or three 1-cm (0.4-inch) long centerline indications were noted in the MA-956E bar. These areas have been marked and will not be used for specimen fabrication.

The candidate NPH alloys which will be evaluated in the screening program are listed in Table 2.2, along with GE code number, producer, heat number, as-received form, as-received heat treatment, and applicable specifications for each alloy. All test specimen numbers will be referenced to the code numbers shown in this table.

The chemical composition of the as-received alloys are presented in Table 2.3. For the most part, the values are the result of vendor material certifications. Chemical analyses of the Mnaurite 900 and Mnaurite 36XS alloys also were conducted by the International Nickel Company (INCO) Research Laboratories for General Atomic Company (GAC). It should be noted that the Ni value of the Mnaurite 36XS alloy, as determined by INCO (36.0% Ni) is slightly in excess of the vendor specification (32.0% min.-35.0% max. Ni). The chemical compositions of the other as-received alloys were within the specification limits for the alloys.

The vendor supplied high-temperature stress-rupture and room temperature tensile mechanical properties for the specific alloy heats to be evaluated are presented in Table 2.4. Also shown in Table 2.4 are vendor supplied hardness and ASTM Grain Size values. Mechanical properties met the minimum requirements of the applicable specifications.

Table 2.2

NUCLEAR PROCESS HEAT TEST MATERIALS PROCESSING HISTORY

Alloy	GE (a) Code Number	Producer	Heat No.	As-Received Form	As-Received Heat Treatment	Applicable Specification
Incoloy 800H	1000	Huntington	HH8099A	1.59-cm x 111.8-cm x 195.6-cm plate	S.A. 1232°C	EPD 01-0001-00-0
Incoloy 802	1100	Huntington	HM290B	1.59-cm x 86.4-cm x 121.9-cm plate	S.A. 1271-1282°C	EPD 01-0002-00-0
Incoloy 807	1200	Henry Wiggin	PTH0823	1.59-cm x 91.4-cm x 121.9-cm plate	S.T. 1230°C/5 min., WQ	EPD 01-0005-00-0
Incoloy DS	1300	Henry Wiggin	UTT0583	1.59-cm x 91.4-cm x 121.9-cm plate	S.T. 1150°C/5 min., AC	EPD 01-0004-00-0
HD-556	1400	Cabot		To Be Received		EPD 01-0008-00-1
Manaurite 36XS	1500	Aciéries Manoir Pompey	1268.0726	15.6-cm O.D. x 11.9-cm I.D. cast tube	As-cast	
Manaurite 900	1600	Aciéries Manoir Pompey	1268.0402	15.6-cm O.D. x 11.9-cm I.D. cast tube	As-cast	
HK-40	1700	Duraloy		To Be Received	As-cast	EPD 01-0009-00-1
IN-519	1800	Duraloy		To Be Received	As-cast	EPD 01-0011-00-0
Hastelloy X	1900	Cabot	2600-7-4760	1.59-cm x 91.4-cm x 121.9-cm plate	S.T. 1177°C/31 min., WQ	EPD 01-0007-00-1
Inconel 617	1A00	Huntington	XX14A6UK	1.59-cm x 121.9-cm x 167.6-cm plate	S.A. 1204°C	EPD 01-0003-00-0
Inconel 618E	1B00	Huntington	Y09B9S	1.90-cm x 20.3-cm x 43.2-cm plate	S.T. 1232°C/1 hr., WQ	
Mo-Re 2	1C00	Duraloy		To Be Received	As-cast	EPD 01-0010-00-1
MA-956E	1D00	Henry Wiggin	LCWZ	2.50-cm dia. x 152.4-cm long bar	S.T. 1330°C/1 hr., AC	EPD 01-0006-00-1

Notes: S.A. = Solution annealed

S.T. = Solution treated

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

Table 2.3

CHEMICAL COMPOSITION OF NUCLEAR PROCESS HEAT TEST MATERIALS

CE 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	--
1300	Incoloy DS (b)	0.065	35.3	Bal	18.35	1.08	2.30	--	0.07	--	--	--	--	0.05	0.07	--	--	--	--	--	0.005	--
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	--	--	--	--	--	--	--	--	0.24	0.018	--
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	--
1D00	MA-956E (b)	--	--	Bal	19.04	--	--	--	--	--	--	--	4.63	0.31	--	--	--	--	--	--	--	Y ₂ O ₃ : 0.46 O: 0.20 N: 0.044

Notes: (a) Values determined by International Nickel Research Laboratories for General Atomic Co.

(b) Values from Vendor Certifications.

(c) Balance of alloy obtained by difference.

