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ADVANCED GAS COOLED NUCLEAR REACTOR MATERIALS EVALUATION AND DEVELOPMENT PROGRAM

PROGRESS REPORT
FOR PERIOD

October 1, 1979 - December 31, 1979

BY
PROJECT STAFF

GENERAL ELECTRIC COMPANY
ENERGY SYSTEMS PROGRAMS DEPARTMENT
SCHENECTADY, NEW YORK 12345

GENERAL ELECTRIC

April 18, 1980

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

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FOREWORD

The Advanced Gas Cooled Nuclear Reactor Materials Evaluation and Development Program is being conducted for the Nuclear Power Development Division, U.S. Department of Energy, by the Energy Systems Programs Department, General Electric Company, Schenectady, New York 12345 under Contract EY-76-C-02-2975. 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, with responsibility for overall technical coordination of the Program is Dr. O. F. Kimball, Manager, Gas Reactor Materials, assisted by Dr. J. F. Stubbins, Materials Engineer, Gas Reactor Materials. Major contributors to the Program are:

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report period.

ABSTRACT

This report presents the results of work performed from October 1, 1979 through December 31, 1979 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 (VHTR) Nuclear Process Heat (NPH) and Direct Cycle Helium Turbine (DCHT) applications, in terms of the effect 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 status of the simulated reactor helium supply system, testing equipment and gas chemistry analysis instrumentation and equipment. The progress in the screening test program is described. This includes: screening creep results, weight gain and post-exposure mechanical properties for materials thermally exposed at 750° and 850°C (1382° and 1562°F). In addition, the status of the data management system is described.

OTHER REPORTS IN THIS SERIES

QUARTERLY PROGRESS REPORTS

September 23, 1976 to December 31, 1976	C00-2975-3
January 1, 1977 to March 31, 1977	C00-2975-10
April 1, 1977 to June 30, 1977	C00-2975-13
July 1, 1977 to September 30, 1977	C00-2975-17
October 1, 1977 to December 31, 1977	C00-2975-20
January 1, 1978 to March 31, 1978	C00-2975-21
April 1, 1978 to June 30, 1978	C00-2975-22
July 1, 1978 to September 30, 1978	C00-2975-25
October 1, 1978 to December 31, 1978	C00-2975-28
January 1, 1979 to March 31, 1979	C00-2975-31
April 1, 1979 to June 30, 1979	C00-2975-34
July 1, 1979 to September 30, 1979	C00-2975-37

TOPICAL REPORTS

1. Selection of Candidate Alloys	C00-2975-16
Volume 1 - Advanced Gas Cooled Reactor Systems Definition by M. Marvin	October 31, 1978
Volume 2 - Selection of Alloys for Screen- ing Creep and Structural Stability Studies by R.M. Goldhoff, R.V. Hillery, and S. Yukawa	December 31, 1978
Volume 3 - Selection of Surface Coating/ Substrate Systems for Creep and Structural Stability Studies by D.A. Grey	To Be Released

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 Direct Cycle Helium Turbine (DCHT) Systems are being developed to provide an expanded energy capability and to facilitate conservation of or substitution for scarce energy resources. In both cases, the use of high temperature helium-cooled reactors will require a knowledge of the long term properties of reactor primary coolant containment materials and of the materials used in constructing related hardware. Because of the very high temperatures required for NPH and DCHT applications, the need is evident for materials testing in the proper helium environment in the temperature range from 750° - 1050°C (1382° - 1922°F) on those alloys which might serve as materials of construction for heat exchangers, ducting, turbine blades 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 and thermal exposure on:
  - Surface stability ("corrosion" resistance) in 10,000 hours.
  - Structural stability in 10,000 hours - changes in microstructure and tensile, impact and fatigue properties.
  - Creep - rupture properties in 15,000 hours.
  - Fatigue properties
    - Low Cycle 10^3 to 10^5 cycle
    - High Cycle 10^5 to 10^7 cycle
2. Select and recommend materials for future test facilities and more extensive qualification programs.

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

Section 2.0

PROGRAM STATUS

2.0 PROGRAM STATUS

The Advanced Gas Cooled Reactor Materials Evaluation and Development Program is organized into nine (9) tasks which are designed to accomplish the program objectives listed in Section 1.0 of this report. The task structures (Program Work Breakdown Structure) and a brief description of each task (Program Work Statement) have been included in the first Quarterly Report covering the period September 23, 1976 - December 31, 1976, report number 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 topical report number C00-2975-16, Volume 2, dated December 31, 1978 and entitled: Selection of Alloys for Screening Creep and Structural Stability Studies.

2.2 TASK 2 - MATERIALS PROCUREMENT AND CHARACTERIZATION

2.2.1 Direct Cycle Helium Turbine (DCHT) Alloys

2.2.1.1 Materials Procurement

The procurement of all DCHT materials for the screening test program was completed by June 1978.

The procurement of DCHT alloys for the second phase of the program (also referred to as the intensive screening phase) was initiated during the quarter. This action was started as soon as approval of alloys that were selected for the intensive screening phase was received from the DOE Program Manager. Since most of the DCHT alloy test specimens are cast-to-size, it was deemed inappropriate, because of cost considerations, to procure sufficient material for both screening and intensive screening testing phases at the outset of the program. Three (3) of the original twelve (12) DCHT alloys were selected for inclusion in the intensive screening testing phase.

The choice of alloys for intensive testing is covered in section 2.5.1
Selection of Alloys for Intensive Screening Test Program.

2.2.1.2 Materials Characterization

This subtask was completed and the final results reported in the Progress Report for July 1, 1978 - September 30, 1978, report number C00-2975-25.

2.2.2 Nuclear Process Heat (NPH) Alloys

2.2.2.1 Materials Procurement

The procurement of all NPH materials, sufficient for both testing phases, was completed by September 1978.

2.2.2.2 Materials Characterization

The materials acceptance and characterization testing was completed in the quarter ending in December 1978.

2.2.2.3 Materials Joining Studies

The final results for Vareststraint tests were covered in the quarterly report for the period October 1, 1978 - December 31, 1978, report number C00-2975-28.

2.3 TASK 3 - TESTING AND ANALYSIS FACILITIES AND EQUIPMENT

2.3.1 Multi-Specimen Creep (MSC) Equipment

A third multi-specimen creep stand was proof-tested and calibrated during the quarter. This stand, for use at 950°C (1742°F), was put on test during the quarter, joining the two other stands already on test at 750° and 850°C (1382° and 1562°F). The 950°C (1742°F) test is the first stand to incorporate a ceramic retort, (the lower temperature tests utilize Inconel 601, metallic retorts) and the use of ceramic retorts has presented several problems.

The principal problems are associated with the difficulties in fabricating α -alumina tubes of the size, straightness, uniform wall thickness, and uniform circular cross-section required for these test stands. Problems with thermal gradients in the ceramic retorts between the points at which they exit the

furnace and intersect the upper and lower support clamps have required reductions in the length of the furnace hot zones, from 99.1 cm (39 inches) to 78.7 cm (31 inches), and a redesign of the retort upper and lower clamps and the retort support system. It has been determined that non-uniformities in the wall thickness can substantially affect the thermally induced stresses in the tubes. In addition, the ovalness (out of roundness) often present in the tube cross-section can lead to dangerously thin wall sections at portions of the tube ends when they are machined to accommodate the end caps and O-ring seals.

