TID/SNA-679

MATERIALS REVIEW

21-22 SEPTEMBER 1971

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27 September 1971
TAR:mc:N8130R:71-0160

ENGINEERING OPERATIONS

MEETING REPORT

ENGINEERING STAFF DEPARTMENT

PROJECT 187

PURPOSE OF MEETING

The meeting was held to review for SNSO the current status of the Materials Program and to present a technical review of several specific subjects requested by SNSO (See Enclosure (1)).

DATE AND LOCATION

The meeting was held at ANSC on 21-22 September 1971.

ATTENDEES

The attendance list is attached as Enclosure (2).

SIGNIFICANT RESULTS

Since this meeting was intended as a presentation of information flowing from ANSC to SNSO there were no areas of agreement or disagreement, per se. SNSO asked questions for clarification of information presented when this was desired and also suggested areas for re-evaluation of our proposed activity in light of their input. These were discussed and those not resolved were compiled into two lists for post-meeting action. The first, a list of questions was discussed at a post-meeting session. It was agreed that the few questions that were not completely answered at the session would be handled informally between appropriate ANSC and SNSO personnel. The second list set forth ANSC's version of action items resulting from the meeting. Several additions, deletions and minor changes were made in the list at SNSO's request during the post-meeting session resulting in a revised list, Enclosure (3).

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Material used at the meeting in the presentation of information to SNSO is included in enclosures as follows:

Material Priority and Maturity Status Report, 15 September 1971
Issue (Enclosure (4)).

Viewgraphs (Enclosure (5)).

Handouts (Enclosure (6)).

Prepared by:

T. A. Redfield, Supervisor
Materials Section

Approved by:

K. Sato, Manager
Engineering Staff Department

Enclosure (1)
27 September 1971
TAR:mc:N8130R:71-0160

MATERIALS REVIEW FOR SNSO

21-22 September 1971

AGENDA

<u>Subject</u>	<u>Speaker</u>
Status Review of Current M-Plans	T.A.Redfield/H.Derow
Special Subjects	
Processing history of Ti 5Al-2.5Sn	P.P.Dessau
Processing history of ARMCO 22-13-5	H.W.Spaletta
M-40 (LH ₂ , LH ₂ , GH ₂ Correlation)	C.E.Dixon
M-23 (Stress and radiation synergistic effects)	C.E.Dixon
Discussion of Current DRM's	H.Derow
Maturity of materials data	
Organization and maintenance of DRM manuals	
Utilization of DRM data	
SNSO Comments	
Action Items	

Enclosure (2)
27 September 1971
TAR:mc:N8130R:71-0160

MATERIALS REVIEW 21-22 SEPTEMBER 1971 FOR SNSO

ATTENDEES

<u>NAME</u>	<u>ORGANIZATION</u>
Ira L. Helms	SNSO-W
E. W. Miller	SNSO-C
A. A. Medeiros	
J. J. Lombardo	
E. O. Woolridge	
* J. E. Richardson	
* J. C. Montgomery	
* Keith Estes	
* W. E. Campbell	ANSC
* J. J. Stewart	
* G. F. Mader	
T. A. Redfield	
H. Derow	
K. Sato	
U. A. Pineda	
L. Shenfil	
* K. E. Unmack	
* C. M. Kawashige	
* L. A. Shurley	
* E. F. Thacher	
* J. L. Watkins	
* H. W. Spaletta	
* P. P. Dessau	
* C. E. Dixon	

* Part time.

Enclosure (3)
27 September 1971
TAR:mc:N8130R:71-0160

MATERIALS REVIEW 21-22 SEPTEMBER 1971 FOR SNSO

ACTION ITEMS

1. Hastelloy X should not be dropped from LCF test program as long as Hastelloy X remains a candidate material for the nozzle.
2. M-16. Eliminate Line 5 if "C" data is already available; otherwise reduce number of specimens. Increase Line 2a matrix to get "A" data.
3. Consider repeat of Lines 1 and 4, M-19 when 440C material is procured under ring forging specification.
4. M-21, Line 2. Review salt spray portion of test to determine whether 555°R is the most appropriate test temperature because of possible significant temperature dependence.
5. M-21, Line 7a. Consider with project and stress personnel the use of flat specimens with center notch in lieu of K_{Ic} specimens.
6. M-31, Line 4. Property data requirements should be reviewed with stress to determine whether tensile tests or some other type of testing should be done. Change test classification in next Materials Priority and Maturity Status Report from D to M.
7. M-38, Line 6a. Consider inclusion of K_{Ic} irradiation tests of welded plate. If more than one type of welding rod is a candidate for 22-13-5 weldments, specimen matrix should include different weldments.
8. M-39. Test plan for unirradiated testing should be reviewed with stress and project to determine need for additional tests such as fatigue. Need for irradiated test, Line 1a, should be reviewed.
9. Provide in process and QC acceptance testing steps for Ti forgings.
10. Provide in process and QC acceptance testing steps for ARMCO 22-13-5 forgings.
11. SNSO will provide guidance on irradiation and LCF test of AISI 347 specimens.

Action Items

-2-

Enclosure (3)
27 September 1971
TAR:mc:N8130R:71-0160

12. Southern Research report on fibrous graphite will be reviewed by ANSC for potential NDT procedures.
13. M-40. Consider irradiating encapsulated AA 6061 specimens at 10^{19} .
14. M-23. Provide pedigree data for Ti notched tensile specimens.
15. Provide Arcturus forging procedures for Ti 5Al-2.5Sn.

Enclosure (4)
27 September 1971
TAR:mc:N8130R:71-0160

MATERIALS REVIEW 21-22 SEPTEMBER 1971 FOR SNSO

MATERIAL PRIORITY AND MATURITY STATUS REPORT

15 SEPTEMBER 1971 ISSUE

NERVA PROGRAM - CONTRACT SNP-1
PROJECT 187 - MATERIALS DEVELOPMENT

MATERIAL PRIORITY & MATURITY STATUS

15 SEPTEMBER 1971

MATERIALS & PROCESSES STAFF

T. A. Redfield, Manager

MATERIAL TEST PLAN INDEX

TEST PLAN	TOPIC	PAGE
M-1	ALLOY 718	1a *
M-2	AISI 347	2 & 2a
M-3	AA 7039-T63	3a *
M-4	TI-5AL-2.5SN ELI	4 & 4a *
M-5	A-286	5 & 5a
M-6	FIBROUS GRAPHITE	6 & 6a
M-7	AA 6061-T6	7 & 7a
M-9	TI-6AL-4V	9 & 9a
M-11	FRICTION AND WEAR	11
M-12	HASTELLOY X	12a *
M-14	FEURALON POLYIMIDE	14a
M-16	MARAGING STEEL (18 NI)	16 & 16a
M-19	AISI 440C	19
M-21	7075-T73	21 & 21a
M-22	GH ₂ EMBRITTLEMENT	22
M-23	STRESS AND RADIATION SYNERGISTIC EFFECTS	23a
M-31	CARBURIZED 9310	31 & 31a
M-38	STAINLESS STEEL 22-13-5 (ARMCO)	38 & 38a
M-39	BeCu	39 & 39a
M-40	LH ₂ , LN ₂ , GH ₂ , CORRELATION	40a

* IRRADIATED SPECIMEN EVALUATION WAS SHOWN COMPLETED IN 15 MAY 1971 REPORT.

RECOMMENDED REVISED PRIORITY LIST

<u>PRIORITY</u>	<u>TOPIC</u>	<u>TEST PLAN</u>	<u>PAGE</u>
1	TI-5AL-2.5SN	M-4	4 & 4a *
2	GAS-RADIATION CORRELATION	M-40	40a
3	STRESS, RADIATION, HYDROGEN SYNERGISTIC	M-23	23a
4	GH ₂ EMBRITTLEMENT	M-22	22
5	FIBROUS GRAPHITE	M-6	6 & 6a
6	22-13-5 ARMCO SS	M-38	38 & 38a
7	7075-T73	M-21	21 & 21a
8	347 SS	M-2	2 & 2a
9	A286	M-5	5 & 5a
10	FEURALON POLYIMIDE	M-14	14a
11	6061-T6	M-7	7 & 7a
12	CARBURIZED 9310	M-31	31 & 31a
13	BeCu	M-39	39 & 39a
14	FRICTION/WEAR	M-11	11
15	440C	M-19	19
16	MARAGING STEEL	M-16	16 & 16a
17	TI-6AL-4V	M-9	9 & 9a

* IRRADIATED SPECIMEN EVALUATION WAS SHOWN COMPLETED IN 15 MAY 1971 REPORT.

REVISIONS TO
MATERIALS MATURITY STATUS REPORT
FOR 15 MAY 1971

M-6 The following changes resulted from SNSO-C/ANSC April component status review at ANSC.

Line 3.2.3 - Add 3-D tufted liner testing

Line 4.1.4 - Substitute modulus for shear determination

Line 5.3.2 - Add breakdown of liner concepts to be evaluated

General - Redistribution of specimens

M-11 Line 6 Vacuum Friction Test

Test definition revised based on project information that wire braid is no longer considered as a bellows support candidate. However there are other questionable areas with respect to bellows and/or valves which appear to require testing. Therefore 321 SS wire braid has been eliminated and other alternative materials will be selected.

M-23 Lines 3.a through 8.a

It was mutually agreed with SNSO-C that 9310 should be tested. Thus 9310 replaces 302 in lines 3.a/4.a; and 9310 becomes the 3rd material in lines 5.a/6.a and the 4th material in lines 7.a/8.a

Line 9.a - These are control specimens which, while always a part of the test matrix, had not been shown previously.

M-38 Line 3.a

Forging rejected at vendor due to unacceptable defects. Substitution of plate for forging planned to meet GTR-23 schedule.

Lines 4 and 5.a - These lines were eliminated based on project information that a transition weld joint is no longer a component requirement.

M-40 Line 6

In accordance with SNSO-C/ANSC discussion during December, the 300°R temperature for radiation was changed to 140°P. Thus Line 6 becomes superfluous since Line 4 can serve as control specimens (complimenting Line 7 testing).

REVISIONS TO
MATERIALS DATA MATURITY STATUS REPORT
FOR 15 JULY 1971

M-2 Line 2.a

Irradiated low cycle fatigue test specimen fabrication added in accordance with SNSO-C/ANSC contract negotiation agreement June 1971.

M-4 Lines 2, 5, 16 and 17

Major schedule revision required due to forging delivery slip. See 15 May 1971 report for previous schedule.

Line 17

Test difficulty and blade availability caused report completion slip into CY 1973.

M-21 Line 7.a

Irradiated fracture toughness test specimen fabrication (flame spray coated specimens) added in accordance with SNSO-C/ANSC contract negotiation agreement June 1971.

M-22 Lines 15, 15.1, 15.2

Changes in Form due to availability of material in NERVA furnace-brazed condition.

M-39 Line 1.a

Temperature change based on agreement with Project that 140°R is more meaningful relative to actual spring operating environment.

REVISIONS TO
MATERIAL PRIORITY AND MATURITY
STATUS REPORT FOR 15 SEPTEMBER 1971

M-2 Lines 5.0, 5.1 and 9

The contract at Creative Pathways has been cancelled due to non-performance. A new vendor is being solicited for semi-automatic tube welding process development for 347-347 tube joints. The transition joint evaluation (line 9) is also being held because its use is contingent on successful development of the process to weld this joint into the line system.