Table 2.4

VENDOR SUPPLIED QUALIFICATION PROPERTY DATA FOR NUCLEAR PROCESS HEAT TEST MATERIALS

Material	Applicable Specification	Condition For Qualification Tests	Stress Rupture Properties						Tensile Properties									
			Temp. (°C)	Stress [MPa (ksi)]	Rupture Time		Elongation		Temp. (°C)	0.2% Offset Yield Strength		Ultimate Tensile Strength		Elongation		Reduction-in-area (%)	Hardness (RB)	Grain Size ASTM #
					Actual (hr.)	Min. (hr.)	Actual (%)	Min. (%)		Actual [MPa (ksi)]	Min. (a) [MPa (ksi)]	Actual [MPa (ksi)]	Min. (a) [MPa (ksi)]	Actual (%)	Min. (%)			
Incoloy 800H	EPD 01-0001-00-0	S.A. 1232°C	---	---	---	---	---	---	20	186 (27.0)	170 (25)	520 (75.5)	450 (65)	55	30	69	67	1
Incoloy 802	EPD 01-0002-00-0	S.A. 1271-1282°C	---	---	---	---	---	---	20	252 (36.5)	207 (30.0)	620 (90.0)	517 (75)	47	18	52	75	1
Incoloy 807	EPD 01-0005-00-0	S.T. 1230°C/5 min., W.Q.	---	---	---	---	---	---	20	286 (41.5)	250 (36.2)	666 (96.6)	620 (89.9)	53.1	30	---	86	3
Incoloy DS	EPD 01-0004-00-0	S.T. 1150°C/5 min.-AC	---	---	---	---	---	---	20	227 (32.9)	170 (24.6)	600 (87.0)	480 (69.6)	53.1	30	---	86	0.0-5.5
Manaurite 36XS	None	As-cast	---	---	---	---	---	---	20	310 (44.9)	245 (35.6)	534 (77.5)	441 (64.0)	15.5	8	---	---	---
Manaurite 900	None	As-cast	---	---	---	---	---	---	20	205 (29.7)	186 (27.0)	499 (72.4)	441 (64.0)	42.5	25	---	---	---
Manaurite 900	None	As-cast	---	---	---	---	---	---	20	194 (28.2)	---	475 (68.8)	---	44	---	---	---	---
Hastelloy X	EPD 01-0007-00-1	S.T. 1177°C/31 min., WQ	816	110 (16.0)	72	24	164	8	20	345 (50.0)	276 (40.0)	765 (111.0)	689 (100.0)	49.0	35	53.0	---	6
Inconel 617	EPD 01-0003-00-0	S.A. 1204°C	---	---	---	---	---	---	20	317 (46.0)	207 (30.0)	755 (109.5)	620 (90.0)	75	35	56	84	00
Inconel 618E	None	S.T. 1232°C/1 Hr., W.Q.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MA-956E	EPD 01-0006-00-1	S.T. 1330°C/1 Hr., A.C.	1100	48 (7.0)	53 ^(b)	7.5	10	---	---	---	---	---	---	---	---	---	---	---

Notes: S.A. - Solution Annealed
S.T. - Solution Treated

(a) Minimum Values are Specified Minima

(b) Step Loaded: 38 MPa/24 Hrs., 48 MPa/24 Hrs.,
59 MPa/5 Hrs.

2.2.2 Direct Cycle Helium Turbine (DCHT) Alloys - (R. V. Hillery)

2.2.2.1 Materials Procurement

The ordering cycle for the DCHT alloys was completed during December 1977. Delivery of these materials is expected to begin by early February, and all alloys are expected to be received by the end of March, 1978.

The alloys, vendors, and material forms ordered are shown in Table 2.5. Eleven nickel-base alloys and one molybdenum-base alloy will be procured in as-cast and wrought forms. MM-0011 will be evaluated in conventionally cast (vacuum investment cast) and directionally solidified conditions. Alloys that are available as conventionally cast will be cast to test bar configuration to facilitate machining (minimal metal removal) of the test specimens. The common cast bar configuration (TBM128) shown in Figure 2.1 has been selected for the as-cast configuration for screening creep and tensile test specimens.

2.2.2.2 Materials Characterization

The final list of Material and Process Specifications prepared is shown in Tables 2.6 and 2.7 respectively. Materials specifications specify the class, requirements, quality assurance, and delivery preparation for vendor supplied materials. Process and measurement specifications describe the equipment and procedures to be used in the quality assurance evaluations.

Two materials, YD-Ni and M-21, are being procured without a prepared GE specification. However, these materials are to be tested only in the structural stability exposure tests and, in the case of YD-Ni, the material is developmental and is to be made on a "product of best effort" basis. The M-21 alloy, although available in Europe, is not commonly produced and cast in the USA and difficulty in preparing a specification acceptable to vendors was encountered. In both cases, sufficient controls on chemistry and other properties of the material will be called out on

TABLE 2.5

DCHT MATERIALS PROCUREMENT INFORMATION

<u>Alloy</u>	<u>Applicable Specification</u>	<u>Material Vendor</u>	<u>Form Ordered</u>
MM-0011 CC ^(a)	EPD-01-0016-00-0	Misco	CTS Test Bars ^(b)
MM-0011 DS ^(c)	EPD-01-0016-00-0	TRW	CTS Test Bars
Rene'80 CC	EPD-01-0014-00-0	Misco	CTS Test Bars
Rene'100 CC	EPD-01-0015-00-0	Misco	CTS Test Bars
IN-713LC CC	AMS 5391B	Misco	CTS Test Bars
IN-738 CC	EPD-01-0019-00-0	Misco	CTS Test Bars
NX-188 CC	EPD-01-0017-00-0	Misco	CTS Test Bars
M-21 CC	---	Misco	CTS Test Bars
YD-Ni	---	Special Metals	Hot Finished Bar
YD-NiCrAl	EPD-01-0013-00-0	Special Metals	Hot Finished Bar
U-720	EPD-01-0018-00-0	Special Metals	Hot Finished Bar
MA-754	EPD-01-0012-00-0	Hungtington Alloys	Hot Finished Bar
Mo-TZM	AMS 7819	AMAX Specialty Metals	Hot Finished Bar

(a) Conventionally Cast

(b) Cast-to-Size Test Specimens

(c) Directionally Solidified

TABLE 2.6DCHT MATERIALS SPECIFICATIONS

<u>Specification Number</u>	<u>Description</u>
EPD-01-0012-00-0	Nickel-Chromium-Yttria Hot Finished Bars
EPD-01-0013-00-0	Nickel-Chromium-Aluminum-Yttria Hot Finished Bars
EPD-01-0014-00-0	Investment Vacuum Cast Rene '80
EPD-01-0015-00-0	Investment Vacuum Cast Rene '100
EPD-01-0016-00-0	Investment Vacuum Cast MM-0011
EPD-01-0017-00-0	Investment Vacuum Cast NX-188
EPD-01-0018-00-0	Vacuum Cast and Wrought U-720
EPD-01-0019-00-0	Investment Vacuum Cast IN-738
AMS 5391B	Alloy Castings, Investment, Corrosion & Heat Resistant 73 Ni-13Cr-4.5Mo-2.3 (Cb + Ta)-0.75Ti-6.0Al-0.01B.- 0.10Zr Vacuum Melted IN-713 (0.05C)
AMS 7819	Molybdenum Alloy Bars 0.5Ti-0.09Zr Hot Worked and Stress Relieved