Two ceramic retorts were received on a provisional basis at the beginning of the quarter. These retorts had been rejected by the test stand vendor for failure by the retort vendor to meet their specifications. However, the retorts were forwarded to GE for a further determination of their utility, with the provision that, if they passed the GE proof test, they could be accepted for use in testing. One of the tubes was rejected outright since it had an extreme bow, which would have prohibited specimen stringers to hang properly in the retort. The other retort was put through the proof test procedure. The proof test consists of heating the empty retort to 1093°C (2000°F) with twice the normal operating internal pressure (30 psig vs. 15 psig), holding 4 hours with a He flow rate of 10 l/min, then undergoing a maximum cool down rate by cutting off the furnace power. This procedure is designed to be a more severe test than any retort is likely to see under normal or transient operating conditions. The second retort was subjected to this test and failed due to the opening of a small crack at the upper retort clamp, just above the top of the furnace. Thus, this retort also was rejected and returned to the vendor. It was not clear whether the crack was present initially or due to the proof test. The retort vendor has since stated that they will no longer attempt to supply ceramic tubes to the present specifications.

Subsequent to the proof test, a decision was made to further reduce the furnace hot zone length in the multi-specimen creep stands. This will be carried out to further flatten the thermal gradient at the ends of the furnace. This second furnace revision will bring the hot zone length to 78.7 cm (31 inches), as stated earlier.

2.3.2 Thermal Stability [Aging/Corrosion (A/C)] Test Equipment

During the report period, cleaning of the thermal stability stands to remove possible traces of residual P was completed. Three (3) of eight (8) stands were verified to be free of P, and the specimen exposure tests were restarted. The other five (5) stands were undergoing cleanliness verification testing. Two (2) of these five (5) had been verified to be clean and ready for use for specimen exposure testing. Retort cleaning procedures and the cleanliness verification tests are described in the previous quarterly progress report (C00-2975-37).

2.3.3 Single Specimen Creep-Rupture (ST) Equipment

Ten (10) of the forty-five (45) test stands have been in use in the screening test program. During this quarter, the checkout of all remaining single specimen test stands was begun. Ten (10) of the stands, in addition to those presently in use, have had their load trains calibrated, in preparation for the start of the intensive testing phase.

2.3.4 Fatigue Test Equipment

The design of the once-through-then-out (OTTO) test gas supply system for the fatigue stands has been completed, and parts for construction are presently being procured.

The design of the gas supply system is shown in Figure 2.1. Impurity gases are added to purified welding grade He through micrometering valves. This mixture can be fed to either or both fatigue retorts. The gas analysis system, comprised of three (3) Shaw dew point meters, an Antek gas chromatograph, and an oxygen probe, is capable of analyzing the chemistry of the gas feeding the retorts and exiting the retorts. A gas flow rate of over 10 l/min. is possible with the system, though an operating flow rate somewhere in the range of 1 to 10 l/min. will be used.

FIGURE 2.1. SCHEMATIC OF THE ONCE-THROUGH-THEN-OUT GAS SUPPLY SYSTEM FOR FATIGUE TESTING.

2.3.5 Temperature Control System

During the period, the first problem with long term use of the Inconel 601 clad chromel-alumel thermocouples was encountered. A thermocouple failed after 2,128 hours of service at 1050°C (1922°F) in one of the single specimen creep units. Since it was apparent that there may be some degradation of thermocouples after extended use, thermocouples from test stands are removed after completion of certain periods of service and are recalibrated to check for drift. Some examples are given below:

Type of Stand	Test Temperature (°C)	Test Duration (hours)	ΔT (°C) at the Recalibration Temperature		
			750°C	850°C	950°C
Multi-Specimen Creep	750	1000	-4.0	-0.5	-2.5
Single Specimen Creep	850	3000	-1.0	-1.6	+2.0
Aging/Corrosion	1050	500	-2.4	-1.3	-1.0

These results are not conclusive but the recalibration of thermocouples will be continued in an effort to establish the thermocouples' useful service lives as a function of test temperature.

2.3.6 New Equipment

During the quarter the following items of capital equipment were received:

1. Stereo Macroscope
2. Two (2) Carle gas chromatographs and strip chart recorders for the two (2) portable gas analysis systems
3. Gas chemistry data handling system to automatically integrate and print-out impurity gas level read-outs from the loop gas chromatograph. (See section 2.4.4, Instrumentation.)

2.4 TASK 4 - SIMULATED REACTOR HELIUM ENVIRONMENT

2.4.1 Loop No. 1 Operation

The average gas composition of the He supplied to the retorts during the report period is shown in Table 2.1. A few excursions outside normal chemistry ranges were encountered during the period. These were usually less than one (1) hour in duration, and, as has been past experience, often associated with retort tie-in to the loop. None of these occurrences were large enough to substantially

TABLE 2.1

LOOP NO. 1 GAS CHEMISTRY HISTORY
OCTOBER 1, 1979 THROUGH DECEMBER 31, 1979

<u>Constituent</u>	<u>Target Chemistry and Normal Limits (μatm)</u>	<u>Actual Average Chemistry (μatm)</u>		
		<u>October</u>	<u>November</u>	<u>December</u>
H ₂	400 $\pm$ $\begin{smallmatrix} 100 \\ 50 \end{smallmatrix}$	399.0	395.0	388.0
H ₂ O	2.0 $\pm$ 1.0	1.2 (a)	1.1 (a)	1.1 (a)
CO	40 $\pm$ 10	40.3	39.0	39.7
CO ₂	0.2 $\pm$ 0.15	0.21	0.21	0.18
CH ₄	20 $\pm$ 5	19.1	18.5	19.4
N ₂	6 $\pm$ 4	4.5	5.3	6.8

(a) These numbers are taken from the initial calibration curves of the Shaw hygrometers. As reported in the last quarterly progress report (C00-2975-37), these Shaw probe readings are believed to indicate an actual water level of $\sim 2 \mu$ atm, following a check with an EG&G dew point meter. This will be verified as soon as an adequate water calibration system is available.

affect the oxidized and carburizing potentials of the test gas. One additional problem was encountered, this with the gas addition valves. In two cases, certain gas addition valves did not respond properly when their settings were changed. The potential for this sort of problem was identified during loop commissioning in early 1979, and for that reason the valves were replumbed in two (2) banks of four (4) (one valve in each bank for H_2 , CO , CO_2 and CH_4) so that backup control was available. When a problem with a control valve is identified, the switch over to backup control can result in a minor chemistry excursion.

2.4.2 Pumping, Purification and Analysis Station (PP&A) No. 1

The only significant revision to PP&A No. 1 during the quarter was the installation of an automatic system designed to maintain return receiver pressure within narrow pressure limits. This system was installed because fluctuations in the return receiver pressure had been sufficient to activate the fill gas system when it was not needed.