M-6 Line 6a

Because tests described by lines 3a, 4a and 5a will not occur until GTR-24 it was deemed advisable to run preliminary tests early and irradiate in GTR-23 to establish trends in radiation effects. Thus, addition of this line.

Line 7a

Intremold III specimens were added to the radiation test program to effect complete evaluation of the material.

M-7 Lines 5 and 6

Creative Pathways' performance on developing the semi-automatic tube welding process was sufficiently unsatisfactory to warrant cancellation of the order. An alternate source is to be selected.

M-14 Lines 1a and 2a

Number of specimens increased from 16 to 32 to improve chances of obtaining "A" data.

M-16 Lines 1a and 2a

The exposure fluence was reduced on Line 1a to a level consistent

with the actual service condition. Changed K_{IC} to K_I on Line 2a to better simulate actual engine environment which includes cyclic operating mode. One radiation level reduction made to accommodate need for increased stress levels associated with change.

M-21 Lines 4, 4a, 5a and 6a

Due to delay in forging delivery, form for coating evaluation changed to plate. Either form is equally adequate for meeting test requirements.

M-23 Lines 5a thru 9a

Changed material from forgings. Plate and bar will produce data with lower variability thus enhancing analysis for synergistic effects.

M-31 Line 1a

The number of exposure fluences and lots was reduced in the interest of cost savings based on the requirements for C data specimen matrix.

Line 2a

As requested by SNSO-C at a Radiation Test Review Meeting, 8 June 1971, the test matrix was revised to obtain A data in place of C. This revision is based on the presumption that the material is brittle and A data will be needed ultimately. Doing so in GTR-23 represents an overall cost saving.

M-38 Line 6a

Evaluation of the fracture toughness of 22-13-5 was added as a screening test to confirm the presumed ductile classification of the material at 140°R.

Line 7a

Irradiated tensile properties required for determination of fracture toughness properties (Line 6a).

KEY TO MATERIALS DATA MATURITY STATUS SHEETS

<u>SCHEDULE</u>	<u>STATUS</u>	<u>DATA CATEGORIES</u>	<u>DECISION</u>
p = PLANS COMPLETED m = MATERIAL DELIVERED f = SPECIMENS FABRICATED t = TESTS COMPLETED s = IRRAD TEST REQ SUBMITTED x = IRRADIATION STARTED d = DATA AVAILABLE FROM TEST r = DATA RELEASED	Ax = AHEAD OF SCHEDULE BY x WEEKS Bx = BEHIND SCHEDULE BY x WEEKS Ø = ON SCHEDULE H = ON HOLD COMP = COMPLETED	A B C D SEE TD 69-37	(D) = DESIGN (M) = MATERIAL DEVELOPMENT
<u>MATERIAL FORM</u>	<u>ATMOSPHERE</u>	<u>TEST FACILITY</u>	
B = BAR C = CAST CW = COLD WORK R = ROD S = SHEET T = TUBE W = WELD P = PLATE F = FORGING	A = ARGON AMB = AMBIENT H ₂ O = WATER GH ₂ = GASEOUS HYDROGEN LH ₂ = LIQUID HYDROGEN GHe = GASEOUS HELIUM LN ₂ = LIQUID NITROGEN ALC = ALCOHOL	A = AEROJET B = BOEING BMI = BATTELLE MEMORIAL INSTITUTE GD = GENERAL DYNAMICS GE = GENERAL ELECTRIC KSC = KENNEDY SPACE CENTER O = OUTSIDE AGC (NOT CURRENTLY IDENTIFIED) PBRF = PLUMBROOK R = ROCKETDYNE NBS = NATIONAL BUREAU OF STANDARDS TBD = TO BE DETERMINED WANL = WESTINGHOUSE ASTRONUCLEAR LABORATORY	

M-2 (AISI 347)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU/SPALETТА

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS			
				TEMP °R	ATMOS.				CY 71					CY 72												
									M	A	M	J	J	A	S	O	N	D	J	F	M	A		M	J	J
1	NOZZLE COOLANT CHANNELS	S	CREEP 100 HOUR	1660, 1860, 2060	GH ₂	GE	216 (D)	3	C	t					r				A					B ₄		
2	NOZZLE JACKET	F	THERMAL CONDUCTIVITY	140 TO 2260	VAC	BMI	1 (M)	1	D	C														COMP 2/1		
3	NOZZLE COOLANT CHANNELS	B	FATIGUE LOW CYCLE	1460, 1860 2060	GH ₂	BMI	384* (D)	3	D	t					r				A					B ₂₀		
5.0	LINES	TW	SEMI PERM JOINT DEV.(TENS)	540, 140	AIR, LN ₂	WANL & TBD	(1) 6 (M)(2)	1	D						f		t		r		(2)			C	H ⁽¹⁾	
5.1	LINES	TW	SEMI PERM JOINT DEV.(BEND)	540, 140	AIR, LN ₂	WANL & TBD	(1) 6 (M)(2)	1	D						f		t		r		(2)			C	H ⁽¹⁾	
9	VALVES & LINES	S/F	TRANSITION JOINT DEV.-TENS (TO 6061-T6)	40, 540	LH ₂ , AIR	WANL	20 (M)	2	D						p		m		f		t		r		C	H ⁽¹⁾
10	NASS	PW	LOW CYCLE FATIGUE	1460	AIR	(3)	12 (M)	1	D						m		f		t		r		C		A ₂	

* COMPARATIVE EVALUATION OF HAST. X WITH AISI 347 IS INCLUDED IN SPECIMEN TOTAL.
384 SPECIMENS INCLUDE 204 AISI 347 AND 180 HAST. X.

- (1) SEE REVISION SUMMARY DATED 15 SEPTEMBER (ATTACHED).
- (2) SIX TESTS AT 540°R TO BE PERFORMED. NUMBER AND SCHEDULE OF LN₂ TESTS TO BE DETERMINED BASED ON R.T. RESULTS AND AMOUNT OF TUBING REMAINING FROM PROCESS DEVELOPMENT PHASE.
- (3) TESTING BY MAR TEST

M-2 (AISI 347)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO.OF SPECIMENS	LOTS	SCHEDULE														STATUS	
				TEMP °R	NVT RAD	ATMOS.				CY 71							CY 72								
				RAD/TEST	10 POWER	RAD/TEST				M	A	M	J	J	A	S	O	N	D	J	F	M	A		M
1a	NOZZLE	F	TENSILE	140/140	0,17,18,19	LN ₂ /LN ₂	GD/GD	24 (M)	1	D	C														COMP
2a ⁽¹⁾	NOZZLE COOLANT CHANNELS	B	LOW CYCLE FATIGUE	AMB/2060	5(18) (THERMAL)	H ₂ O/AIR	TBD/TBD	18 (M)	1	D	m (2) C														Ø

(1) SEE REVISION SUMMARY DATED 15 JULY 1971 (ATTACHED)

(2) FABRICATION SCHEDULE PENDING DETERMINATION OF SPECIMEN CONFIGURATION

M-4 (T1 5Al-2.5Sn ELI)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE		STATUS								
				TEMP °R	ATMOS.				CY 71					CY 72					
									M	A		M	J	J	A	S	O	N	D
1	TPA ROTOR	F/DIE F	FATIGUE	40	LH ₂	0	100 (D)	2	D	t	(m)	r	(f)	(t)	(r)	A	B ₁₂		
2	TPA ROTOR	DIE F	K ₁	540, 300, 40	GH ₂ , LH ₂	0	144 (D)	4	D	m	f	t	r			A	B ₁₂		
3	TPA ROTOR	F	K _{IC}	40	LH ₂	A	18 (D)	2	D	B						COMP			
5	TPA ROTOR	F	PHYSICAL PROPERTIES (ν, E)	540	AIR	A	4 (M) (2 PANCAKE, 2 DIE F)	2	D	m	f	t	r			C	B ₁₂		
16	ROTOR	DIE F	K _{IC}	540	AIR	A	35 (D)	4	D	m	f	t	r			A	B ₁₂		
17	BLADE	DIE F	HIGH CYCLE FATIGUE	540	AIR, GH ₂	0	60 (D)	1	D	m	f ⁽¹⁾	t	r			C	B ₁₂		

(1) SPECIMENS PROVIDED BY TPA PROJECT

M-5 (A-286)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU/GIANNUZZI

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE																		STATUS	
				TEMP °R	ATMOS.				CY 71						CY 72													
									M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A		S
1	VALVE SPRING	B(CW)	FAB DEVELOP	--	--	0	3 (M)	1	D	m																		B ₈
2	VALVE SPRING	B(CW)	TENSILE	140, 540	LN ₂ , AIR	WANL	8 (M)	1	D	m p f t r																		C B ₈
7	TPA ROTOR & VALVE SPRING	F & B(CW)	MODULUS & POISSON'S RATIO	540 TO 40	LH ₂	0	2 (M)	1	D	m f t r																		C B ₈
11	TPA TIE BOLT	B(CW)	TENSILE	40	LH ₂	WANL	2 (M)	1	D	p f t r																		C A ₂₄
12	BLADE	DIE F	HIGH CYCLE FATIGUE	540	AIR/GH ₂	0	60(D)	1	D	f ⁽¹⁾ t r																		C B ₂₁

(1) SPECIMENS PROVIDED BY TPA PROJECT

M-5 (A286)		MATERIALS DATA MATURITY STATUS (MATERIALS IRRADIATION)										15 SEPT 71 DIXON												STATUS					
LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE																			
				TEMP °R RAD/TEST	NVT RAD 10 POWER	ATMOS. RAD/TEST				CY 71						CY 72													
										M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1a	PRESSURE VESSEL CLOSURE	B(CW)	FRACTURE TOUGHNESS	140/140	0,18,7,(18)	LN ₂ /LN ₂	GD/GD	11 (M)	1	D	r C															COMP			
2a	PRESSURE VESSEL CLOSURE	B(CW)	TENSILE	140/140	0,17,7,(18)	LN ₂ /LN ₂	GD/GD	21 (M)	1	D	r C															COMP			
3a	TPA	B(CW)	TENSILE	40/40	0,17,18	LH ₂ /LH ₂	GD/GD	9 (M)	1	D	m p sf x ** C															A ₈			
4a	NOZZLE PV	B(CW)	TENSILE	140/140	0,17,18,19	LN ₂ /LN ₂	GD/GD	29 (M)	2	D	r C															COMP			

** DRM WILL BE SCHEDULED WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

TEST CONDITIONS

TEMPERATURE: 535°R
 ATMOSPHERE: AIR
 FACILITY: OP

LINE	PROPERTY	NO. OF * SPECIMENS	SCHEDULE		STATUS
			CY 71 M A M J J A S	CY 72 O N D J F M A M J J A S	
1	<u>PREPREG DEVELOPMENT (USING WCA FABRIC)</u>				
1.1	PROCESS DEVELOPMENT AND PLATE FABRICATION - EC 260 & EC-260 + USP-39 SYSTEMS		m		COMP
1.2	PROPERTY TESTING (2 GRAPHITIZED PLATES PER SYSTEM)				
	TENSILE - BLOCK, WARP, & FILL	42			
	COMP - BLOCK, WARP, & FILL	42			
	SHEAR - WARP & FILL	28			
	MODULUS - BLOCK, WARP, & FILL	12 16		f t r B	Ø
2	<u>BINDER DEVELOPMENT (USING WCA FABRIC & USP-39 RESIN)</u>				
2.1	PROCESS DEVELOPMENT AND PLATE FABRICATION		m f		COMP
2.2	SCREENING TESTS - 24 COMPOSITIONS(1 PLATE PER COMPOSITION)				
	TENSILE - BLOCK	72			
	SHEAR - WARP	72			
	MODULUS - WARP	24		t r c	Ø
2.3	PROPERTY CHARACTERIZATION - 2 BEST COMP. FROM ABOVE(2 PLATES PER COMP.)				
	TENSILE - BLOCK, WARP, & FILL	42			
	COMP - BLOCK, WARP, & FILL	42			
	SHEAR - WARP & FILL	28			
	MODULUS - BLOCK, WARP, & FILL	12 16			
	CTE - BLOCK, WARP, & FILL	4 16		m f t r c	Ø
3	<u>LAYUP DEVELOPMENT</u>				
3.1	FLANGE SECTION - PLATE SPECIMENS				
3.1.1	PROCESS DEVELOPMENT AND PLATE FABRICATION - 2 DESIGNS EACH OF SINGLE LAP & ROSETTE(2 PLATES PER DESIGN)		m	f	Ø
3.1.2	SHEAR TESTS**	16		t r c	Ø

*EQUAL DISTRIBUTION OF SPECIMENS OVER GROUPED COMBINATIONS.