TABLE 2.7PROCESS AND MEASUREMENT SPECIFICATIONS

<u>Specification Number</u>	<u>Description</u>
EPD-02-0009-00-0	Acceptability Limits for Trace Elements in Nickel & Cobalt Base Superalloys
EPD-02-0010-00-0	Vacuum Heat Treating & Brazing
EPD-02-0011-00-0	Etching of Superalloys
EPD-02-0012-00-0	Radiographic Inspection
EPD-02-0013-00-0	Phacomp Electron-Vacancy Number Calculations ($\bar{N}_V$ 3 Method)
EPD-02-0014-00-0	Flourescent Penetrant Inspection

FIGURE 2.1 CTS Bar (TBM 128) for Vacuum Cast DCHT Alloy Specimens

the purchase order to provide material suitable for the screening phase of the program. Detailed specifications could be prepared at a later date if found to be necessary -- i.e., if either alloy were to be tested in the intensive testing phase of the program.

After receipt of all alloys, GE will conduct characterization tests (in air) to confirm and supplement the Specification testing done by the alloy vendor. In addition, 300-hour rupture and 300-hour one percent creep tests will be conducted in air to confirm the stresses selected for the 3000 to 10,000-hour helium and air screening creep testing program.

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

2.3.1 High Temperature Reactor Materials Testing Laboratory (HTRMTL)

2.3.2.2 Utility Frames

Installation of the helium distribution sub-assemblies in the utility frames is well underway. Subassemblies for all six screening creep test stations have been installed and connections made to supply, return and purge headers. Sub-assemblies for the first 30 single specimen creep/rupture test stands have been installed; no connections have been made, due to scheduling priorities.

Some minor revisions to all utility frames in the laboratory were necessary in order to accommodate water flowmeters which differed from catalog dimensions used to design the utility frames. These changes have been completed for utility frames serving all single specimen creep/rupture stands and all screening creep stands, and are nearly complete for structural stability stand utility frames.

2.3.1.2 Power Distribution

Wiring connections to the six screening creep stands, the water pump unit, and the electrical control console of Loop No. 1 are in progress. The primary power system is complete and is energized as needed for checkout purposes.

Back-up power is not yet available. All wiring for this system within the HTRMTL is complete, as is most of the cable-run to the secondary substation.

Instrumentation wiring is complete to the point of test stand connections. Wiring has been installed throughout the laboratory for:

- 1) Connecting thermocouples in each test retort to the digital control system.
- 2) Connecting the digital control system to solid state relays located near each furnace.
- 3) Connecting LVDT's in precision creep test stands to the data logger.

2.3.1.3 Water Distribution System

The water pump and heat exchanger package has been received and set in place. Electrical and plumbing connections are in progress. Cooling water manifolding and connections at utility frames have been completed for the six screening creep test stands.

2.3.1.4 Helium Distribution Piping

Installation of stainless steel piping for distribution of conditioned helium from the pumping, purification and analysis (PPA) console to each utility frame sub-assembly has been the major effort in the HTRMTL during the past quarter. The entire system is of stainless steel construction, GTA-welded with argon shielding gas and helium mass-spectrometer leak checked to verify leak tightness to 2×10^{-8} std cc/sec of air. The special cleaning procedures employed on the stainless steel have been mentioned in earlier reports, as have the efforts made to maintain a clean working environment during fabrication to avoid contamination of the system components. By the end of CY1977, the following had been accomplished:

- 1) Supply headers for each loop fabricated, installed, leak checked and leaks repaired.
- 2) Return headers for each loop fabricated, installed, leak checked and leaks repaired.
- 3) Purge supply manifold fabricated and installed, along with drops to six screening creep stand utility frames.

Gas bottle racks and manifolds have been fabricated by Matheson Gas Products. These units are to be floor-mounted behind the helium control consoles. Their fabrication was completed in December, but leak checking was delayed by the vendor's helium leak detector malfunction and delivery was postponed until January, 1978.

The remaining work to be done on the helium distribution system fabrication during the second quarter includes:

- 1) Supply and return drops to the five single specimen creep/rupture stand utility frames.
- 2) Purge line connections to thermal stability and creep/rupture utility frames.
- 3) Connections to both pumping, purification and analysis control consoles.
- 4) Connections from gas bottle racks and manifolds to the helium control consoles.
- 5) Fabrication of a system of sense lines from each utility frame throughout the facility to the two control consoles.

It is estimated that Loop No. 1 will be operable and ready for two months of commissioning tests by March 1 and dedicated to the test program in May 1978. Loop No. 2 will follow approximately two months behind Loop No. 1.

2.3.2 Multi-Specimen Screening Creep Equipment

All six multi-specimen screening creep stands have been completed, delivered to GE, and set in place in the HTRMTL. The furnace design was revised several times in an effort to produce a constant temperature zone long enough to encompass the lengthened specimen stringers required by the finalized test matrices. These stringers will be several inches longer than contemplated at the time the original purchase specifications were written. The desired hot-zone was obtained by revising heating element configurations without altering the original outside dimensions of the furnace.