2.4.3 Pumping, Purification and Analysis Station (PP&A) No. 2

The replications in PP&A No. 2 of all plumbing modifications previously made to PP&A No. 1 were completed. These include:

1. Modification of impurity gas metering valves to provide a flushing flow of loop helium through all valves .
2. Replumbing gas addition valves into two banks of four valves each to permit maintenance and repair without loop shutdown.
3. Welding of joints which were threaded in the original construction.
4. Relocation of the main LN_2 cooled activated charcoal trap to permit the use of an automatic liquid N_2 fill system.
5. Dedication of the 16th port of the analytical scan valve to sampling the flushing gas flow through the impurity gas addition valves.

Leak detection and repair activities were begun for PP&A No. 2 and for the utility frame subassemblies serving an additional ten (10) of the single specimen creep-rupture stands.

2.4.4 Instrumentation

A Hewlett Packard Model 3352 data processor was acquired near the end of the report period and dedicated to the gas chromatograph on Loop No. 1. It also will be used for the Loop No. 2 gas chromatograph once that unit has been commissioned. This microprocessor system is interfaced with a Texas Instruments 700 ASR terminal/printer and with an analog to digital converter for each of the two (2) gas chromatographs. The system also is equipped with event control modules for eventual hook-up with the laboratory alarm system.

2.5 TASK 5 - MECHANICAL PROPERTIES EVALUATION

2.5.1 Selection of Alloys for Intensive Screening Test Program

A review of mechanical properties, thermal (phase) stability, He exposure experience, fabricability, data base status, and other critical material properties was carried out for a wide range of high temperature alloys. This list included all of the alloys presently in the screening phase of the program, as well as other alloys included in other programs or of significant interest for use in VHTR systems. These alloys are listed by class in Tables 2.2 and 2.3. Of these alloys, seven (7) were chosen for more intensive testing:

- Alloy 800H
- Hastelloy X
- Inconel 617
- MA-956
- Rene' 100
- Alloy 713LC
- MA-754

These alloys were picked to represent the best materials properties, and to maintain a representation of most classes of alloys of the intensive screening program. This should allow the best flexibility for applying materials testing results to the wide range of component requirements in advanced gas-cooled nuclear reactors. It should be noted that the centrifugally cast Fe- and Ni-base alloys were dropped from consideration because their only application would be as reformer tubes. Since the present belief is that reformer tubes could only be used in an intermediate loop where the He atmosphere is presently unknown, there is no reason to test these alloys in a simulated primary loop He environment.

TABLE 2.2

CANDIDATE NUCLEAR PROCESS HEAT ALLOYS FOR
INTENSIVE SCREENING TEST PROGRAM

Wrought Fe-Base

FV 548
DIN 1.4981
Alloy 800H*
Incoloy 802*
Incoloy 807*
Incoloy DS*
HD-556*

Wrought Ni-Base

Inconel 617*
Inconel 618E*
Inconel 625
Hastelloy X*
Hastelloy C-4
Hastelloy S
IN-586 (Nimonic 86)

Cast Fe-Base

HK-40*
IN-519*
Manaurite 900*
Manaurite 36X
Manaurite 36XS*
HD-50
Mo-Re 1

Cast Ni-Base

Mo-Re 2*
Supertherm
22H
Super 22H

Cobalt-Base

Haynes 25
Haynes 188

Oxide Dispersion Strengthened

MA-956*

*Indicates alloys in the present screening program.

TABLE 2.3

CANDIDATE DIRECT CYCLE HELIUM TURBINE ALLOYS
FOR INTENSIVE SCREENING TEST PROGRAM

Ni-Base Superalloys

MM-200
MM-0011*
B-1900
Rene' 100*
Rene' 80*
IN-792
M-21*
IN-738*
Alloy 713LC*
NX-188*
Udimet 720*(a)

Mo-Base

TZM*

Oxide Dispersion Strengthened

MA-754*
MA-755
MA-757
YD-NiCrAl*

*Indicates alloys in the present screening program.
(a) Wrought alloy, all other Ni-base superalloys are cast.

One of these alloys, Alloy 713LC, will be tested both coated and uncoated. The coating for Alloy 713LC was chosen to be Codep B, an aluminide-type coating.

Weldments will be tested for these alloys:

Alloy 800H with Inconel Filter Metal 82
Hastelloy X with Hastelloy X Matching Composition
Inconel 617 with Inconel 617 Matching Composition

These choices are the concensus of the National Gas Cooled Reactor Materials Coordinating Committee and have received DOE approval.

2.5.2 Test Specimen Machining

Machining of the test specimens required for the screening test program was completed by September 1978.

Machining of all replacement test specimens for the screening, aging/corrosion exposures was initiated during the quarter. By the end of the quarter, all nuclear process heat alloy specimen machining was complete, as was most of the direct cycle helium turbine alloy specimen machining.

A purchase order for machining of the four (4) nuclear process heat alloys selected for the intensive screening testing was placed by the end of the quarter. Delivery is expected by February 15, 1980. The machining for the direct cycle helium turbine alloys will await their procurement.

2.5.3 Selection of Stresses for Screening Creep Tests

Stresses for multi-specimen creep (MSC) testing in the screening phase of the program have been selected and were reported in the quarterly report for the period April 1, 1979 to June 30, 1979, report number C00-2975-34.

2.5.4 Screening Creep Testing

Results of three (3) sets of multi-specimen creep measurements were obtained during the report period. These are 1,000-hour results from the 750°C (1382°F) tests and 1,000- and 2,000-hour values for the 850°C (1562°F) tests. Numerical values are given in Tables 2.4 and 2.5 respectively. Note that average strain

TABLE 2.4

SCREENING (MULTISPECIMEN) CREEP RESULTS FOR THE
NUCLEAR PROCESS HEAT ALLOYS

Alloy	Temp. °C	Exposure Time-Hrs.	Specimen Number	Stress		%ε Strain	
				MPa	KSI	1000 Hrs.	2000 Hrs.
Alloy 800H	750	3,000	1000SC1	48	7	.386	
		6,000	1000SC2	48	7	.44	
		10,000	1000SC3	21	3	.002	
	850	6,000	1000SC5	21	3	.396	.811
		3,000	1000SC6	7	1	-.0095	-.0032
		10,000	1000SC7	7	1	-.0275	-.0042
Alloy 800H (Coated)	750	3,000	1001SC2	21	3	.016	
		6,000	1001SC2	21	3	.018	
		10,000	1001SC3	21	3	.018	
	850	3,000	1001SC6	7	1	.0095	.0042
		6,000	1001SC7	7	1	.0105	.019
		10,000	1001SC8	7	1	.0095	.0095
Incoloy 802	750	3,000	1100SC1	76	11	-.026	
		10,000	1100SC3	48	7	-.0495	
	850	3,000	1100SC5	34	5	-.022	.024
		10,000	1100SC7	21	3	-.042	-.0349
Incoloy 807	750	3,000	1200SC1	62	9	.437	
		6,000	1200SC2	62	9	.074	
		10,000	1200SC3	21	3	-.010	
	850	6,000	1200SC6	21	3	.038	.0623
		3,000	1200SC07	28	4	.058	.0919
		10,000	1200SC08	7	1	-.0063	-.0074