**BACK-TO-BACK GROSS FLANGE SECTION TESTS.

15 SEPT 71

M-6 (CONTINUED)

LINE	PROPERTY	NO. OF SPECIMENS	SCHEDULE		STATUS
			CY 71 M A M J J A S	CY 72 O N D J F M A M J J A S	
3.2	PARENT MATERIAL SECTION - PLATE SPECIMENS				
3.2.1	PROCESS DEVELOPMENT AND PLATE FABRICATION - 3-D ORTHOGONAL & ANGLE INTERLOCK CONFIGURATIONS		m	f	Ø
3.2.2	PROPERTY TESTING - 1 PLATE PER CONFIGURATION				
	TENSILE				
	BLOCK	6			
	WARP	4			
	COMP - WARP	6		t r	Ø
	SHEAR - WARP	6			
	MODULUS - WARP	2			
3.2.3	PROPERTY TESTING - 3-D TUFTED LINER FABRIC				
	TENSILE - BLOCK, WARP, & FILL	21			
	INTERLAMINAR SHEAR - WARP & FILL	14			
	COMPRESSION - BLOCK & WARP	14		f t r	Ø
	MODULUS - BLOCK, WARP & FILL	6			
4	<u>INTREMOLD III EVALUATION</u>				
4.1	CYLINDER TESTING - DIAMOND & ORTHOGONAL CELL 6 CYLINDERS. 9 IN. CYLINDERS PROJECT-FURNISHED. FINANCING OF TECHNICAL SUPPORT OF CARBONIZING AND GRAPHITIZATION FURNISHED BY PROJECT 143				
4.1.1	TENSILE/COMPRESSIVE - AXIAL (24 SPECIMENS/CYL)	48		(Gp.1-3 cyl.) m f t r	B4
4.1.2	TENSILE - HOOP	48			
4.1.3	TENSILE/COMPRESSIVE - BLOCK	48		(Gp.2-3 cyl.) m f t r	Ø
4.1.4	MODULUS (2 SPECIMENS/DIRECTION) - BLOCK WARP, & FILL	36			
4.2	PLATE TESTING - 2 DESIGN SELECTED FROM CYLINDER TESTS ABOVE (1 PLATE PER DESIGN)				
4.2.1	SHEAR TESTS	12			
4.2.2	CTE TESTS (NOT CURRENTLY FUNDED)	12			
4.2.3	THERMAL CONDUCTIVITY TESTS (NOT CURRENTLY FUNDED)	4			
				m f t r	B Ø

15 SEPT 71

LINE	PROPERTY	NO. OF SPECIMENS	SCHEDULE		STATUS
			CY 71 M A M J J A S	CY 72 O N D J F M A M J J A S	
5	<u>STIFFENER DEVELOPMENT</u>				
5.1	MACERATION				
5.1.1	PROCESS DEVELOPMENT & PLATE FABRICATION - 2 TECHNIQUES FOR EACH OF TAPE, ROSETTE, & SHINGLE(1 CURVED PANEL PER TECHNIQUE)		m _____ f		Ø
5.1.2	TEE BAR PULL STRENGTH	72		t r _____ c	Ø
5.2	TEE-BAR				
5.2.1	PROCESS DEVEL. & PLATE FABRICATION FOR 6 DESIGNS(1 FLAT PLATE PER DESIGN)		m _____ f		Ø
5.2.2	PULL STRENGTH	36		t r _____ c	Ø
5.3	HONEYCOMB				
5.3.1	PROCESS DEVEL. & PANEL FAB FOR ⁴ / ₃ LINER CONCEPTS		m _____ f		Ø
5.3.2	TEE-BAR PULL STRENGTH				
	3-D TUFTED - 1 PANEL	12			
	ROSETTE - 2 PANELS	24			
	SHINGLE - 2 PANELS	24			
	TAPE - 2 PANELS	24			tr c Ø

M-6 (FIBROUS GRAPHITE COMPOSITE)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		ATMOS. RAD/TEST	FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS					
				TEMP °R RAD/TEST	NVT RAD 10 POWER					CY 71							CY 72												
										M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1a	NOZZLE EXTENSION	AGCARB- 101 PLATES	FLEXURE	140/RT 1460,2460	0,17,18	LN ₂ /AIR, ARGON	GD/A	25	1	D	d			r		C													COMP 8/71
2a	NOZZLE EXTENSION	"	TENSILE	140/RT 1460,2460	0,17,18	LN ₂ /AIR, ARGON	GD/A	25	1	D	d			r		C													COMP 8/71
3a	NOZZLE EXTENSION	DEV PLATES	FLEXURE	1460/1460	0,17,18,19	He/He	GD/A	32	2	D											s m	f					(1)	C	B ₄
4a	NOZZLE EXTENSION	DEV PLATES	TENSILE	1460/1460	0,17,18,19	He/He	GD/A	32	2	D											s m	f					(1)	C	B ₄
5a	NOZZLE EXTENSION	DEV PLATES	K _i	1460/1460	0,17,18,19	He/He	GD/A	32	2	D											s m	f					(1)	C	B ₄
6a ⁽²⁾	NOZZLE EXTENSION	CELL WALL & LINER	FLEXURE	1460/1460	0,5(18)	He/He	GD/A	16	1	D											s m	f _x					(1)	C	Ø
7a ⁽²⁾	NOZZLE EXTENSION	INTRE- MOLD	FLEXURE	1460/1460	0,5(18)	He/He	GD/A	8	1	D											s m	f					(1)	C	Ø

(1) DRM WILL BE SCHEDULED WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED. RADIATION SCHEDULED FOR GTR-24

(2) SEE REVISION SUMMARY DATED 15 SEPTEMBER 1971 (ATTACHED)

M-7 (AA 6061-T6)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE		STATUS
				TEMP °R	ATMOS.				CY 71 M A M J J A S	CY 72 O N D J F M A M J J A S	
1	LINES	WS	FRACTURE TOUGHNESS, K_{IC}	40	LH ₂	GD	16 (M)	1	D <u>tr</u> C		COMP 8/71
2	LINES	WS	FLEXURAL FATIGUE	40	LH ₂	ANAMET	50 (D)	1	D <u>tr</u> C		COMP 8/71
3	LINES	S	FLEXURAL FATIGUE	540	AIR	BOEING W.	50 (D)	1	D <u>r</u> C		COMP 8/71
5	LINES	TW	SEMI-PERMANENT WELD JOINT DEVEL. (TENSILE)	540, 140	AIR, LN ₂	WANL & TBD ⁽¹⁾	6 (M) (2)	1	D <u>m f t r</u> C		H ⁽¹⁾
6	LINES	TW	SEMI-PERMANENT WELD JOINT DEVEL. (BEND)	540, 140	AIR, LN ₂	WANL & TBD ⁽¹⁾	6 (M) (2)	1	D <u>m f t r</u> C		H ⁽¹⁾

(1) SEE REVISION SUMMARY DATED 15 SEPTEMBER (ATTACHED)

(2) SIX TESTS AT 540°R TO BE PERFORMED. NUMBER AND SCHEDULE OF LN₂ TESTS TO BE DETERMINED BASED ON R.T. RESULTS AND AMOUNT OF TUBING REMAINING FROM PROCESS DEVELOPMENT PHASE.

M-7 (6061-T6)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)

15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE		STATUS
				TEMP °R RAD/TEST	NVT RAD 10 POWER	ATMOS. RAD/TEST				CY 71 M A M J J A S	CY 72 O N D J F M A M J J A S	
4a	VALVES	WF	FRACTURE TOUGHNESS K _{IC}	140/140	0,17,18,19	LN ₂ /LN ₂	GD/GD	16(D)	2	D	^P _m s f x (1) C	Ø

(1) DRM WILL BE SCHEDULED WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

M-9 (T1 6A1-4V)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS					
				TEMP °R	ATMOS.				CY 71							CY 72												
									M	A	M	J	J	A	S	O	N	D	J	F	M	A		M	J	J	A	S
2	THRUST STRUCTURE	SW	TENSILE	360, 540 960, 1160	AIR, GN ₂	WANL	16 (M)	1	D										p		m			f	t	r	c	Ø
8	THRUST STRUCTURE	SW	FRACTURE TOUGHNESS, K _C	360, 540	AIR, GN ₂	WANL	8 (M)	1	D										p		m			f	t	r	c	Ø

M-9 (T1 6A1-4V)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS					
				TEMP °R	NVT RAD	ATMOS.				CY 71							CY 72												
				RAD/TEST	10 POWER	RAD/TEST				M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1a	THRUST STRUCTURE BACKUP	S	TENSILE	140,540/ 140,540	0,17,18	LN ₂ ,H ₂ O/ LN ₂ ,AIR	GD/GD	28(M)	1	D	m	p					s	f	x							(1)	C	A ₈	
2a	THRUST STRUCTURE BACKUP	WS	TENSILE	140/140	0,17,18	LN ₂ /LN ₂	GD/GD	12(M)	1	D		m					s	f	x									C	A ₄
3a	THRUST STRUCTURE BACKUP	WS	FRACTURE TOUGHNESS K _C	140/140	0,17,18	LN ₂ /LN ₂	GD/GD	12(M)	1	D		m					s	f	x									C	Ø

(1) DRM WILL BE SCHEDULED ON ALL TESTS WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

M-11 (FRICTION AND WEAR)