The revision of test matrices to larger sized specimens necessitated other changes in these test stands as well. Specifically, new, larger couplings and shorter pull rods were designed and ordered. Couplings are machined from cast-to-size blanks. The vendor estimates delivery to GE during March, 1978.

2.3.3 Thermal Stability Equipment

Construction of the eight structural stability furnaces and stands was completed; they were shipped to GE and set in place in the HTRMTL. Retorts for these stands have been completed and will undergo final assembly, checkout and delivery to GE during January, 1978.

General Electric is fabricating control panels for these furnaces. These panels contain thermocouple jacks, overtemperature controllers, elapsed time meters, solid state relays, and power indicating lights, and will be mounted on the utility frames near each furnace. At the close of CY1977, cabinets for these units were complete, ready for painting and wiring. The finished units will be mounted on utility frames near their respective furnaces.

2.3.4 Single Specimen Creep/Rupture Equipment

The vendor was able to fabricate more of this equipment during 1977 than originally planned. At the end of CY1977, the following items had been received:

- 30 Test Stands
- 30 Furnaces
- 30 Load Weight Sets
- 6 LVDT Power Supplies
- 8 Ceramic Retorts
- 12 Inconel Retorts
- 35 Extensometers with Linear Variable
Differential Transducers

Ten of these stands have been assembled and set in position in the HTRMTL. General Electric is fabricating control panels for these stands, similar in function to those described for thermal stability furnaces, but built to complement three zone rather than five zone furnaces. Cabinets and most of the internal parts had been procured at the close of CY1977.

2.3.5 Temperature Control System

The basic hardware for this system, including the first modification mentioned in the previous report have been delivered to GE. The second modification (system extension) has been fabricated by Research Incorporated and was shipped December 22, 1977 but had not reached GE at the close of CY1977. Research Incorporated personnel conducted a hardware checkout at GE during December. Several minor faults were detected and corrected.

Software generation is incomplete and Research Incorporated has indicated that this will be completed in February, 1978. An on-site software checkout will be performed by Research Incorporated, along with an operator training school.

2.4 TASK 4 - SIMULATED REACTOR HELIUM ENVIRONMENT FACILITIES & EQUIPMENT

2.4.1 Simulated Reactor Helium "Loop" System Design and Construction

Several changes were made in the detailed design of the purification sub-system. No changes were made in the basic purification components; they remain as previously discussed in the Progress Report for January to March, 1977 (COO-2975-10). The changes made were in the arrangements of individual purification components and in gas flow paths and were necessary to meet the requirements for the purification sub-system which include:

1. Some flow through all components at all times, to prevent build-up of contaminants from leaks or outgassing from purification agents, etc., which would occur in components under stagnant flow conditions.
2. Controlled flow through all components, with varying (controlled) flow through different components, under steady state conditions.
3. Increased flow rates through components, required to handle transients.
4. Possibility of automation to accommodate transient conditions (to be accomplished later).

The changes included the following:

1. The molecular sieves, whose primary function is methane removal, were placed on separate, parallel, legs. Either sieve can be used for methane removal with the other one used as a back-up for methane removal or as a back-up for water or carbon dioxide removal.
2. The liquid nitrogen cooled activated charcoal trap, whose primary function is nitrogen removal, was placed on a separate leg.

3. A by-pass with a separate controlling valve system, leading directly into the ascarite cannister was provided to allow independent steady-state carbon dioxide removal without the attendant reduction in carbon monoxide and hydrogen due to initial passage through the copper oxide furnace.

The helium purification schematic is shown in Figure 2.2; details of the purification cannister valving system and the flowmeter and valves complex used to regulate flow in each leg are shown in Figure 2.3. All solenoid valves are normally closed; steady state flow through each leg, set to maintain a dynamic equilibrium level of each controlled impurity (gas added from bottles of pure gas plus gas generated anywhere in the system minus gas depleted in the test retorts balanced by gas removed by the purification system) is regulated by the micrometer valve of the flowmeter and valve complex (Figure 2.3) and read on the flowmeter.

The solenoid valve in the flow meter and valve complex is opened when additional controlled impurity removal is necessary under transient conditions. Under this condition the flow rate is set by the flowmeter valve setting; this transient flow rate can be "fine-tuned" by the valve setting on the flowmeters associated with individual purification cannisters (for purification legs with more than one cannister).

Each purification cannister, as shown in Figure 2.3, can be isolated from the rest of the purification system by closing its flowmeter valve and the shut-off valve on the other side of the cannister (V in Figure 2.3). The cannister can be either regenerated in place (using the vacuum valves, VV) or removed from the system and replaced.

The changes discussed above have been made in the pumping, purification, and gas analysis package; the first such package is nearly complete. Shipment to the HTR/MTL will take place in January, followed by installation, integration with the rest of the distribution system

FVC: Flow Meter & Valves Complex
S: Solenoid Valve
RV: Regulating Valve
MV: Micrometer Valve

FIGURE 2.2 Schematic of Helium Loop Purification Subsystem

Purification Cannister Valving

Flow Meter and Valves Complex

FIGURE 2.3 Details of Purification Cannister Valving and of Flow Meter and Valves Complex

for Loop No. 1, final leak checking, checkout, and commissioning.

2.4.2 Simulated Reactor Helium Instrumentation and Control System (R.K. Elton)

2.4.2.1 Instrumentation

The Antek 320D helium ionization gas chromatograph has been delivered; all of the instrumentation for the first loop is now in the laboratory. This instrument is scheduled to be checked out during the next quarter once the necessary installation requirements have been completed. The Carle 111 portable gas chromatograph has been examined and found to be capable of satisfactorily detecting a standard sample containing various impurity gases at 25 ppmv. The Shaw SADP portable dew point meter has also been checked out and appears capable of responding to sub-ppmv levels of water vapor. Subsequent calibration will establish the sensitivity of this instrument. The portable analysis cart system design has been finalized, and the requisite components for it are being fabricated.