TABLE 2.4
(CONTINUED)

Alloy	Temp. °C	Exposure Time-Hrs.	Specimen Number	Stress		%ε Strain	
				MPA	KSI	1000 Hrs.	2000 Hrs.
Incoloy DS	750	3,000	1300SC1	21	3	-.063	
		10,000	1300SC2	21	3	.0074	
	850	6,000	1300SC4	7	1	.00212	-.0116
		3,000	1300SC5	7	1	-.0063	-.0042
		10,000	1300SC6	7	1	.0106	-.0053
	HD-556	750	3,000	1400SC1	76	11	.20
6,000			1400SC2	62	9	.1215	
10,000			1400SC3	21	3	-.024	
850		3,000	1400SC31	34	5	.035	.075
		6,000	1400SC7	21	3	-.013	-.0116
		10,000	1400SC8	21	3	-.0085	-.0116
Manaurite 36XS	750	6,000	1500SC1	48	7	.30	
		3,000	1500SC2	48	7	.297	
		10,000	1500SC3	21	3	.0265	
	850	3,000	1500SC6	34	5	.174	.305
		10,000	1500SC7	21	3	.018	.0338
		6,000	1500SC8	28	4	.062	.0920
HK-40	750	10,000	1700SC3	48	7	.037	
		10,000	1700SC4	48	7	.0455	
		6,000	1700SC1	62	9	.095	
		3,000	1700SC2	62	9	.0645	
	850	3,000	1700SC7	34	5	.036	.0993
		10,000	1700SC8	21	3	-.026	.0095
6,000		1700SC9	28	4	.021	.024	

TABLE 2.4
(CONTINUED)

Alloy	Temp. °C	Exposure Time-Hrs.	Specimen Number	Stress		%ε Strain	
				MPA	KSI	1000 Hrs.	2000 Hrs.
IN-519	750	6,000	1800SC1	76	11	.68	
		3,000	1800SC2	62	9	.1825	
		10,000	1800SC3	48	7	.138	
	850	3,000	1800SC6	34	5	.034	.073
		6,000	1800SC7	28	4	-.018	.0160
		10,000	1800SC8	28	4	-.0032	.00212
	750	3,000	1900SC1	62	9	.378	
		10,000	1900SC2	21	3	-.0318	
		6,000	1900SC3	48	7	.228	
Hastelloy X	850	6,000	1900SC6	21	3	.126	.140
		3,000	1900SC7	28	4	.238	.340
		10,000	1900SC8	7	1	-.00104	-.0074
	750	3,000	1A00SC1	76	11	-.026	
		6,000	1A00SC2	76	11	-.0075	
		10,000	1A00SC3	62	9	-.143	
	850	3,000	1A00SC6	34	5	.000	.020
		6,000	1A00SC7	34	5	-.011	.00105
		10,000	1A00SC8	28	4	-.0286	-.0064
Inconel 617 (Coated)	750	3,000	1A01SC1	76	11	-.005	
		6,000	1A01SC2	48	7	.018	
		10,000	1A01SC3	21	3	-.022	
	850	3,000	1A01SC6	34	5	1.33	2.52
		6,000	1A01SC7	21	3	.031	.053
		10,000	1A01SC8	7	1	-.0243	-.0095

TABLE 2,4
(CONTINUED)

<u>Alloy</u>	<u>Temp.</u> <u>°C</u>	<u>Exposure</u> <u>Time-Hrs.</u>	<u>Specimen</u> <u>Number</u>	<u>Stress</u>		<u>%ε Strain</u>	
				<u>MPA</u>	<u>KSI</u>	<u>1000 Hrs.</u>	<u>2000 Hrs.</u>
Mo-Re 2	750	1,000	1C00SC7	76	11	.68	
		6,000	1C00SC1	76	11	.703	
		10,000	1C00SC03	48	7	.304	
	850	3,000	1C00SC8	34	5	.198	.236
		6,000	1C00SC39	34	5	.166	.222
		10,000	1C00SC11	28	4	.166	.191
MA-956	850	6,000	1D00SC1	42	6	.010	.022
		10,000	1D00SC2	42	6	.029	.041
		3,000	1D00SC3	55	8	.0088	.0293

TABLE 2.5

SCREENING (MULTISPECIMEN) CREEP RESULTS FOR THE
DIRECT CYCLE HELIUM TURBINE ALLOYS

Alloy	Temp. °C	Exposure Time-Hrs.	Specimen Number	Stress		%ε Strain	
				MPA	KSI	1000 Hrs.	2000 Hrs.
TZM	750	10,000	C01SC16	345	50	.044	
		6,000	C01SC17	345	50	.058	
		3,000	C01SC19	345	50	.041	
	850	6,000	C01SC1	152	22	.0225	.0183
		3,000	C01SC2	152	22	.00857	.00714
		10,000	C01SC3	152	22	.00288	.00144
	850	6,000	B00SC1	110	16	.0660	.0663
		10,000	B00SC2	110	16	.0660	.0692
		3,000	B00SC3	110	16	.0636	.0537
MM-0011	750	10,000	100SC1	262	38	.013	
		10,000	100SC31	262	38	.010	
		6,000	100SC7	345	50	.0584	
		3,000	100SC19	345	50	.0385	
		6,000	100SC32	345	50	.0370	
	850	10,000	100SC5	110	16	.029	.063
		6,000	100SC2	152	22	.065	.0896
		3,000	100SC3	152	22	.056	.0915
		3,000	100SC4	152	22	.083	.106

TABLE 2.5
(CONTINUED)

Alloy	Temp. °C	Exposure Time-Hrs.	Specimen Number	Stress		%ε Strain	
				MPA	KSI	1000 Hrs.	2000 Hrs.
MM-0011DS	750	10,000	120SC1	345	50	.0286	
		6,000	120SC7	345	50	.0472	
		3,000	120SC19	345	50	.037	
	850	6,000	120SC3	152	22	.0390	.0859
		3,000	120SC4	152	22	.0370	.0840
		10,000	120SC23	152	22	.0340	.0840
	750	10,000	200SC1	262	38	.035	
		10,000	200SC26	262	38	.044	
		6,000	200SC6	345	50	.275	
		3,000	200SC16	345	50	.269	
Rene' 80	850	10,000	200SC4	110	16	.0397	.0694
		6,000	200SC2	152	22	.0426	.172
		3,000	200SC3	152	22	.0990	.168
	750	10,000	300SC32	124	18	-.014	
		10,000	300SC1	262	38	-.0085	
		10,000	300SC31	262	38	-.0057	
		6,000	300SC7	345	50	.064	
		3,000	300SC19	345	50	.0497	
		10,000	300SC5	110	16	-.00850	-.00570
Rene' 100	850	6,000	300SC2	152	22	.00330	.0600
		3,000	300SC3	152	22	.0260	.0583
		3,000	300SC4	152	22	.0130	.0600