MATERIALS DATA MATURITY STATUS

15 SEPT 71

DEROW/MURCHISON

LINE	COMPONENT	BASE MATERIAL	COAT	TEST CONDITIONS					FACILITY	NO. OF SPECIMENS	SCHEDULE														STATUS					
				TEMP °R	ATMOS	MOTION	LOAD	SPEED			CY 71							CY 72												
											M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1	VALVE (SEALS)	A286/ BRONZE	Cr/NONE	540	GHe	OSCILLATING	MED	MED	WANL	5 (M)	D	m p f t r							c	Ø										
6	LINE BELLOWS &/OR VALVES (SEALS) (WIRE BRAID)	TBD(1) 321 SS/ 321 SS	MoS ₂	540	10 ⁻¹⁰ VAC	PRESSURE CYCLES	TBD	TBD	WANL	2(M)	D	p m f t r							c	Ø										

(1)SEE REVISION SUMMARY DATED 15 MAY 1971 (ATTACHED)

M-14 (FEURALON POLYIMIDE)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS	
				TEMP °R	RADS	ATMOS.				CY 71							CY 72								
				RAD/TEST	10 POWER	RAD/TEST				M	A	M	J	J	A	S	O	N	D	J	F	M	A		M
1a	ACTUATOR BEARING CAGE	FEURALON	TENSILE	40/140, 540	0, 9	LH ₂ / LN ₂ AIR	GD/GD	(2) 32 (D)	2	D	m . f s x (1)														A Ø
2a	ACTUATOR BEARING CAGE	FEURALON	FLEXURE	40/140, 540	0, 9	LH ₂ /LN ₂ AIR	GD/GD	(2) 32 (D)	2	D	m f s x														A Ø

(1) DRM WILL BE SCHEDULED FOR ALL TESTS WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

(2) SEE REVISION SUMMARY DATED 15 SEPTEMBER (ATTACHED)

M-16 (MARAGING STEEL - 18 Ni)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DEROW/MURCHISON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS									
				TEMP °R	ATMOS.				CY 71							CY 72																
									M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S					
1	GIMBAL FLEXURE PIVOT	P	TENSILE	140, 540-760	LN ₂ , AIR	WANL	24 (D)	2	C	m									p							f		t	r	A	A ₂₀	
5	GIMBAL FLEXURE PIVOT	P	FRACTURE TOUGHNESS, K _{IC}	140, 540	LN ₂ , AIR	WANL	24 (D)	2	C	m									p								f		t	r	A	A ₂₀
6	GIMBAL FLEXURE PIVOT	COATED PLATE	STRESS CORROSION	555	5% SALT	A	90 (M)	1	D	m									P C(1)								f		t	r	C	A ₈
7	GIMBAL FLEXURE PIVOT	COATED PLATE	CORROSION FATIGUE	540	PRETREAT (5% SALT) FATIGUE (TBD)	WANL	48(M)	1	D	m									P C(1)								f		t	r	C	A ₈

(1) 3 COATINGS WHICH ARE TO BE SELECTED BASED ON LITERATURE AND INDUSTRY SURVEY. MILESTONE FOR COATING SELECTION IS INDICATED BY "C"

M-16 (MARAGING STEEL - 18 Ni)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)

15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE		STATUS
				TEMP °R RAD/TEST	NVT RAD 10 POWER	ATMOS. RAD/TEST				CY 71 M A M J J A S	CY 72 O N D J F M A M J J A S	
1a	GIMBAL ACTUATOR FLEXURE	F	TENSILE	140/140	0, 17	LN ₂ /LN ₂	GD/GD	6(M)	1	D <u>m</u>	<u>s f x</u> (1)	C Ø
2a	GIMBAL ACTUATOR FLEXURE	F	FRACTURE TOUGHNESS K _I (2)	140/140	0,17	LN ₂ /LN ₂	GD/GD	24(D)	2	D <u>m</u>	<u>s f x</u>	C Ø

(1) DRM WILL BE SCHEDULED FOR ALL TESTS WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

(2) SEE REVISION SUMMARY DATED 15 SEPTEMBER 1971 (ATTACHED)

M-19

(AISI 440C)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU/GIANNUZZI

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE																		STATUS	
				TEMP °R	ATMOS.				CY 71									CY 72										
									M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A		S
1	TPA BEARINGS	B	HARDNESS	540, 140	AIR, LN ₂	A	20 (D)	2	C	f t r																		A COMP 8/71
2	TPA BEARINGS	B	MODULUS OF ELASTICITY	540, 40	AIR, LH ₂	A	20 (D)	2	C	f t r																		A COMP 8/71
3	TPA BEARINGS	B	POISSON'S RATIO	540, 40	AIR, LH ₂	A	20 (D)	2	C	f t r																		A COMP 8/71
4	TPA BEARINGS	B	COMPRESSIVE YIELD	540, 40	AIR, LH ₂	A	20 (D)	2	C	f t r																		A COMP 8/71

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS						
				TEMP °R	ATMOS.				CY 71							CY 72													
									M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S		
1	PRESSURE VESSEL	F	FRACTURE TOUGHNESS, K_{IC}	140, 360, 540	LN ₂ , ALC	WANL	32 (D)	2	D			m	p	f					t	r							A	B ₈	
2	PRESSURE VESSEL	F	STRESS CORROSION	555 AMB	5% SALT- SPRAY SEA COAST	WANL, KSC	60 (M)	1	D			m	f												t	r	C	B ₈	
3	PRESSURE VESSEL	F	TENSILE	140, 360, 540, 660, 760	LN ₂ , ALC,	WANL	48 (D)	2	C			m	p						f	t	r						A	B ₈	
4	PRESSURE VESSEL	p ⁽³⁾	FLAME SPRAY COATING DEGRADATION	540	AIR	WANL ⁽¹⁾	30 (M)	1	D			m				p			f					t	r	C	A ₄		
5	PRESSURE VESSEL	F	LOW CYCLE FLAW GROWTH, K_i	140, 360	LN ₂ , ALC	WANL	24 (D)	2	D			m				p			f					t	r	A	B ₈		
7	PRESSURE VESSEL	S	THERMAL CONTROL COATING α_s/ϵ	540	10 ⁻¹⁰ VAC ULTRAVIOLET RAD	TBD	8 (M)	2	D			c ⁽²⁾				p			m				f		t	r	C	Ø	

(1) ANSC WILL PREPARE COATED SPECIMENS

(2) MILESTONE FOR COATING SELECTION

(3) SEE REVISION SUMMARY DATED 15 SEPTEMBER 1971 (ATTACHED)

M-21 (AA 7075-T73)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS
				TEMP °R RAD/TEST	NVT RAD 10 POWER	ATMOS. RAD/TEST				CY 71							CY 72							
										M	A	M	J	J	A	S	O	N	D	J	F	M	A	
1a	PRESSURE VESSEL	F	TENSILE	140/140	0,18,19	LN ₂ /LN ₂	GD/GD	9 (M)	1	D	m s f x (1) C Ø													
3a	PRESSURE VESSEL	F	FRACTURE TOUGHNESS K _{IC}	140/140	0,17,18,19	LN ₂ /LN ₂	GD/GD	36 (D)	2	D	m s f x A Ø													
4a	PRESSURE VESSEL	p ⁽⁴⁾	THERMAL COATING α/E	140/540	19	LN ₂ /VAC	GD/TBD	4 (M)	2	D	m s f x C Ø													
5a	PRESSURE VESSEL	p ⁽⁴⁾	FLAME SPRAY COATING ADHESION	140/140	0,19	LN ₂ /LN ₂	GD/GD	8 (M)	1	D	m s f x C Ø													
6a	PRESSURE VESSEL	p ⁽⁴⁾	FLAME SPRAY COATING ADHESION	540/540	0,19	H ₂ O/AIR	GD/GD	8 (M)	1	D	m s f x C Ø													
7a ⁽³⁾	PRESSURE VESSEL	F	K _{IC} (FLAME SPRAY COATED)	140/140	0,18,19	LN ₂ /LN ₂	GD/GD	9 (M)	1	D	m f (2) C Ø													

(1) DRM WILL BE SCHEDULED ON ALL TESTS WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

(2) CONTROLS ONLY. CURRENT PLAN CALLS FOR 9 ADDITIONAL SPECIMENS FROM SAME LOT TO BE IRRADIATED IN GTR-24.

(3) SEE REVISION SUMMARY DATED 15 JULY 1971 (ATTACHED).

(4) SEE REVISION SUMMARY DATED 15 SEPTEMBER 1971 (ATTACHED)

M-22

(GH₂ EMBRITTLEMENT)

MATERIALS DATA MATURITY STATUS

15 SEPT 71

LESSAU/GIANNUZZI

[illegible]

M-23 (STRESS AND RADIATION SYNERGISTIC EFFECTS)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)15 SEPT 1971
DIXON

LINE	COMPONENT	FORM (2)	PROPERTY	TEST CONDITIONS				FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS			
				TEMP °R RAD/TEST	NVT RAD 10 POWER	ATMOS. RAD/TEST	CY 71							CY 72														
							M				A	M	J	J	A	S	O	N	D	J	F	M	A	M		J	J	A
1a	718	F	GH ₂	660/540	20	H ₂ O/1500 PSI GH ₂	PBRF/GD	4	1	D	d	r				C												COMP 7/71
	Ti (α)	F	SYNERGISTIC			NO STRESS																						
2a	301	CW	NOTCH	660/540	20	H ₂ O/1500 PSI GHe	PBRF/GD	2	1	D	d	r				C												COMP 7/71
	A286	B(CW)	TENSILE PHASE 2			NO STRESS																						
						TOTAL NO. SPECIMENS 4 MATL X 6 =		24																				
3a	718	F	GH ₂	660/540	20	1000 PSI GH ₂ */	PBRF/GD**	6	1	D	m																	
	A286	B	SYNERGISTIC			1500 PSI GH ₂																						
	***302 9310	B(CW)				NO STRESS																						
4a	(CARBURIZED)		NOTCH		20	1000 PSI GH ₂ */	PBRF/GD	2	1	D	m																	
			TENSILE PHASE 2			1500 PSI GHe																						
						NO STRESS																						
						TOTAL NO. SPECIMENS 3 MATL X 8 =		24																				
5a	718	B	CRACK	660/660	19	1000 PSI GH ₂ */	PBRF/PBRF	4	1	D		m																
	A286	R	GROWTH			1000 PSI GH ₂																						
	3rd MAT'L TBD	B(CW)	RATE			MAX STRESS																						
6a	***9310			660/660	19	1000 PSI GHe*/	PBRF/PBRF	2	1	D		m																
						1000 PSI GH ₂ **																						
						MAX STRESS																						
						TOTAL NO. SPECIMENS 3 MATLS X 6 =		18																				
7a	718	B	CRACK	260/260	19	500 PSI GH ₂ */	TBD	4	1	D		m																
	Ti (α)	P	GROWTH			1500 PSI GH ₂																						
	A286	B	RATE			MAX STRESS																						
3a	***4th MAT'L TBD	B(CW)			19	500 PSI GHe/	TBD	2	1	D		m																
	9310					1500 PSI GHe																						
						MAX STRESS																						
						TOTAL NO. SPECIMENS 4 MATLS X 6 =		24																				
9a	***718	B	CRACK	260, 660	-	GN ₂ , AIR		4	1	D		m																B4
	Ti(α)	P	GROWTH	660	-	WATER		2	1	D		m																B4
	A286	B	RATE	260, 660	-	GH ₂		4	1	D		m																B4
	9310	B	CONTROLS							D		m																
						TOTAL NO. SPECIMENS 4 MATLS X 10 =		40																				

*GAGE SECTIONS OF SPECIMENS ARE ENCAPSULATED IN BELLOWS AND PRESSURIZED TO 1000 PSI (AT 200°F).