The instrumentation selections for Loop No. 2 have been made, and will consist essentially of duplicates of equipment ordered for Loop No. 1. This instrumentation has been ordered, with the exception of the integrator to accompany the gas chromatograph. The integrator will be ordered early in 1978.

2.4.2.2 Calibration of Hygrometers

Numerous calibration methods have been investigated, and a decision has been reached for the technique to be employed on the hygrometers. They will be calibrated by using analyzed water vapor standards in compressed helium. These standards, available in concentrations as low as 1 ppmv in specially treated cylinders will retain their specified composition as long as the cylinder pressure remains above 500 psig. This technique was chosen over the vapor permeation cell, the NBS-type humidity generator, and the

catalytic water vapor reactor because the latter three processes require large capital investments for equipment. The generation of known water vapor concentrations by the passage of ultra dry helium over a bed of hydrated reagent in equilibrium with its anhydrous counterpart is a convenient one point calibration process. However, temperatures and flow rates must be carefully regulated and the results were adjudged to be too susceptible to human error. The compressed water vapor standards, in contrast, are convenient to use, and remain independent of flow rates, pressure effects or temperature. The 10% accuracy of the cylinder assay can be verified and improved by sampling the gas in the cylinder and performing a standard Karl Fischer titration using equipment which is available at GE.

2.4.2.3 Loop Commissioning Procedure

Revisions have been made in the loop commissioning procedure to allow for system design considerations. This includes a new strategy for filling and purging the loop prior to the gas chemistry measurements. The original plan was to evacuate the complete system and heat as much tubing as possible under a dynamic vacuum to desorb gases. Due to the scale of the system, it seems likely that such desorbed gases would be readsorbed before they were evacuated unless large amounts of the system could be heated simultaneously. The new plan will allow desorption to occur as a continuous stream of helium, purified by passage through a liquid nitrogen cooled activated charcoal trap, is allowed to purge the loop directionally. This stream will initiate at the fill gas manifold and will pass through the entire system to the most extreme point.

Other modifications planned for the commissioning phase include:

- o Lower temperatures and extended periods for the regeneration of purification cannisters which contain Viton O-rings.
- o Isolation of the oxygen sensors to prevent rupture during pressurization for helium leak detection in the sniffing mode usually done at 50 to 60 psig.

- o Sufficient bleeding of impurity gases through addition lines prior to gas chemistry characterization experiments to remove all air in these lines. A vacuum cannot be achieved in this region of the loop.

2.5 TASK 5 - MECHANICAL PROPERTY EVALUATION

2.5.1 Test Specimen Machining

Six potential machining sources were contacted to obtain quotations for test specimen machining for the screening program. Most of the test specimens are required for Tasks 5, 6 and 7; fewer test specimens are required for characterization tests in Task 2. Test specimen requirements are outlined in Tables 2.8 (for Task 2) and 2.9 (for Task 5 - Screening Creep, Impact and Tensile Specimens and for Tasks 6 and 7 - Structural Stability and Screening Weld Test Specimens). Dimensions, tolerances, surface finish and other requirements are shown in Figures 2.4 to 2.10.

The six machining vendors solicited for quotations included four components within the General Electric Co. and two external vendors. Three of the six vendors lacked sufficient experience, manpower, or equipment for the job. The quotations that were received from the other three vendors, to machine test specimens from the nuclear process heat candidate alloys, were evaluated in terms of cost, scheduling requirements, and competence of the vendor. The vendor chosen as best qualified in terms of the above criteria was Metcut (Cincinnati, Ohio). Work was begun to prepare the purchase order and supporting documentation required to obtain DOE Contracting Officer approval for the subcontract.

2.5.2 Test Matrices

Details of the proposed tests for the materials chosen for the screening studies were presented in the last Quarterly Progress Report (COO-2975-17, Reference 1).

TABLE 2.8

SPECIMENS REQUIRED FOR ACCEPTANCE (CHARACTERIZATION) TESTING

<u>Type</u>	<u>Figure No.</u>	<u>NPH Alloys</u>	<u>DCHT Alloys</u>	<u>Total No.</u>
Tensile	2.4 (part 2)	144	150	298
Stress-Rupture	2.5	84		84
Varestraint Weld	2.6	<u>66</u>	<u>---</u>	<u>66</u>
Totals		294	150	444

TABLE 2.9

SPECIMENS REQUIRED FOR THE SCREENING PORTION OF THE PROGRAM

<u>Type</u>	<u>Figure No.</u>	<u>NPH Alloys</u>	<u>DCHT Alloys</u>	<u>Total No.</u>
Screening Creep	2.7 (Type B)	35 ^(a)	409	444
	(Type C)	390	---	390
Structural Stability	2.8	396	376	772
Screening Weld	2.9	22	---	22
Impact	2.10	130	---	130
Tensile	2.4	<u>177</u>	<u>107</u>	<u>284</u>
Totals		1150	892	2042

(a) MA-956E Employs a Type B Screening Creep Specimen

A	B	C		L	R	T
.251 (6.375)	.254 (6.452)	.625 (15.875)		3.150 (80.0)	.260 (6.60)	.500-13 (12.70-.512)

NOTES:

1. Unless otherwise specified - remove all burrs and sharp edges with .015 (.381) max rad. or chamfer
2. Rad. and gage section to blend smoothly without undercuts
3. Unless noted $63 \sqrt{\text{in}}$ all surfaces
4. Rad. and gage section $16 \sqrt{\text{in}}$ and low stress ground.
5. Dimensions in inches (mm).
6. Scale: 2:1

FIGURE 2.4 Tensile Test Specimen

NOTES:

1. Dimensions in inches (mm).
2. Unless otherwise specified-remove all burrs and sharp edges with .015 (.381) max. rad. or chamfer.
3. Unless noted, 63 $\sqrt{\text{ }}$, all surfaces.
4. Rad. and gage section to blend smoothly without undercut.
5. Rad. and gage section 16 $\sqrt{\text{ }}$ and low stress ground.
6. Scale: 2:1
7. H centered on gage section within $\pm 1/64$ ($\pm .397$)

FIGURE 2.5 Creep and Stress Rupture Test Specimen

- Notes: 1. Surface finish, except where noted and on ends, 128 $\sqrt$; Ends not critical.
 2. Dimensions are in inches (mm).
 3. Scale 1:2 (Half Scale)

FIGURE 2.6 Varestraint Weld Specimen

$.045 \pm .005$
($1.143 \pm .127$)

Notes:

1. Dimensions given in inches (mm).
2. On 1/4-inch (6.35 mm) cast pin, clean up diameter to .230"-.240" (5.84-6.10).
3. Break edges 0.005" (.127 mm) + radius or chamfer.
4. Scale: 1:2

FIGURE 2.8 Structural Stability Test Specimen

NOTES: Notch Area 16 ✓ and Low Stress Ground
 Otherwise 63 ✓ All Over, Except Ends
 Remove all burrs
 Flatness -- no parts of a surface will vary by more than .001 (.025) total
 indicator reading over entire length. Not required on ends
 Scale: 2:1
 Dimensions in inches (mm)

FIGURE 2.10 Charpy V-Notch Impact Test Specimen

2.5.3 Screening Creep Loading Schedule

Screening test stresses have been determined for 1% total strain in 100,000 hours (to be tested for at least 10,000 hours), 1% total strain in 6,000 hours (to be tested for 6,000 hours), and 80% of the stress for rupture in 10,000 hours (to be tested for 3,000 hours). Creep specimens removed from test subsequent to 3,000 and 6,000 hours of exposure will be replaced by test coupons of the same material, loaded at the same stress levels. These samples will be on test for at least 7,000 and 4,000 hours, respectively. In all cases, creep strain measurements will be made approximately every 1,000 hours until termination of test. This specimen replacement procedure will provide an additional method of obtaining reproducible results and will most effectively utilize screening creep furnace capacity. It should also be noted that selected duplicate specimens will be employed to complete unfilled stringers as discussed in Reference 1. The three (3) stress values for each DCHT and NPH alloy were calculated for each of the four (4) screening test temperatures 750°C (1382°F), 850°C (1562°F), 950°C (1742°F) and 1050°C (1922°F). These values were tabulated in Reference 1. Additionally, (controlled-impurity) helium screening creep furnace loading matrices were compiled for the four (4) test temperatures and are also shown in Reference 1. It should be noted that two other multi-specimen screening creep furnaces will be employed for uninstrumented air testing. The air tests will be conducted in parallel with the controlled purity helium tests (identical alloys and test matrices) at the two intermediate evaluation temperatures, 850°C (1562°F) and 950°C (1752°F). The data generated herein will serve as a baseline comparison in the evaluation of the controlled purity helium screening creep results.

Tables 2.10 and 2.11 present the number of screening creep specimens per alloy required (including duplicate specimens) and the screening creep specimen loading schedules for the DCHT and NPH alloys, respectively. As mentioned above and indicated in these tables, four controlled-impurity helium screening creep furnaces, in addition to two air screening creep

furnaces, will be utilized in this phase of the program. The time (hours) indicated across the top of Tables 2.10 and 2.11 refer to the onset of test (0 hours) and the sample replacement schedule (3,000, 6,000 and 9,000 hours of cumulative furnace operation) which will be employed. The right hand column presents the minimum number of specimens per alloy required for the screening creep tests. Since stringer space is limited, a number of NPH samples to be tested at stress levels to yield 1% total strain in 6,000 hours (to be tested for 6,000 hours) will be substituted for discontinued specimens tested at 80% of the stress for rupture in 10,000 hours. Samples tested at 80% of the stress for rupture in 10,000 hours will be creep tested for 3,000 hours. Thus, a limited number of samples tested at stress levels to yield 1% total strain in 6,000 hours (to be tested for 6,000 hours) will be removed from test subsequent to 9,000 hours of cumulative furnace operation and replaced by similar samples which will be on test for at least 1,000 hours or until the termination of screening creep tests.

Since the creep strength capability of TZM is significantly in excess of other DCHT and NPH alloys, the material will be screened (coated) at 850°C (1562°F), 950°C (1742°F) and 1050°C (1922°F) in both the uninstrumented creep frames as well as single specimen creep stands as indicated in Table 2.10. Additionally, TZM will be evaluated in the uncoated condition at temperatures of 750°C (1382°F) and 1050°C (1922°F) in uninstrumented creep. Thus, a total of 44 TZM screening creep specimens are required for the program.

2.6 TASK 6 - THERMAL STABILITY EVALUATION

2.7 TASK 7 - PRIMARY COOLANT CORROSION RESISTANCE EVALUATION

Except for preparation of test specimens, which was discussed under Task 5, no work was scheduled during this period for these tasks.