TABLE 2.5
(CONTINUED)

Alloy	Temp. °C	Exposure Time-Hrs.	Specimen Number	Stress		%ε Strain		
				MPA	KSI	1000 Hrs.	2000 Hrs.	
Alloy 713LC	750	10,000	400SC26	124	18	-.010		
		10,000	400SC27	124	18	-.014		
		10,000	400SC1	262	38	.0485		
		3,000	400SC16	262	38	.033		
		6,000	400SC6	345	50	.24		
	850	10,000	400SC4	55	8	-.028	.00852	
		3,000	400SC2	110	16	.0380	.1067	
		6,000	400SC3	110	16	.0410	.0994	
	IN-738	750	10,000	500SC32	124	18	-.0185	
			10,000	500SC1	152	22	-.013	
6,000			500SC7	262	38	.028		
3,000			500SC19	262	38	.030		
850		10,000	500SC4	55	8	-.0028	.000	
		3,000	500SC2	110	16	.0430	.0625	
		6,000	500SC3	110	16	.0430	.0784	
U-720		750	10,000	A00SC1	152	22	.027	
			6,000	A00SC6	262	38	.041	
			3,000	A00SC16	262	38	.054	
	850	10,000	A00SC4	55	8	.017	-.00285	
		3,000	A00SC2	110	16	.031	.0555	
		6,000	A00SC3	110	16	.028	.0313	

TABLE 2.5
(CONTINUED)

<u>Alloy</u>	<u>Temp.</u> <u>°C</u>	<u>Exposure</u> <u>Time-Hrs.</u>	<u>Specimen</u> <u>Number</u>	<u>Stress</u>		<u>%ε Strain</u>	
				<u>MPa</u>	<u>KSI</u>	<u>1000 Hrs.</u>	<u>2000 Hrs.</u>
NX-188	750	10,000	600SC1	152	22	.093	
		10,000	600SC26	152	22	.102	
		6,000	600SC6	262	38	.054	
		3,000	600SC16	262	38	.224	
	850	3,000	A00SC4	110	16	.200	.254
		10,000	A00SC2	69	10	.140	.170
		6,000	A00SC3	110	16	.184	.236

is reported, based on measurements made 180° apart around the specimen axis. Also, the gauge length used for strain calculations is the initial distance between the shoulder reference grooves of each specimen. This basis for strain calculation has been chosen because the effective gauge lengths of the specimen geometrics employed are not precisely known.

In general, the results are consistent with what was expected. The test stresses are set to approximate, as closely as possible, the following:

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

The stresses are listed along with the scheduled time and temperature in Table 2.4 and 2.5.

One surprising result is the large amount of creep strain, relative to air characterization test results, of NX-188 alloy. The characterization rupture tests at 750°C/551.6 MPa (1382°F/80 ksi) and 850°C/296.5 MPa (1562°F/43 ksi) showed 0.8% elongation in a rupture life of 240 hours and 2.5% elongation in a rupture life of 451 hours respectively. Compared to these elongation values, the strains in multi-specimen creep are substantial.

It is not possible to draw conclusions from the limited data generated thus far; this will have to await results at longer exposure times. It is notable that negative creep was found in several cases. Of course, these results usually occur at the lowest stress levels for alloys where negative creep strain is observed.

2.5.5 Post-Exposure Tensile Testing

Tensile tests were carried out on specimens which had been exposed for 1279 hours at 750°C (1382°F) and 1104 hours at 850°C (1562°F). The results are reported in Tables 2.6 and 2.7 for the nuclear process heat and direct cycle helium turbine alloys, respectively. In general, the nuclear process heat alloys showed losses in tensile ductility after exposure. The exposure effects for the direct cycle helium turbine alloys were mixed, with some losses in strength and/or

TABLE 2.6

TENSILE TEST RESULTS FOR THE
NUCLEAR PROCESS HEAT ALLOYS

Alloy	Exposure Temp/Time °C/Hrs.	Test Temp.	UTS		0.2% YS		Elong. %	R of A %
			MPa	KSI	MPa	KSI		
Alloy 800H	As Received	RT	531	77.1	180	26.1	54.0	70.3
	As Received	RT	531	77.1	180	26.1	55.0	70.3
	750/1279	RT	550	79.8	205	29.8	42.0	43.2
	850/1104	RT	534	77.5	156	22.7	40.0	40.9
Alloy 800H (Coated)	As Received	RT	534	77.4	154	22.4	44.2	53.9
	As Received	RT	532	77.2	154	22.4	44.5	59.4
	750/1279	RT	539	78.2	163	23.7	36.0	42.6
	850/1104	RT	524	76.1	149	21.6	38.0	41.1
Incoloy 802	As Received	RT	610	88.5	221	32.0	47.0	58.0
	As Received	RT	613	88.9	221	32.0	49.0	59.0
	750/1279	RT	719	104.4	412	59.8	24.0	27.3
	850/1104	RT	681	98.8	320	46.4	27.0	29.0
Incoloy 807	As Received	RT	662	96.1	255	37.0	53.0	61.0
	As Received	RT	662	96.0	255	37.0	53.0	61.4
	750/1279	RT	700	101.6	278	40.4	28.0	25.5
	850/1104	RT	689	100.0	267	38.7	28.5	28.1
Incoloy DS	As Received	RT	600	87.0	221	32.0	54.0	73.1
	As Received	RT	600	87.0	221	32.0	53.0	73.1
	750/1279	RT	623	90.4	221	32.1	44.0	63.0
	850/1104	RT	608	88.3	209	30.3	46.0	63.4
HD-556	As Received	RT	810	117.6	371	53.9	57.0	64.2
	As Received	RT	808	117.2	373	54.2	61.0	70.7
	750/1279	RT	898	130.4	402	58.3	21.0	19.9
	850/1104	RT	841	122.0	358	51.9	22.0	18.9

TABLE 2.6
(CONTINUED)

Alloy	Exposure Temp/Time °C/Hrs.	Test Temp.	UTS		0.2% YS		Elong. %	R of A %
			MPa	KSI	MPa	KSI		
Manaurite 36XS	As Received	RT	569	82.5	269	39.0	15.3	15.4
	As Received	RT	585	84.8	268	38.8	16.0	16.2
	750/1279	RT	647	93.9	348	50.5	3.0	3.2
	850/1104	RT	613	88.9	303	44.0	5.0	3.2
HK-40	As Received	RT	667	96.8	309	44.8	23.0	22.4
	As Received	RT	643	93.3	309	44.8	23.0	22.4
	750/1279	RT	701	101.8	380	55.2	6.0	7.1
	850/1104	RT	645	93.3	362	52.5	6.0	6.3
IN-519	As Received	RT	688	99.8	288	41.8	26.0	24.6
	As Received	RT	686	99.5	285	41.4	26.0	25.2
	750/1279	RT	676	98.1	311	45.2	10.0	6.7
	850/1104	RT	572	83.0	275	39.9	9.5	8.9
Hastelloy X	As Received	RT	776	112.5	358	52.0	49.0	61.0
	As Received	RT	772	112.0	357	51.8	49.0	60.5
	750/1279	RT	953	138.3	449	65.1	21.0	24.6
	850/1104	RT	865	125.5	362	52.5	19.5	20.4
Inconel 617	As Received	RT	781	113.0	318	46.0	67.0	58.4
	As Received	RT	780	113.1	318	46.0	64.0	56.4
	750/1279	RT	923	133.9	437	63.4	30.0	29.1
	850/1104	RT	712	103.4	348	50.5	18.0	17.8
Inconel 617 (Coated)	As Received	RT	767	111.3	324	47.0	44.8	45.9
	As Received	RT	776	112.6	329	47.7	41.4	37.4
	750/1279	RT	825	119.8	407	59.1	34.0	28.1
	850/1104	RT	741	107.5	314	45.5	36.0	39.9