**IRRADIATED SPECIMENS SHIPPED TO GD IN CAPSULE, CAPSULE PUNCTURED IN HIGH PRESSURE CLEAN GASEOUS HYDROGEN AND TESTED FOR NTS.

THESE RESULTS ARE COMPARED WITH AN IRRADIATION ATMOSPHERE OF 660°R REACTOR WATER.

*** SEE REVISION SUMMARY DATED 15 MAY 1971 (ATTACHED)

(1) DRM WILL BE SCHEDULED FOR ALL TESTS WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

M-31 (AISI 9310)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
				TEMP °R	ATMOS.				CY 71							CY 72																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
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4	ACTUATOR GEAR & BALL SCREW	B (CARBURIZED)	TENSILE	40, 140, 360, 540 660, 760	LH ₂ , LN ₂	WANL	24 (D)	1	D																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											

M-31 (AISI 9310 LOW ALLOY STEEL)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)

15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS		
				TEMP °R	NVT RAD	ATMOS.				CY 71						CY 72										
				RAD/TEST	10 POWER	RAD/TEST				M	A	M	J	J	A	S	O	N	D	J	F	M	A		M	J
1a ⁽¹⁾	ACTUATOR GEARS	AISI *9310 BAR	TENSILE	140/140	0,18	LN ₂ /LN ₂	GD/GD	6 (M)	1	D	m						s f x								**	C A ₆
2a	ACTUATOR GEARS	AISI *9310 BAR.	FRACTURE TOUGHNESS K _i	140/140	0,17,18	LN ₂ /LN ₂	GD/GD	36 ⁽¹⁾ (D)	2	D	m						s f x								A	A ₆

* CARBURIZED

** DRM WILL BE SCHEDULED ON ALL TESTS WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

(1) SEE REVISION SUMMARY DATED 15 SEPTEMBER 1971 (ATTACHED)

M-38 (ARMCO 22-13-5)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU/SPALETТА

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE		STATUS
				TEMP °R	ATMOS.				CY 71 M A M J J A S	CY 72 O N D J F M A M J J A S	
1	NOZZLE JACKET	F	TENSILE	140, 360 540, 960 1460	LN ₂ , AIR, A	WANL	198 120 (D)	3	C	m f t r	A B24
2	NOZZLE JACKET	FW	TENSILE	140, 360, RT, 960, 1460	LN ₂ , AIR, A	WANL	72 (D)	3	D	m f t r	A B24
3	NOZZLE JACKET	P	THERMAL EXPANSION COEFFICIENT	140 TO 2260	A	NBS	1 (M)	1	D	m f t r C	B20
(1) 4	NOZZLE JACKET	FW	TRANSITION WELD JOINT TO 347	140, RT	LN ₂ , AIR	TBD	10	1	D	m f t r C	
5	NOZZLE JACKET	P	THERMAL CONDUCTIVITY	40, 540	VAC	NBS	1 (M)	1	D	t r C	COMP
6	NOZZLE JACKET	PW	DISSIMILAR WELD JOINT DEVELOPMENT (TO 347)	140, 540	LN ₂ , AIR	A	40 (M)	1	D	f t r C	B12
8	NOZZLE JACKET	P, F	FRACTURE TOUGHNESS, K _{IC}	40, 140	LH ₂ /LN ₂	WANL	20 (M)	1	D	r(2) + m f t r C	B24
9	NOZZLE JACKET	P ^B	STRESS CORROSION	I. 770 II. AMB	BOILING MgCl ₂ (42%) SEA COAST	A KSC	10 (M)	1	D	t r I. C t r II. C	Ø
10	NOZZLE JACKET	P	DYNAMIC MODULUS	140, 540 1060	LN ₂ AIR	WANL	1 (M)	1	D	f t r C	B20

(1) SEE REVISION SUMMARY DATED 15 MAY 1971 (ATTACHED)

(2) PLATE TESTS .

M-38 (ARMCO ALLOY 22-13-5)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		ATMOS. RAD/TEST	FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS					
				TEMP °R RAD/TEST	NVT RAD 10 POWER					CY 71							CY 72												
										M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1a	NOZZLE	F	TENSILE	140/140	0,17,18,19	LN ₂ /LN ₂	GD/GD	20 (M)	2	D	d	r				C													B ₁₆
3a	NOZZLE	PW* FW	TENSILE	140/140	0,18,19	LN ₂ /LN ₂	GD/GD	9 (M)	1	D		m					s	f	x								**	C	Ø
*5a	NOZZLE	PW	TENSILE DISSIMILAR WELD JOINT (TO 347)	140/140	0,18,19	LN₂/LN₂	GD/GD	9 (M)	1	D		m	f	x						d						r		C	
6a ⁽¹⁾	NOZZLE	P	FRACTURE TOUGHNESS, K _{IC}	140/140	0,18,19	LN ₂ /LN ₂	GD/GD	16 (M) ⁽²⁾	1	D							s	f	x									C	Ø
7a ⁽¹⁾	NOZZLE	P	TENSILE	140/140	0,18,19	LN ₂ /LN ₂	GD/GD	6 (M)	1	D							s	f	x									C	Ø

* SEE REVISION ON SUMMARY DATED 15 MAY 1971 (ATTACHED)

** DRM WILL BE SCHEDULED WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

(1) SEE REVISION SUMMARY DATED 15 SEPTEMBER 1971 (ATTACHED)

(2) SPECIMEN DISTRIBUTION INCLUDES 8 AT 10¹⁹, 4 OF WHICH ARE ANNEALED AND 4 UNANNEALED

M-39 (BeCu)

MATERIALS DATA MATURITY STATUS

15 SEPT 71
DESSAU

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS		FACILITY	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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1	BELLEVILLE SPRINGS, VALVES	SPRING	RELAXATION	140, 540, 860	LN ₂ , AIR	WANL	24 (M)	2	D																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												

* SHEET WILL BE PROCESSED SO AS TO REPRESENT FINAL SPRING MATERIAL CONDITION

M-39 (BeCu)

MATERIALS DATA MATURITY STATUS
(MATERIALS IRRADIATION)

15 SEPT 1971
DIXON

LINE	COMPONENT	FORM	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	NO. OF SPECIMENS	LOTS	SCHEDULE														STATUS					
				TEMP °R RAD/TEST	NVT RAD 10 POWER	ATMOS. RAD/TEST				CY 71							CY 72												
										M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1a	BELLEVILLE SPRINGS	S	SPRING CONST & RELAXATION	140/140,535 40740 (1)	0,18	LN ₂ /LN ₂ , AIR LH₂/LH₂	GD/GD	10 (M)	1	D				m	f					s		x				(2)	C	Ø	

(1) SEE REVISION SUMMARY DATED 15 JULY 1971 (ATTACHED)

(2) DRM WILL BE SCHEDULED WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

M-40 (LH₂, LN₂, GH₂ CORRELATION)

MATERIALS DATA MATURITY STATUS

15 SEPT 1971
DIXON

LINE	MATERIAL	PROPERTY	TEST CONDITIONS			FACILITY RAD/TEST	(1) NO. OF SPECIMENS		LOTS	SCHEDULE														STATUS
			RAD/ANN/TEST	NVT RAD 10 POWER	ATMOSPHERE RAD/ANN/TEST		CY 71							CY 72										
							M A M J J A S	O N D J F M A M J J A S																
1	HASTELLOY X (2)	TENSILE	40/40/40	0,17,18	LH ₂ /LH ₂ /LH ₂	GD/GD	8	12	1	m									s	f	x	(8)	A ₁₀	
	6061-T6 (3)		40/40/40	0,17,18	LH ₂ /LH ₂ /LH ₂		8	12	1	m									s	f	x		A ₁₀	
	Ti-5Al-2.5Sn ELI(4)		40/40/40	0,17,18	LH ₂ /GH ₂ /LH ₂		8	12	1	m									s	f	x		A ₁₀	
2	HASTELLOY X		(5) 40/140/40	18	LH ₂ /GH ₂ /LH ₂		-	4	1	m									s	f	x		A ₁₀	
	6061-T6		(5) 40/140/40	18	LH ₂ /GH ₂ /LH ₂		-	4	1	m									s	f	x		A ₁₀	
	Ti-5Al-2.5Sn ELI		(5) 40/140/40	18	LH ₂ /GH ₂ /LH ₂		-	4	1	m									s	f	x		A ₁₀	
3	HASTELLOY X		40/140/140	17,18	LH ₂ /LN ₂ /LN ₂		4	8	1	m									s	f	x		A ₁₀	
	6061-T6		40/140/140	17,18	LH ₂ /LN ₂ /LN ₂		4	8	1	m									s	f	x		A ₁₀	
	Ti-5Al-2.5Sn ELI		40/140/140	17,18	LH ₂ /LN ₂ /LN ₂		4	8	1	m									s	f	x		A ₁₀	
4	HASTELLOY X		140/140/140	0,18,19	LN ₂ /LN ₂ /LN ₂		12	12	1	m									s	f	x		A ₁₀	
	6061-T6		140/140/140	0,18,19	LN ₂ /LN ₂ /LN ₂		12	12	1	m									s	f	x		A ₁₀	
	Ti-5Al-2.5Sn ELI		140/140/140	0,18,19	LN ₂ /LN ₂ /LN ₂		12	12	1	m									s	f	x		A ₁₀	

LINE	MATERIAL	PROPERTY	TEST CONDITIONS		ATMOSPHERE RAD/ANN/TEST	FACILITY RAD/TEST	(1) NO. OF SPECIMENS		LOTS	SCHEDULE		STATUS
			RAD/ANN/TEST	NVT RAD 10 POWER			N	UN		CY 71 M A M J J A S	CY 72 O N D J F M A M J J A S	
5	HASTELLOY X	TENSILE	140/40/40	18,19	LN ₂ /LH ₂ /LH ₂	GD/GD	8	8	1	m	s f x	A ₁₀
	6061-T6		140/40/40	18,19	LN ₂ /LH ₂ /LH ₂		8	8	1	m	s f x	A ₁₀
	Ti-5Al-2.5Sn ELI		140/40/40	18,19	LN ₂ /LH ₂ /LH ₂		8	8	1	m	s f x	A ₁₀
(6) 6	HASTELLOY X		300/140/140	18	1000 PSI GHe*/LN ₂			10				
	6061-T6		300/140/140	18	1000 PSI GHe*/LN ₂			10				
	Ti-5Al-2.5Sn ELI		300/140/140	18	1000 PSI GHe*/LN ₂			10				
7	HASTELLOY X		140/140/140	18	1000 PSI GH ₂ (7)/LN ₂		3	7	1	m	s f x	Ø
	6061-T6		140/140/140	18	1000 PSI GH ₂ (7)/LN ₂		3	7	1	m	s f x	Ø
	Ti-5Al-2.5Sn ELI		140/140/140	18	1000 PSI GH ₂ (7)/LN ₂		3	7	1	m	s f x	Ø

(1) N = NOTCHED: UN = UNNOTCHED

(2) LOW A1 AS BRAZED BAR

(3) WANL BARREL

(4) GTR 20-C FORGING

(5) ANNEAL 1 HOUR

(6) SEE REVISION SUMMARY DATED 15 MAY 1971

(7) SPECIMENS ARE ENCAPSULATED IN GH₂

(8) DRM'S WILL BE SCHEDULED ON ALL TESTS WHEN FIRM DATA AVAILABILITY DATE IS ESTABLISHED.