Table 2.10

SCREENING CREEP SPECIMEN LOADING SCHEDULE FOR DCII ALLOYS

Furnace:

Environment
Temperature →

		He 750°C				He 850°C				He 950°C				He 1050°C				Air 850°C				Air 950°C				Total No. of Specimens Per Alloy
Time (Hrs.) →		0	3000	6000	9000	0	3000	6000	9000	0	3000	6000	9000	0	3000	6000	9000	0	3000	6000	9000	0	3000	6000	9000	
Alloy	Condition																									
TZM	Uncoated	3	1	1	-	-	-	-	-	-	-	-	-	3	1	1	-	-	-	-	-	-	-	-	-	
	Coated	-	-	-	-	3	1	1	-	3	1	1	-	3	1	1	-	3	1	1	-	3	1	1	-	
	Single Spec. (Coated)	-	-	-	-	3	-	-	-	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	44
MA-754	Uncoated	-	-	-	-	4	2	1	-	5	2	2	-	8	3	2	-	4	2	1	-	5	2	2	-	45
MM-0011	Uncoated	4	1	1	-	3	1	1	-	5	2	2	-	5	2	2	-	3	1	1	-	5	2	2	-	43
MM-0011DS	Uncoated	3	1	1	-	3	1	1	-	5	2	2	-	5	2	2	-	3	1	1	-	5	2	2	-	42
René 80	Uncoated	4	2	1	-	5	2	2	-	3	1	1	-	-	-	-	-	5	2	2	-	3	1	1	-	35
René 100	Uncoated	7	2	2	-	5	2	2	-	4	1	2	-	4	1	1	-	5	2	2	-	4	1	2	-	49
IN-713LC	Uncoated	7	4	2	-	4	1	2	-	2	1	2	-	-	-	-	-	4	1	2	-	2	1	2	-	37
IN-738	Uncoated	4	1	2	-	4	1	2	-	5	2	2	-	5	1	2	-	4	1	2	-	5	2	2	-	47
Udimet-720	Uncoated	6	3	2	-	4	1	2	-	3	-	1	-	-	-	-	-	4	1	2	-	3	-	1	-	33
HX-188	Uncoated	4	1	1	-	4	2	1	-	4	1	2	-	-	-	-	-	4	2	1	-	4	1	2	-	34

Table 2.11

SCREENING CREEP SPECIMEN LOADING SCHEDULE FOR NPH ALLOYS

Furnace:

Environment
Temperature →

Alloy	Condition	He 750°C				He 850°C				He 950°C				He 1050°C				Air 850°C				Air 950°C				Total No. of Specimens Per Alloy
		0	3000	6000	9000	0	3000	6000	9000	0	3000	6000	9000	0	3000	6000	9000	0	3000	6000	9000	0	3000	6000	9000	
Incoloy 800H	Uncoated	2	1	-	1	2	1	-	1	3	1	1	-	-	-	-	-	2	1	-	1	3	1	1	-	42
	Coated	2	1	-	1	2	1	-	1	2	1	-	1	-	-	-	-	2	1	-	1	2	1	-	1	
Incoloy 802	Uncoated	3	-	1	-	3	-	1	-	2	1	-	1	-	-	-	-	3	-	1	-	2	1	-	1	20
Incoloy 807	Uncoated	2	2	-	1	2	2	-	1	3	1	1	-	3	1	1	-	2	2	-	1	3	1	1	-	30
Incoloy DS	Uncoated	2	1	-	1	2	1	-	1	3	-	1	-	-	-	-	-	2	1	-	1	3	-	1	-	20
HD-556	Uncoated	3	-	1	-	3	1	1	-	3	1	1	-	4	1	1	-	3	1	1	-	3	1	1	-	30
Manaurite 36XS	Uncoated	2	2	-	1	2	2	-	1	3	1	1	-	4	1	1	-	2	2	-	1	3	1	1	-	31
HK-40	Uncoated	3	-	1	-	3	-	1	-	3	1	1	-	4	1	1	-	3	-	1	-	3	1	1	-	28
IN-519	Uncoated	3	-	1	-	3	1	1	-	2	1	-	1	3	1	1	-	3	1	1	-	2	1	-	1	27
Hastelloy X	Uncoated	2	1	-	1	2	1	-	1	2	1	-	1	3	1	1	-	2	1	-	1	2	1	-	1	25
Inconel 617	Uncoated	3	1	1	-	3	1	1	-	2	1	-	1	3	1	1	-	3	1	1	-	2	1	-	1	58
	Coated	2	2	-	1	3	1	1	-	2	2	-	1	3	1	1	-	3	1	1	-	2	2	-	1	
Mo-Re 2	Uncoated	4	4	-	1	3	1	1	-	3	1	1	-	6	2	3	-	3	1	1	-	3	1	1	-	40
MA-956E	Uncoated	-	-	-	-	2	1	-	1	3	1	1	-	8	3	3	-	2	1	-	1	3	1	1	-	32

2.8 TASK 9 - DATA MANAGEMENT AND PROGRAM MANAGEMENT

2.8.1 Data Management

2.8.1.1 Data Acquisition

During the initial phase of the program, the test matrices for each material and property will be reviewed to assure a coordinated approach by the NPH and DCHT programs and to assure that the planned testing is compatible with evaluation and analysis requirements. Also, coincident with the material procurement phase and prior to the testing phase, the appropriate encoding must be selected.

o Test Matrices Coordination

The completed matrices have been examined. The NPH and DCHT matrices are consistent with one another and are compatible with evaluation and analysis requirements.

o Data Encoding Coordination

Modified, revised, and additional encoding forms have been developed and have been found acceptable to program personnel. These forms will permit suitable computer input to provide for management control of the test program.

o Encoding Instructions

The Introduction, Encoding Forms and Encoding Instructions for Data Management Program "PAMMED" have been issued. PAMMED is an acronym for "Planning and Management - Materials Evaluation and Development". These sections will be updated and finalized during January 1978.