TABLE 2.6
(CONTINUED)

<u>Alloy</u>	<u>Exposure Temp/Time °C/Hrs.</u>	<u>Test Temp.</u>	<u>UTS</u>		<u>0.2% YS</u>		<u>Elong. %</u>	<u>R of A %</u>
			<u>MPa</u>	<u>KSI</u>	<u>MPa</u>	<u>KSI</u>		
Mo-Re 2	As Received	RT	585	84.9	351	50.9	13.0	15.0
	As Received	RT	590	85.5	351	50.9	12.4	11.6
	750/1279	RT	890	129.2	650	94.3	2.5	1.2
	850/1104	RT	764	110.9	502	72.9	3.5	2.4
MA-956	As Received	RT	796	115.5	786	114.0	13.0	41.6
	As Received	RT	800	116.0	786	114.0	12.0	39.1
	850/1104	RT	806	117.0	789	114.5	14.5	31.3

TABLE 2.7

TENSILE TEST RESULTS FOR THE
DIRECT CYCLE HELIUM TURBINE ALLOYS

Alloy	Exposure Temp/Time °C/Hrs.	Test Temp. °C	0.2% YS MPa	KSI	UTS MPa	KSI	Elong. %	R of A %	Specimen Identification
TZM	As Received	RT	768	111	812	118	37.8	-	C00-TN6
	As Received	RT	767	111	824	120	35.5	24.1	C00-TN3
	As Received	850	483	70	503	73	18.9	89.0	(a)
	850/1104	RT	754	109	858	125	5.0	1.2	C01-TN2
MA-754	As Received	RT	557	81	949	138	21.4	54.7	B00-TN2
	As Received	RT	572	83	950	138	21.1	51.3	B00-TN3
	850/1104	RT	560	81	938	136	22.0	45.4	B00-TN8
MM-0011CC	As Received	RT	798	116	1034	150	10.3	13.2	100-TN1
	As Received	RT	781	113	1053	153	12.2	13.8	100-TN4
	750/1279	RT	831	121	1015	147	9.5	10.5	100-TN7
	850/1104	RT	782	114	1061	154	11.0	13.1	100-TN11
MM-0011DS	As Received	RT	881	128	1077	156	11.1	12.8	120-TN2
	As Received	RT	878	127	981	142	4.6	3.2	120-TN3
	750/1279	RT	924	134	1105	160	9.0	8.2	120-TN7
	850/1104	RT	845	123	1098	159	11.0	-	120-TN11
Rene' 100	As Received	RT	808	117	1003	146	11.1	13.9	300-TN3
	As Received	RT	821	119	1023	148	12.7	14.9	300-TN4
	As Received	704	781	113	1012	147	16.0	18.2	300-TN1
	750/1279	RT	854	124	989	144	11.0	12.4	300-TN7
	850/1104	RT	737	107	874	127	10.0	7.9	300-TN11
Rene' 80	As Received	RT	871	126	947	137	2.0	3.2	200-TN2
	As Received	RT	879	128	976	142	3.3	2.8	200-TN3
	As Received	871	530	77	696	101	14.9	18.2	200-TN4
	750/1279	RT	867	126	956	139	4.0	2.8	200-TN7
	850/1104	RT	814	118	954	139	4.5	4.9	200-TN11

TABLE 2,7
(CONTINUED)

Alloy	Exposure Temp/Time °C/Hrs.	Test Temp. °C	0,2T YS		UTS		Elong. %	R of A %	Specimen Identification
			MPa	KSI	MPa	KSI			
Alloy 713LC	As Received	RT	787	114	1013	147	11.8	11.4	400-TN2
	As Received	RT	786	114	958	139	10.6	11.5	400-TN3
	750/1279	RT	792	115	882	128	6.0	6.3	400-TN7
	850/1104	RT	723	105	834	121	7.5	7.4	400-TN11
Alloy 713LC (Coated)	As Received	RT	700	102	837	121	7.5	9.5	400-TN5
	As Received	RT	690	100	803	116	5.4	9.6	400-TN6
	750/1279	RT	717	104	806	117	6.5	10.1	401-TN1
	850/1104	RT	689	100	785	114	7.5	9.8	401-TN5
IN-738	As Received	RT	827	120	1066	155	8.4	9.7	500-TN6
	As Received	RT	836	121	1087	158	9.5	10.1	500-TN3
	As Received	649	714	104	1134	165	12.7	13.6	500-TN2
	750/1279	RT	834	121	978	142	5.0	7.1	500-TN7
	850/1104	RT	703	102	847	123	6.0	2.4	500-TN11
NX-188	As Received	RT	999	145	1113	161	4.2	5.3	600-TN1
	As Received	RT	1001	145	1078	156	2.6	5.5	600-TN4
	750/1279	RT	840	122	1089	158	6.0	5.2	600-TN7
	850/1104	RT	565	82	944	137	6.0	3.9	600-TN11
Udimet 720	As Received	RT	797	116	1097	159	7.7	7.9	A00-TN2
	As Received	RT	794	115	1109	161	8.2	9.3	A00-TN1
	As Received	871	494	72	607	88	25.2	44.6	A00-TN3
	750/1279	RT	799	116	1116	162	9.0	7.8	A00-TN7
	850/1104	RT	716	104	1068	155	10.0	9.0	A00-TN11

(a) Identification not available.

ductility. The oxide dispersion strengthened alloys MA-956 and MA-754 showed little effects of exposure, which is consistent with other post exposure tensile results for these alloys. A full explanation of the exposure effects, that is the influence of surface attack versus thermal stability on the results, will have to await metallographic analysis.

2.5.6 Post Exposure Impact Testing

Instrumented charpy impact tests were carried out on specimens exposed for 1279 hours at 750°C (1382°F) and 1104 hours at 850°C (1562°F). Only the nuclear process heat alloys are tested in impact; the results are reported in Table 2.8. The results list the total energy absorbed and lateral expansion which are properties measured in normal uninstrumented impact tests. The energy at maximum load is a parameter available only from instrumented tests, and is an indication of the energy required to initiate the crack. The difference between the total energy and the energy at maximum load can be associated with the amount of energy required to propagate the crack to failure.