PROJECT 187 - MATERIALS DEVELOPMENT STATUS REPORT

15 SEPTEMBER 1971

Test Plan M-2: AISI 347

Line 1

The creep test results developed by General Electric to date were reviewed. The initial tests conducted on the same heats of material by Battelle Memorial Institute were included for comparative purposes. Preliminary analysis of this data indicate the following trends:

a. 1200°F Test Temperature Data (Figures 1 and 2)

1. Very little creep occurs at 1200°F as indicated by the lack of slope for the 1% offset or the 3% offset versus time plots.
2. The 1% offset-100 hour life at the 1200°F test temperature appears to be > 16 ksi.

b. 1400°F Test Temperature Data (Figures 3 and 4)

1. The plot at 1% offset confirms the correlation between grain size and creep resistance, i.e., fine grained material has less creep resistance than large grained material.
2. The 1% offset-100 hour life at 1400°F appears to be > 2.2 ksi.

Preliminary creep tests were conducted by Battelle Memorial Institute for the same heats of material supplied by General Electric. BMI's results compare favorably with the trends indicated by the General Electric test results. An inadequate amount of testing has been accomplished in the 100 hour range to predict a minimum 100 hour life at 1600°F. Testing was discontinued at 1600°F on the recommendation of the Reliability Group because the test results received appeared inconsistent. The data reflect a comparatively wider variance than the results attained at 1200°F and 1400°F. The Reliability Department will analyze the 1600°F data further.

The current test matrix includes 165 tests out of a planned total of 216, which will be completed shortly. After statistical analysis is accomplished by the Reliability Section the test temperatures and stress levels will be defined for the 51 currently unassigned specimens.

Figure 2

Figure 3

Figure 4

Line 2

Thermal conductivity test data were analyzed. The effect on design properties in the currently existing DRM 02-10 was insignificant and no change is deemed required.

Line 3

The 1400°F and 1000°F low cycle fatigue tests on AISI 347 and Hastelloy X have been completed at Battelle Memorial Institute. Test results are being analyzed by the Reliability Section.

Lines 5 and 5.1

The purchase order for the line welding and cutting tool and semiautomatic welding procedure that was awarded to Creative Pathways Inc. has been terminated due to non-performance of the subcontractor. A request for quotation has been sent to four subcontractors to select a replacement for Creative Pathways.

Line 9

No activity this report period.

Line 10

Low cycle fatigue tests have been completed and a report, "An Evaluation of the Low-Cycle Fatigue Resistance of 347 Stainless Steel at 1000°F", dated July 1971 was received from Mar-Test Laboratories. Test results are being analysed preparatory to publishing a DRM.

The specimens were cycled in compression-tension rather than the specified compression-compression cycle. The NASS duct specimen drawing title (Dwg. 1139330, Specimen-Tension, Compression, Fatigue) was confused with the actual test requirements by the test laboratory. Mar-Test has offered to machine and test additional AISI 347 specimens using compressive-compressive cycles to correlate the test data submitted with the actual test requirements. Material is presently being shipped to accomplish 1000°F compressive-compressive tests at a total strain of 0.010% and at 0.015%.

In addition to the comparative tests being accomplished by Mar-Test, AISI 347 tests at 1000°F will be accomplished at Battelle using compressive-tensile cycles. These data will be used to correlate the differences between the compressive-compressive currently being accomplished by Battelle and the tensile-compressive cycle developed by Mar-Test.

Radiation Testing

The test data on tensile properties of forgings have been received. Based on these properties it appears 347 stainless steel retains ductility at cryogenic temperatures after a neutron fluence of 10^{19} nvt > 1.0 Mev. Preparation of a DRM is scheduled. Material for the low cycle fatigue tests is available. Specimen fabrication is awaiting selection of an irradiation facility since that selection impacts upon the design of the specimen.

Test Plan M-4: Ti 5Al-2.5Sn ELI

Line 1

A final report, GDCA-DBG-71-003 dated July 1971 was received from General Dynamics on the flexural fatigue tests and a DRM is in process. Responses were received from the AQR for the second set of 60 tests. These are being analyzed preparatory to placing the order.

Line 2

A purchase order to Boeing Company incorporating sharp-notch specimen testing as an addition to the original work scope of cyclic fracture toughness testing is being processed.

Die forging was initiated at one forging source. This source is using billets which were prepared without a final reduction below the Beta transus temperature. Consequently the billet microstructure contains an elongated alpha microstructure rather than the elongated fine grain structure desired. Disc specimens were forged down from 2 in. to 5/8 and 3/4 in. thickness and properties determined. The grain structure was satisfactory and the mechanical properties exceeded the minimum specified in the ANSC specification, ANS 90297. Consequently the billets were released to the forger, Arcturus Mfg. Co., with the proviso that they perform preliminary cross rolling to refine the grain structure prior to making the actual forging. Arcturus has been working on this basis with close follow-up by ANSC materials to insure the acceptability of the final die forged product.

Currently it is not planned to use the die forgings for material tests in view of the deviation in processing specifications.

Line 5

Fabrication was initiated of two specimens from pancake forgings for physical property tests. Specimens from die forgings await die forged material (See Line 2 above).

Line 16

Die forging was initiated at one forging source.

Currently it is not planned to use the die forgings for material tests in view of the deviation in processing specifications.

Line 17

A purchase order was placed with Electro-Physics, Folsom, Calif. for the development of a test method for determining high cycle fatigue properties of titanium turbine blades. The effort is directed at establishing an in-house capability. Thus the vendor will utilize the support of ANSC manpower and facilities for test procedure and set-up development.

Test Plan M-5: A-286

Line 1

Fabricated valve spring material was rejected because it failed to meet strength requirements. The supplier inadvertently used an excessive temperature for post coldwork aging. Fabrication of replacement material has been initiated.

Line 2

Fabrication of test specimens has been initiated.

Lines 7 and 11

No activity this report period.

Line 12

The status of this task of determining the high frequency fatigue properties of blades is identical to that indicated under Test Plan M-4, Line 17. Both materials will be tested as part of the same task.

Radiation Testing

Irradiated fracture toughness test results were forwarded by General Dynamics. The data require additional analysis because the ASTM standards were not met. A DRM will be written when this analysis is complete.

Irradiated cold worked bolts were tensile tested. While the average elongation decreased from 16 to 10% after a neutron fluence of 6.5×10^{18} nvt the reduction of area remained unchanged at 35% implying material ductility. A DRM will be published after statistical analysis of the data.

Material was shipped to WANL on 21 July for fabrication of tensile specimens for irradiation and testing at 40°R.

Test Plan M-6: Fibrous Graphite

A. Prepreg Development

Line 1.1

The formulation of the second batch of two special prepregs has been completed by U.S. Polymeric Corporation, Santa Ana, California. This prepreg will now be used to complete the fabrication of the six panels needed for the remaining property tests in Line 1.2. One lot of prepreg consists of 50:50 resin mixture of USP-39 resin/filler and EC-260 resin. The other lot contains only EC-260 resin with the filler used for USP-39 as an additive.

Line 1.2

The first series of property tests on the first batch of the two prepreg resins have been completed by the Advanced Composites Department, Ferro Corporation, Huntington Beach, California. This property data is in the process of being transmitted to ANSC for data analysis.

B. Binder Development

Line 2.1

The remaining six of the 24 candidate binder compositions were impregnated into the six fibrous graphite plates being used for property test measurements. The completion of these impregnation runs finishes the scope of work scheduled for this line item.

Line 2.2

The mechanical property testing of the 24 plates impregnated with the 24 candidate binder compositions has been completed by the Advanced Composites Department, Ferro Corporation. A statistical correlation analysis is being planned for this data to aid in the selection of the two best compositions for further property tests scheduled for Line 2.3.

Line 2.3

No activity as work is pending results of Line 2.2.

C. Layup Development

Line 3.1.1

A second rosette flange layup has been completed using a pattern designed to minimize wrinkles as well as increase the interlaminar shear strength through the use of Intremold III pins through fabric layers.

Line 3.1.2

No activity scheduled for this work.

Lines 3.2.1 and 3.2.3

No activity, plates awaiting to be impregnated with the best binder system to be selected from the results of Line 2.3.

D. Intremold III Evaluation

Line 4.1

The first set of three Intremold cylinders have been processed through the first carbonization cycle and are presently awaiting to be graphitized at Poly Carbon, North Hollywood, California. Two graphitization runs on these cylinders had to be aborted midway through the runs due to furnace difficulties.

Lines 4.1.1 thru 4.1.4

Sectioning diagrams have been prepared for each of the six Intremold cylinders showing the locations where test specimens are to be removed. Testing fixtures have been designed for tensile and compressive tests to be determined on rings removed from the cylinders.

E. Stiffener Development

Line 5.1.1

Three curved panels consisting of two shingle lap layups and one rosette layup have been fabricated from FM 5228 prepreg. These panels duplicate the thickness and curvature of the liner of the nozzle extension near the forward flange. These plates which are in the debulk stage will be used to evaluate two maceration techniques. Maceration being one technique that has been selected for raising fibers which promote bonding of the honeycomb to the liner.

Line 5.2

A total of eight, 12 in. long tee bars have been fabricated to the graphitized state and are presently undergoing bond strength tensile tests. All of these tee bars were fabricated using the selected 45° tapered root design that was selected for the honeycomb on the nozzle extension. The variables associated with each tee bar are related to evaluating the effect on bond strength between the cell wall and the liner fabric.

Line 5.3

Final prints have been released by the Project to the vendor, Peat Mfg. Company, Los Angeles, California, for the fabrication of the zinc honeycomb dies to be used for the development of the honeycomb onto the liner. FM 5228 prepreg has been received from U.S. Polymeric Company for the laminate liner layup required for the four liner concepts to be fabricated in this work.

Radiation Testing

Plates of fibrous graphite are being processed from the 3-D tufted liner fabric and cell wall fabric for flexure tests in GTR-23 in January 1972. Intremold III composite specimens are also scheduled for irradiated flexure testing in GTR-24.

Irradiated flexure and tensile tests data on AGCarb 101 were analyzed and DRM 06.04 was published.

Test Plan M-7: Aluminum Alloy 6061

Line 1

A final report, GDCA-DBG-71-002, on static fracture toughness tests was received from General Dynamics/Convair. The data are being analyzed preparatory to writing a DRM.

Lines 5 and 6

Creative Pathways has shown that it is incapable of developing an automatic orbital welding device within an acceptable time period. Development of this device will be initiated at an alternate source to be selected by resolicitation of bids.

Radiation Testing

The first set of weldments were rejected by X-ray due to excessive weld porosity. These required rewelding, which is currently in process.

Test Plan M-9: Ti 6Al-4V

Line 2 and 8

No activity during this report period.

Radiation Testing

Sheet material was shipped to WANL on 29 June for fabrication of tensile specimens.

Welded sheet material for weld tensile testing has been fabricated and shipped to WANL during week ending 10 September.