At present, encoding forms have been developed and instructions issued for material descriptions, alloy chemistry, tensile, creep/rupture (and screening creep), strain and load controlled low cycle fatigue, high cycle fatigue, cyclic crack growth rate, residual life, impact, bending, average environmental chemistry, microstructure, hardness, intergranular attack, specimen description, vendors, purchasing (timing and processes), processing, test planning, machine and test status, specimen status (when-where-what),

and environmental history. Still to be developed are: corrosion/oxidation, modulus, thermal expansion, thermal conductivity, and specific heat. These should be complete at the end of January 1978.

2.8.1.2 Data Storage and Retrieval

The definition of the material, material condition, test environment and the test data will be stored in a centralized computer data bank with the capability of selective retrieval. This data bank will be a revised or modified version of the current GE/Aircraft Engine Business Group (AEBG) data bank computer program.

o System Review and Modification

The objective of the data management system, PAMMED, is to provide a computerized system to facilitate the planning and completion of a materials evaluation and development program. This objective may be achieved by interfacing with seven program phases: 1) Program Identification, 2) Initial Planning, 3) Procurement, 4) Testing and Analyzing, 5) Progress Reporting, 6) Control (Plan Updates) and 7) Program Completion. These phases are sequential, 1 through 7, inasmuch as each phase feeds logically into the next until a program is completed. This may lead to the identification of an ensuing program. Each phase encompasses one or more functions as indicated below:

<u>Phase</u>	<u>Functions</u>
I. Identify Program	A. Decide
II. Plan (Initial)	A. Select Materials
	B. Determine Material Availability
	C. Prepare Test Matrices
	D. Determine Machine Availability
	E. Prepare Time Estimates (Milestones)
III. Procure	A. Purchase Materials
	B. Process Materials
	C. Prepare Specimens
	D. Time Procurement

<u>Phase</u>	<u>Functions</u>
IV. Test and Analyze	A. Test Properties B. Time Tests and Machines C. Encode Data D. Analyze Data and Information
V. Report Progress	Determine and Report: A. Procurement Status B. Post Receipt Processing Status C. Specimen Status D. Testing Status E. Machine Status F. Data and Information Handling Status
VI. Control (Update Plans)	A. Make Decisions Based on Status B. Update Program
VII. Complete	A. Issue Final Reports B. Decide Future Programs

The information flow in the system is shown in Figure 2.11. There are two operational modes; the batch system shown to the left and the time-sharing system shown to the right. The various activities are shown to the far left. The data storage system for PAMMED is shown in Figure 2.12. The data sets indicate data stored in the computer system. Files are not stored in the computer, but exist in official documents containing drawings, specifications, microphotographs, etc. The words associated with the arrows show the information which is common to the indicated data sets and files. Such information provides retrieval links within the system. MINOFISH uniquely identifies a specimen.

Encoding forms and encoding instructions are provided for each data set, and permit the computer storage of pertinent information for Phases II, III, and IV of the overall data management program. Retrieval programs and instructions for their use will be provided for selectively retrieving any or all stored information in approved formats for presentation or use in

FIGURE 2.11 Flow Diagram of the Planning and Management - Material Evaluation and Development System; from Acquisition to Application.

FIGURE 2,12 Data Storage System for PAMMED

analysis. The retrieval and presentation activities provide input to Phases IV and V which lead to Phases VI and VII, and ultimated back to I.

The system will automatically compare current status with plans to provide information for making decisions and redirecting the program. It will also track helium loop chemistries and temperatures and provide averages and standard deviations for the test period of each specimen. The helium chemistries and temperatures will be permanently stored for each loop and series of test stands so that this information may be retrieved if required for better understanding of specimen-environment interactions.

The system will accept both English and metric information.

o Storage

The computer program for storing encoded information and data was completed in mid-November 1977. The data and information are stored in such a way that selective retrieval is facilitated. This is an improvement over the current GE/AEBG data bank.

o Retrieval

A program for retrieving and presenting all information and data for specified materials in a logical, fixed sequence in understandable formats was completed at the end of December 1977. Selective retrieval and presentation programs will be developed during the first quarter of 1978.

2.8.2 Program Management

A formal Program Appraisal and Review (PAR) meeting summarizing the technical, schedular and financial status of the program was held for the responsible General Electric Department and Division General Managers and their staff on November 16, 1977 at the Corporate headquarters in Fairfield, Connecticut. On December 8 and 9, 1977 GE Program Management personnel participated in the DOE Thermal Gas Reactor Program planning meeting in Washington, D.C. An overview of the Advanced Gas Cooled Reactor Materials Program was presented with emphasis on plans for FY 1978.

The Program Master Schedule is shown in Figure 2.13.

Task 1 (Alloy Selection) is complete.

Task 2 (Materials Procurement and Characterization) is in the procurement cycle. Ten of the 14 NPH alloys were received by the end of December 1977. Problems with the three centrifugally cast alloys in meeting some of the technical requirements of the specification will delay their shipment until February 1978. All DCHT alloys are expected to be received by the end of March 1978.

Task 3 (Testing and Analysis Facilities and Equipment) and Task 4 (Simulated Reactor-Helium Environment Facilities and Equipment); completion of the test facilities for the initiation of the screening test program continue to be scheduled for May 1978.

FIGURE 2.13 Program Master Schedule

Section 3.0

WORK TO BE COMPLETED DURING THE NEXT QUARTER

3.0 WORK TO BE COMPLETED DURING THE NEXT QUARTER

1. Task 2 - Receive the balance of the alloys for the screening program and initiate their characterization.
2. Task 2 - Complete test specimen machining for characterization tests.
3. Task 3 - Receive the retorts for the eight structural stability stands.
4. Task 4 - Complete assembly of "Helium Loop" No. 1.
5. Task 4 - Start commissioning procedure for Loop No. 1.
6. Task 9 - Complete the development of the data encoding instructions.
7. Task 9 - Conduct the Second Annual Program Advisory Review Board Meeting March 7, 8, 1978.