In all cases, the wrought Fe- and wrought Ni-base alloys lost considerable impact strength after exposure. Hastelloy X and HD-556 were most severely affected. The oxide dispersion strengthened alloy, MA-956, showed only a minor loss in impact strength.

2.6 TASKS 6 & 7 - THERMAL STABILITY EVALUATION AND PRIMARY COOLANT CORROSION RESISTANCE

Weight changes were measured for specimens exposed at 750°C (1382°F) for 1000-hours and 850°C (1562°F) for 1104 hours. These are listed in Tables 2.9 and 2.10 for 750°C (1382°F) - 1000 hours exposure and 850°C (1562°F) - 1104 hours exposure respectively.

The two commercial oxide dispersion strengthened alloys, MA-956 and MA-754, showed relatively small increases in weight, as did TZM alloy. The other two oxide dispersion strengthened alloys, YD-Ni and YD-NiCrAl showed low weight gain at 750°C (1382°F), but much higher values at 850°C (1562°F). In the case of YD-NiCrAl, this increase was due to severe internal oxidation of Al. It is not yet clear why there was such an increase in weight for YD-Ni at 850°C (1562°F).

TABLE 2.8

INSTRUMENTED CHARPY IMPACT TEST RESULTS
FOR NUCLEAR PROCESS HEAT ALLOYS

Alloy	Condition	Specimen Number	Total Energy Absorbed, E_T		Energy at Max. Load, E_M		$E_T - E_M$		Lateral Expansion	
			J	ft-lb	J	ft-lb	J	ft-lb	mm	in
Alloy 800H	As Received	10001M02	325	240	--	--	--	--		Bent
	As Received	10001M13	325	240	--	--	--	--		Bent
	750C/1279 hrs	10001M01	188	139	61	45	127	94	1.7	0.067
	850C/1104	10001M06	194	143	53	39	141	104	0.3	0.013
Alloy 800 (Coated)	As Coated	10011M02	307	227	135	100	172	127	1.6	0.062
	As Coated	10011M03	357	264	--	--	--	--		Bent
	750C/1279	10011M01	120	88.5	51	38	69	50.5	1.3	0.052
	850C/1104	10011M06	169	125	50	37	119	88	1.2	0.047
Incoloy 802	As Received	11001M07	257	190	95	70	162	120	1.6	0.065
	As Received	11001M08	346	256	--	--	--	--		Bent
	750C/1279	11001M01	66	48.5	29	21.5	37	27	0.9	0.036
	850C/1104	11001M04	68	50	27	20	41	30	0.9	0.036
Incoloy 807	As Received	12001M09	178	131.5	84.5	62.5	93.5	69	1.9	0.073
	As Received	12001M10	178.5	132	93	69	85.5	72	1.8	0.070
	750C/1279	12001M01	35	26	15	11	20	15	0.6	0.024
	850C/1104	12001M04	34	25	15	11	19	14	0.6	0.023
Incoloy DS	As Received	13001M07	357	264	--	--	--	--		Bent
	As Received	13001M08	325	240	--	--	--	--		Bent
	750C/1279	13001M01	145	107	60	44	85	63	1.5	0.059
	850C/1104	13001M04	145	107	62	46	83	61	1.4	0.054
HD-556	As Received	14001M02	296	219	108	80	188	129	2.1	0.082
	As Received	14001M03	295.5	218.5	135	100	160.5	118.5	1.8	0.069
	750C/1279	14001M01	20	15	11	8	9	7	0.3	0.011
	850C/1104	14001M06	15	11	4.7	3.5	10.3	7.5	0.15	0.006

TABLE 2.8
(CONTINUED)

Alloy	Condition	Number	Total Energy Absorbed, E_T		Energy at Max Load, E_M		$E_T - E_M$		Lateral Expansion	
			J	ft-lb	J	ft-lb	J	ft-lb	mm	in
Manaurite 36XS	As Received	15001M10	6.8	5	2.7	2	4.1	3	0.1	0.005
	As Received				TO BE RUN					
	750C/1279	15001M01	2.0	1.5	2.0	1.5	0	0	0.05	0.002
	850C/1104	15001M04	2.7	2.0	--	--	--	--	0.03	0.001
HK-40	As Received	17001M09	9.5	7	3.4	2.5	6.1	4.5	0.15	0.006
	As Received	17001M10	10.8	8	4.1	3	6.7	5	0.15	0.006
	750C/1279	17001M01	4.1	3.0	3.4	2.5	0.7	0.5	0.05	0.002
	850C/1104	17001M04	5.4	4.0	5.4	4.0	0	0	0.03	0.001
IN-519	As Received	18001M09	21.6	16	5.4	4	16.2	12	0.5	0.018
	As Received	18001M10	22.3	16.5	6.8	5	15.5	11.5	0.3	0.013
	750C/1279	18001M01	4.7	3.5	4.1	3	0.6	0.5	0.05	0.002
	850C/1104	18001M04	4.7	3.5	2.7	2	2.0	1.5	0.07	0.003
Hastelloy X	As Received	19001M09	334	247	--	--	--	--		Bent
	As Received	19001M17	292	216	--	--	--	--		Bent
	750C/1279	19001M01	11	8.0	5.5	4	5.5	4	0.1	0.004
	850C/1104	19001M04	19	14	9.5	7	9.5	7	0.3	0.013
Inconel 617	As Received	1A001M09	325	240	--	--	--	--		Bent
	As Received	1A001M10	325	240	--	--	--	--		Bent
	750C/1279	1A001M01	99	73	42	31	57	42	1.1	0.042
	850C/1104	1A001M04	21	15.5	9	6.5	12	9	0.25	0.010
Inconel 617 (Coated)	As Coated	1A011M02	181	134	68	50	113	84	1.3	0.052
	As Coated	1A011M03	187	138	101	75	86	63	1.4	0.054
	750C/1279	1A011M01	61	45	26	19	35	26	0.7	0.026
	850C/1104	1A011M06	111	82	45	33	66	49	0.8	0.032

TABLE 2.8
(CONTINUED)

Alloy	Condition	Number	Total Energy Absorbed, E_T		Energy at Max Load, E_M		$E_T - E_M$		Lateral Expansion	
			J	ft-lb	J	ft-lb	J	ft-lb	mm	in
Mo-Re 2	As Received	1C001M10	4.7	3.5	2.0	1.5	2.7	2.0	0.05	0.002
	As Received	1C001M14	4.4	3.25	1.7	1.25	2.7	2.0	0.08	0.003
	750C/1279	1C001M01	2.7	2.0	2.7	2.0	0	0	0.03	0.001
	850C/1104	1C001M04	5.4	4.0	5.4	4.0	0	0	0.03	0.001
MA-956	As Received	1D001M08	70	52	53	39	17	13	0.7	0.028
	850C/1104	1D001M02	62	45.5	42	31	20	14.5	0.5	0.019