Welded sheet material for fracture toughness testing has been fabricated. Precracking of the specimens has been initiated.

Test Plan M-11: Friction and Wear

Line 1

No activity this report period.

Line 6

A discussion was held with representatives of the Valves Department concerning requirements for high vacuum test requirements. The information resulting from this meeting will be used to define a specific test program meeting project's requirements.

Test Plan M-14: Feuralon Polyimide

Radiation Testing

All specimens have been fabricated.

Test Plan M-16: Maraging Steel - 18 Ni

Line 1

Tensile specimens from one lot of material have been fabricated. Specimens representing the second lot of material are in fabrication.

Line 5

Fracture toughness specimens from one lot of material have been fabricated. Specimens representing the second lot of material are in fabrication.

Line 6

Stress corrosion specimens are in fabrication.

Line 7

Material for corrosion fatigue specimens has been procured. Machining of specimens is scheduled to begin shortly.

Radiation Testing

Specimens for irradiated tensile and fracture toughness specimens are in fabrication.

Test Plan M-19: AISI 440C

Lines 1, 2, 3 and 4

Tests have been completed and data statistically analyzed. DRM 19.01-R1 has been published and integrated into the DRM Manual.

Project Support

A procurement specification, ANS-90305, has been issued to require a high quality material for use in bearing manufacture. This specification has been submitted to prospective raw material vendors and bearing manufacturers to determine the impact on the current bearing procurement activity.

The turbomachinery project group conducted 10 hour bearing tests in liquid hydrogen on 60 and 65 millimeter bearings made of 440C stainless steel. Post test examination of the 60 millimeter bearing indicated slight wear. All 65 mm bearings exhibited normal friction values initially, increasing after a few hours to very high values for the remainder of the test. Substantial wear was noted after the test. Microscopic examination at magnifications of 100X and 500X was conducted. Macro and micro hardness measurements were made. In addition, scanning electron microscope studies were conducted at magnifications of 170, 600 and 1800X. Electron beam microprobe measurements were made as well to identify the size and composition of the carbides present in the 440C raceway material.

All examinations have been completed. A comparative study of the data is in process to establish whether differences in the 440C material used for these bearings could have contributed to the markedly different performance.

Test Plan M-21: AA 7075-T73

Lines 1, 2, 3 and 5

The forging material for specimen preparation has been delivered. Fabrication has been initiated for tensile, stress corrosion, fracture toughness and cyclic fracture toughness specimens.

Line 4

Specimens are in fabrication for subsequent flame plating with pure aluminum. Plate material was substituted for forging because forging delivery was being delayed and it was concluded that plate would be as suitable for the flame plating substrate.

Line 7

Specimen material has been procured thermal control coating evaluation.

Radiation Testing

The forging material for irradiated mechanical property testing is being delivered to the appropriate fabricators.

Material for coating (thermal control and flame spray) evaluation is currently being cut into appropriate plate specimens.

Test Plan M-22: GH₂ Embrittlement

Line 3

No activity this report period.

Line 6

Tests to determine the notch tensile ultimate strength of AISI 9310 have been completed. Approximately 75% decrease in strength was measured due to the GH₂ environment. The data are being analyzed preparatory to writing a report and publishing a DRM.

Lines 7, 13 and 16

No activity this report period.

Figure 5

Lines 14, 15, 15.1, 15.2 and 17

Compact tension specimens of A-286, ARMCO 22-13-5, AISI 347, Hastelloy X and phosphor bronze have been machined. Specimens are being returned to ANSC for precracking.

Test Plan M-23: Synergistic Effects

Two compact tension specimens of A-286 were tested at 200°F; the average $K_Q = 93 \text{ ksi-in.}^{1/2}$. As the yield strength is on the order of 90 ksi, the ASTM criteria specimen ($B \geq 2.5 (K_{IC}/FTY)^2$) require a specimen thickness of 2.5 in. This K_Q value will be used to determine a starting K_{IC} value for designing the modified WOL specimens (Rolfe-Novak). Compact tension specimens of Inconel 718 and SAE 9310 and two modified WOL specimens for each material are completed.

Two alternate encapsulation devices are being evaluated. A reference design for a specimen with the proposed encapsulation device has been selected, Figure 5.

Preliminary tests on stress wave emission sensors were conducted which established three warranted further tests.

An experimental method has been devised to check the actual load at the crack tip due to the capsule configuration and the contained gas pressure. An encapsulated specimen is pressurized with argon and then loaded to failure. Knowing the K_{IC} value of the material, it appears possible to calculate the failure load and then subtract the load supplied by the bolt to determine the apparent load supplied by the gas.

A test series is scheduled to be conducted without gaseous hydrogen at Plumbrook to verify instrumentation concepts and the specimen design in a reactor environment.

Two tentative SWAT system designs, one incorporating voltage amplification and the other charge amplification, are being considered for testing in the reactor. Approaches for detection of slow crack growth as alternatives to the use of the SWAT technique have been given some consideration.

Strain gages can be placed in a position so as to monitor the occurrence of slow crack growth. However, under normal conditions, the strain gage technique would be much less sensitive than acoustic emission. Novak at U.S. Steel had previously been contacted with regard to the use of an instrumented bolt to monitor slow crack growth. U.S. Steel was again contacted and the instrumented bolt was partially successful. Some instrumentation problems had occurred. Additional information is being forwarded by U.S. Steel.

Test Plan M-31: AISI 9310

Line 4

Specimen machining was completed; specimens in the process of being carburized.

Test Plan M-38: ARMCO 22-13-5 Alloy

Lines 1 and 2

ARMCO has not been able to produce large forging billets that pass level A ultrasonic standard by either the vacuum arc remelt process or the air melt process. ARMCO has awarded Latrobe Steel, Penn., a contract to melt and convert the required billets, using the electroslag remelt process.

Line 5

DRM 38-02 has been published documenting the results of thermal conductivity tests.

Line 6

Testing of the 347/22-13-5 welded specimens has been accomplished at the room temperature test temperature. Testing at -320°F is in process.

Line 8

Fracture toughness testing will be completed when forged material is available.

Line 10

Material was sent to WANL on 15 July for evaluation of dynamic modulus properties.

Test Plan M-39: Beryllium Copper

Line 1

Belleville springs have been procured.

Line 2

Sheet material has been procured.

Test Plan M-40: Gas-Radiation Correlation

All specimens have been fabricated. The required number of specimens and capsule design drawings were shipped to WANL on 26 August. WANL will prepare and seal the capsules with appropriate internal gas pressure.

Enclosure (5)
27 September 1971
TAR:mc:N8130R:71-0160

MATERIALS REVIEW 21-22 SEPTEMBER 1971 FOR SNSO

VIEWGRAPHS

OBJECTIVES
MATERIALS STATUS REVIEW

- TO REVIEW OVERALL STATUS OF MATERIALS PROGRAM FOR W. S. SCHEIB
- TO REVIEW SPECIAL TOPICS FOR SNSO
 - FABRICATION RESULTS ON TITANIUM AND ARMCO
 - OTHER M-PLANS
 - METHODS OF HANDLING DATA

AEROJET NUCLEAR SYSTEMS COMPANY

MATERIALS REVIEW

<u>SUBJECT</u>	<u>SPEAKER</u>
STATUS REVIEW OF CURRENT M-PLANS	T. REDFIELD/H. DEROW
SPECIAL SUBJECTS	
PROCESSING HISTORY OF Ti 5Al-2.5Sn	P. DESSAU
PROCESSING HISTORY OF ARMCO 22-13-5	H. SPALETTA
M-40 (LH ₂ , LN ₂ , GH ₂ CORRELATION)	C. DIXON
M-23 (STRESS AND RADIATION SYNERGISTIC EFFECTS)	C. DIXON
DISCUSSION OF CURRENT DRM'S	H. DEROW
MATURITY OF MATERIALS DATA	
ORGANIZATION AND MAINTENANCE OF DRM MANUALS	
UTILIZATION OF DRM DATA	
SNSO COMMENTS	
ACTION ITEMS

AEROJET NUCLEAR SYSTEMS COMPANY

SCOPE

- DIRECTIVES
- SPECIFICATIONS - MAIN FEATURES
- PROCUREMENT - DOCUMENTATION
- PRODUCTION - SURVEILLANCE AND TESTS
- CURRENT STATUS AND PLANS
- SPECIFICATION CHANGES

DIRECTIVES

1. ANSC WAS DIRECTED TO USE Ti IN ROTOR ASSEMBLY,
PER TD 70-37 DATED SEPTEMBER 1, 1970.

2. ANSC WAS DIRECTED TO PREPARE SPECIFICATIONS TO
CONTROL QUALITY OF Ti FORGINGS FROM SPONGE TO
FINAL PART, PER TD 71-3 DATED OCTOBER 23, 1970.

PROCURE DIE FORGINGS FOR TEST PURPOSES.

PERFORM TESTS REPRESENTATIVE OF TWO HEATS AND
TWO FORGERS.

SPECIFICATIONS - SPONGE ANS90296A

1. INPUT SOURCES

- A. RMI SPECIFICATION Ti-001
- B. ASTM SPECIFICATION B299-69
- C. PWA 1201 (USED FOR COMPARISON WHEN AVAILABLE)

2. BASIC REQUIREMENTS

- A. PRODUCED BY REDUCTION METHODS
- B. DENSITY RANGE
- C. CONTAMINANT FREE
- D. CHEMISTRY
- E. HARDNESS
- F. SAMPLING

3. EXTERNAL COORDINATION

- A. SNSO-C MATERIALS AND QC
- B. PRODUCERS - TMCA AND RMI

BILLET ANS90295A

1. INPUT SOURCES

- A. PWA ACCEPT. STD. F12
- B. PWA ACCEPT. STD. E52
- C. TMCA PREMIUM GRADE BULLETIN
(FOR Ti6Al-4V AND 8Al-1Mo-1V, DTD 10/66)

2. BASIC REQUIREMENTS

- A. REQUIRES USE OF ANS90296 SPONGE
- B. PURE INPUT MATERIALS (NO SCRAP)
- C. CHEMISTRY EQUIVALENT TO WHAT WAS REQUIRED
EARLIER IN FORGINGS
- D. PRIMARY AND SECONDARY MELTING CONTROLS
(VAC AND POWER)
- E. INERT ATMOSPHERE WELDING
- F. MACRO-GRAIN SIZE LIMIT
- G. LATHE TURNED AND DYE PEN. INSPECTED
- H. 3/64 IN. DIA. ULTRASONIC ACCEPTANCE

3. EXTERNAL COORDINATION

- A. SNSO-C MATERIALS AND QC
- B. PRODUCERS - TMCA, RMI AND TITECH
- C. FORGERS - ARCTURUS, CARLTON AND
WYMAN-GORDON

AEROJET NUCLEAR SYSTEMS COMPANY

FORGINGS ANS90297B

1. INPUT SOURCES

- A. AGC 90163B
- B. NAA RB0170-079 (CRYO. ALLOY)
- C. NAA MB0170-010 (PV GRADE)
- D. PWA F12

2. BASIC REQUIREMENTS

- A. REQUIRES USE OF ANS90295 BILLETS
- B. PROVIDES THREE FORGING TYPES
- C. VAC ANNEALED
- D. LOW HYDROGEN CONTENT
- E. 1/64 IN. (CLASS AAA) ULTRASONIC ACCEPTANCE
- F. RADIOGRAPHIC INSPECTED
- G. TIGHT MICROSTRUCTURE CONTROL; VERY FINE ALPHA GRAIN SIZE
- H. HIGH TENSILE PROPERTIES