TABLE 2.9

WEIGHT CHANGE DATA FOR 1000-HOUR
EXPOSURE AT 750°C

Specimen Identification Number	Alloy	Condition	Wt. Change (Mg/cm ²)	Initial Wt. (Grams)	Exposed Wt. (Grams)
1000C001	Alloy 800H	Coated	0.618	6.33379	6.33743
1001C001	Alloy 800H		0.379	6.45651	6.45874
1100C001	Incoloy 802		0.674	6.36332	6.36729
1200C001	Incoloy 807		0.489	6.68453	6.68741
1300C001	Incoloy DS		0.340	6.28312	6.28512
1400C001	HD-556		0.491	6.58818	6.59107
1500C001	Manaurite 36XS		0.370	6.33494	6.33712
1600C001	Manaurite 900		0.362	6.37558	6.15062
1700C001	HK-40		0.284	6.14895	6.15062
1800C001	IN-519		0.341	6.22062	6.22263
1900C001	Hastelloy X	Coated	0.501	6.61843	6.62138
1A00C001	Inconel 617		0.450	6.70177	6.70442
1A01C001	Inconel 617		0.268	6.75103	6.75261
1B00C001	Inconel 618E		0.389	6.73663	6.73892
1C00C001	Mo-Re 2		0.384	7.08502	7.08728
1D00C001	MA-956		0.212	5.82933	5.83058
0110C001	MM-0011CC		0.367	6.17490	6.17706
0130C001	MM-0011DS		0.364	5.55563	5.55777
0210C001	Rene' 80		0.596	6.01621	6.01972
0310C001	Rene' 100		0.340	5.40695	5.40895
0410C001	Alloy 713LC	Coated	0.465	5.46841	5.47115
0411C001	Alloy 713LC		0.255	5.49090	5.49240
0510C001	IN-738		0.647	5.87493	5.87874
0610C001	NX-188		0.564	5.58898	5.59230
0710C001	M-21		0.493	6.17384	6.17674
0800C001	YD-Ni		0.187	6.31708	6.31818
0900C001	YD-NiCrAl		0.231	6.31356	6.31492
0A00C001	Udimet 720		0.770	6.50768	6.51221
0B00C001	MA-754		0.316	6.68206	6.68392
0C00C001	TZM		0.226	8.14967	8.15100
0C01C001	TZM	Coated	0.059	8.18381	8.18416

TABLE 2.10
WEIGHT CHANGE DATA FOR 1104-HOUR
EXPOSURE AT 850°C

<u>Specimen Identification Number</u>	<u>Alloy</u>	<u>Condition</u>	<u>Wt. Change (Mg/cm²)</u>	<u>Initial Wt. (Grams)</u>	<u>Exposed Wt. (Grams)</u>
1000C007	Alloy 800H	Coated	0.785	6.34397	6.34859
1001C007	Alloy 800H		0.161	6.47262	6.47357
1100C007	Incoloy 802		1.065	6.35654	6.36281
1200C007	Incoloy 807		1.050	6.63863	6.64481
1300C007	Incoloy DS		-0.042	6.27922	6.27897
1400C007	HD-556		0.605	6.58577	6.58933
1500C007	Manaurite 36XS		-1.213	6.18168	6.17454
1600C007	Manaurite 900		0.270	6.37660	6.37819
1700C007	HK-40		-0.268	6.20727	6.20569
1800C007	IN-519		0.165	6.26650	6.26747
1900C007	Hastelloy X	Coated	1.228	6.61065	6.61788
1A00C007	Inconel 617		0.579	6.64288	6.64629
1A01C007	Inconel 617		0.068	6.65083	6.65123
1B00C007	Inconel 618E		0.549	6.82398	6.82721
1C00C007	Mo-Re 2		0.948	7.00027	7.00585
1D00C007	MA-956		0.138	5.73498	5.73579
0110C007	MM-0011CC		0.223	6.04829	6.04960
0130C007	MM-0011DS		0.177	6.18767	6.18871
021C007	Rene ® 80		0.661	5.92066	5.92455
0310C007	Rene ® 100		0.187	5.65020	5.65130
0410C007	Alloy 713LC	Coated	0.931	5.49482	5.50030
0411C007	Alloy 713LC		0.144	5.53183	5.53268
0510C007	IN-738		0.168	5.79708	5.79807
0610C007	NX-188		1.964	5.83759	5.84915
0710C007	M-21		0.938	6.00247	5.00799
0800C007	YD-Ni		1.332	6.58266	6.59050
0900C007	YD-NiCrAl		1.075	6.36667	6.37300
0A00C007	Udimet 720		0.367	6.50452	6.50668
0B00C007	MA-754		0.124	6.57527	6.57600
0C00C007	TZM		0.104	8.15839	8.15900
0C01C007	TZM	Coated	-0.041	8.20507	8.20483

Again, these results will be clearer when the metallography on these specimens has been completed.

2.7 TASK 9 - DATA MANAGEMENT AND PROGRAM MANAGEMENT

2.7.1 Data Management

The Database Definition File is now 50% complete, and will be completed in the next working period. The Mark III world-wide computer system with its data management system (DMS III) retrieval method will be used once the program is in place. Key punching of data generated in the testing program has been initiated, and a significant amount of the data will be ready by the time the database definition file is completed. Some period of time will be needed for checkout of the database definition file once completed, and this will require sufficient data input.

The data reduction and presentation schemes are the next area requiring attention.

2.7.2 Program Management

The following program meetings were attended or conducted by program staff during the report period:

- An HTGR materials program coordination meeting was held in Schenectady, N.Y. on November 7 and 8, 1979. The meeting was attended by program participants representing the Department of Energy (DOE), General Atomic Co. (GAC), Oak Ridge National Laboratory (ORNL), Gas Cooled Reactor Associates (GCRA), and General Electric Co. (GE).
- A program review meeting was held at General Electric in Schenectady, N.Y. with G. A. Newby, Chief, Nuclear Reactor Programs Branch DOE, and J. E. Fox, DOE Program Manager, on November 8, 1979.
- Two program review meetings were held for General Electric management during the reporting period: one (1) on November 27, 1979 and one (1) on December 12, 1979.

In addition, weekly meetings were held with the General Electric program personnel in Schenectady, N.Y. to review technical results and program status.

On December 20, 1979. Modification A012 to the base contract was received to add additional operating funds to the program.

The Program Master Schedule is presented in Figure 2.2.

Section 3.0

WORK TO BE COMPLETED DURING THE NEXT QUARTER

3.0 WORK TO BE COMPLETED DURING THE NEXT QUARTER

- The thermal stability exposure tests will continue.
- The multi-specimen tests at 750°, 850° and 950°C will continue, and the 1050°C tests will be started.
- Metallography on the 1000-hour 750° and 850°C thermal stability pins will be completed.
- Test specimens for the nuclear process heat alloys for phase 2 testing will be received and prepared for test.
- Two retorts for fatigue testing will be checked out and received from the vendor.
- Modifications to Loop No. 2 will continue and the gas analysis equipment for Loop No. 2 will be commissioned.
- The database definition file will be completed.