3. EXTERNAL COORDINATION

- A. SNSO-C MATERIALS AND QC
- B. FORGERS - ARCTURUS, CARLTON AND BERGMAN

AEROJET NUCLEAR SYSTEMS COMPANY

TITANIUM PROCUREMENT AND ALLOCATION

PROCUREMENT - TMCA

1. P.O. N-01331, FOR 5000 LBS OF 8 IN. BILLET PER ANS90295A.

A. SIR 13270 (SUPPLIER EXCEPTIONS)

1. SPONGE DENSITY TO BE 66-76 LBS/FT³
(WAS 35-40 LBS/FT³)
2. SPONGE SAMPLING AND ANALYSIS PER TMCA STANDARD
METHODS, WITH ANSC APPROVAL
(WAS PER SPEC. ANS90296)
3. IN INGOT PRODUCTION, HOLD MELTING VAC LEVEL AT
6000 MICRONS
(WAS: 1000 MICRONS PER ANS90295)
4. CONTROLLED AMOUNT OF OXIDE ALLOWED, PROVIDING
WELDS ARE WIRE-BRUSHED
(WAS: CONTAMINATION MUST BE PRECLUDED BY
WELDING METHOD)

B. SIR 13273 (FORGING SUPPLIER INPUT)

1. MICROSTRUCTURE OF BILLETS SHALL SHOW NO EVIDENCE
OF HEATING OVER BETA TRANSUS
(NOT COVERED BY SPEC. ANS90295)

AEROJET NUCLEAR SYSTEMS COMPANY

PRODUCTION RESULTS - TMCA

BILLET TEST RESULTS - TMCA

<u>TESTS PERFORMED</u>		<u>TEST RESULTS</u>			
1.	DYE PENETRANT:	CRACKS FOUND AND GROUND OUT			
2.	ULTRASONIC:	HI NOISE LEVEL; MEETS AA			
3.	MACROSTRUCTURE:	MEETS ANS 90295			
4.	MICROSTRUCTURE:	FINE EQUIAXED AND TRANSFORMED ALPHA PLATELETS			
5.	TENSILE	<u>UTS (KSI)</u>	<u>TYS (KSI)</u>	<u>%EL</u>	<u>%RA</u>
A.	FORGE-DOWN SAMPLE:	122	113	14	30
B.	BILLET ENDS				
	(1) EQUIAXED:	117	107	12	26
	(2) TRANSFORMED:	111	99	10	24

9

BILLET DISPOSITION - TMCA

ANSC SDAR 40062 (8/3/71):

- A. MICROS ARE TRANSFORMED ALPHA
- B. EXCESSIVE LOSS OF BACK REFLECTION

DISPOSITION:

ACCEPT A. ON FOLLOWING BASIS:

- 1. FORGEABILITY IS OK
- 2. PROPERTIES ARE OK
- 3. FORGERS WILL CROSS-FORGE PRIOR TO DIE-FORGE

ACCEPT B. ON FOLLOWING BASIS:

- 1. AA FLAW SIZE CRITERION MET
- 2. BACK REFLECTION LOSS LIMIT UNREALISTIC
(WAS ORIGINALLY BASED ON Ti 6Al-4V)

ACTION:

- A. SHIP 4 BILLETS TO ARCTURUS
- B. SHIP 1 BILLET TO CARLTON

AEROJET NUCLEAR SYSTEMS COMPANY

PROCUREMENT - RMI

P.O. N-01365, FOR 5000 LBS OF 8 IN. BILLET PER ANS90295A

A. SIR 13276 (SUPPLIER EXCEPTIONS)

1. SPONGE TO BE X-RAY SAMPLED (RATHER THAN 100% VISUAL AND FLUOROSCOPIC INSPECTED)
2. ALLOW UP TO 30 SEC. MELTING POWER INTERRUPTIONS (WAS: MOMENTARY INTERRUPTIONS PER ANS90295)
3. MACRO-GRAIN SIZE AND VARIATION ON BEST EFFORT (WAS: 0.25 IN. MAX. GRAIN SIZE AND VARIATION LIMITED TO 0.125 IN.)
4. USE BEST AVAILABLE SHEAR WAVE TECHNIQUES (WAS: PER ANS90295 AND MIL-I-8950)

B. SIR 13276 (FORGING SUPPLIER INPUT)

1. MICROSTRUCTURE OF BILLETS SHALL SHOW NO EVIDENCE OF HEATING OVER BETA TRANSUS. (NOT COVERED BY SPEC. ANS90295)

PRODUCTION RESULTS - RMI

BILLET TEST RESULTS - RMI

<u>TESTS PERFORMED</u>		<u>TEST RESULTS</u>			
1.	DYE PENETRANT:	CRACKS FOUND AND GROUND OUT			
2.	ULTRASONIC:	MEETS ANS 90295			
3.	MACROSTRUCTURE:	MEETS ANS 90295			
4.	MICROSTRUCTURE:	PREDOMINANTLY TRANSFORMED ALPHA PLATELETS			
5.	TENSILE	<u>UTS</u> (KSI)	<u>TYS</u> (KSI)	<u>%EL</u>	<u>%RA</u>
	A. FORGE-DOWN SAMPLE:	120	111	18	43

BILLET DISPOSITION - RMI

1. ANSC SDAR 40056 (7/28/71):

- A. RED DYE PEN. USED
- B. BILLET ENDS NOT DYE PEN. INSPECTED

DISPOSITION:

ACCEPT A. AND B. ON FOLLOWING BASIS:

- (1) "SPOT-CHECK" DYE SENSITIVITY ADEQUATE FOR PURPOSE
BUT ACID PICKLE AND RINSE BILLETS
- (2) BILLET END MACROETCH SATISFACTORY ALTERNATE TO
DYE PEN. INSPECTION

2. ANSC SDAR 40057 (7/28/71):

- A. TI BILLET MICROS ARE TRANSFORMED ALPHA

DISPOSITION:

ACCEPT A. ON FOLLOWING BASIS:

- (1) FORGEABILITY AND PROPERTIES ARE OK
- (2) FORGERS WILL CROSS-FORGE PRIOR TO DIE-FORGE

ACTION:

- A. SHIP T BILLET TO ARCTURUS
- B. SHIP TI BILLET TO CARLTON

AEROJET NUCLEAR SYSTEMS COMPANY

FORGING PRODUCTION - ARCTURUS

APPROACH:

- MICROSTRUCTURE VERIFICATION
- UPSET AND DRAW (CROSS-FORGE), THEN DIE-FORGE
- HEAT TO 1775°F - USE 25,000 LB HAMMER
- USE BEST BILLET FOR INDUCER AND LARGE FORGING (2915)
- USE OTHER BILLETS FOR PARTS RECEIVING MOST WORK (2916, 2917, 2918)
- AGREEMENT TO MAKE TRIAL FORGINGS SINGLE AND VERIFY MICROSTRUCTURE
- AGREEMENT TO PROCEED WITH PRODUCTION PARTS AFTER MICROSTRUCTURE VERIFICATION; OTHER ACCEPTANCE TESTS TO FOLLOW

TMCA
K-8930
BAR T

ORIGINAL CUT-CHART
PROPOSED BY ARCTURUS
(8/16/71)

TMCA
K-8930
BAR-T1

TMCA
K-8930
BAR T2

TMCA
K-8930
BAR B

TMCA
K-8930
BAR T4

RMI
804722
BAR T

10

FORGING PRODUCTION - ARCTURUS

CHANGES:

- NEEDED TO VENT ALL DIES
- NEEDED 50,000 LB HAMMER TO MAKE 2915
- NEEDED 1800°F HEAT TO MAKE 2915

AEROJET NUCLEAR SYSTEMS COMPANY

TMCA
K-8930
BAR T

17

IST REVISION OF ARCTURUS CUT CHART
(NECESSITATED TO ACCOMMODATE
SECOND 2915 TRY-OUT)

TMCA
K-8930
BAR T1

TO (OK)
(R) INTERCHANGE TO PROVE OUT
WHEN MICRO IS IMPROVED

TMCA
K-8930
BAR T2

THESE OK BECAUSE BAR B OK TO BEGIN WITH/SO INTERCHANGE PER ABOVE

TMCA
K-8930
BAR B

TO₂ (MONDAY) TO

TMCA
K-8930
BAR T4

RMI
804722
BAR T

FORGING PRODUCTION - ARCTURUS

RESULTS:

2ND STAGE ROTOR SUCCESSFUL - MICRO GOOD

1ST STAGE IMPELLER SUCCESSFUL - MICRO GOOD

1ST STAGE ROTOR SUCCESSFUL - MICRO GOOD

2ND STAGE IMPELLER, S/N 2, EXCESSIVE CRACKING -
MICRO GOOD

2ND STAGE IMPELLER, S/N 3, SUCCESSFUL - MICRO GOOD

INDUCER/IMPELLER INSERT SUCCESSFUL - VERIFICATION
THAT MICRO IS IMPROVED FROM CROSS-FORGING, ONLY

AEROJET NUCLEAR SYSTEMS COMPANY

TRY-OUT FORGING TEST RESULTS

- DYE PENETRANT PER ANS 90297 AND 9032
- ULTRASONIC (LONGITUDINAL) PER ANS 90297
- ULTRASONIC (SHEAR) PASSED USING CONTACT METHOD
- GRAIN FLOW PER ANS 90297
- MICROSTRUCTURE PER ANS 90297

AEROJET NUCLEAR SYSTEMS COMPANY

CURRENT STATUS

- CARLTON FORGE ON HOLD
- ALL PARTS MADE AND CUT MULTIPLES ON HOLD
- TMCA "B" BAR AND RMI "T" BAR, ONLY, TO BE USED
- THREE SETS OF PARTS FOR S/N 1 TPA PLUS TRY-OUTS FROM RMI "TI" BAR
- INTERIM MATERIAL TESTS UTILIZING RING MATERIAL AND RMI "T" BAR TRY-OUT
- CORRELATE RING AND CENTER PROPERTIES ON ONE 1138578 RMI "T" BAR FORGING

AEROJET NUCLEAR SYSTEMS COMPANY

2ND REVISION OF ARCTURUS CUT CHART
INCORPORATING SNSO DIRECTIVES

TMCA
K-8930
BAR B

2916 100# S/N 5	X-292 & 293 105#				2917 100# S/N 5	2915 130# S/N 8
	S/N 5	S/N 4	S/N 3	S/N 2	S/N 4	
** VISUAL EXAM 9/2 MICRO						
107" = 866 LB						
TO ₂ TO						

TMCA
K-8930
BAR T4

		2915 130#		2917 100#	2915 130#
S/N 7	S/N 6	S/N 5	S/N 4	S/N 3	S/N 2
109 5/8" = 893 LB					
* VISUAL EXAM 9/2 MICRO					

RMI
804722
BAR T

	2918 88#				2915 130#	
S/N 18 17	16 15 14 13 12	S/N 11	S/N 12	S/N 11	S/N 10	S/N 9
163" = 1330 LB						

TMCA
K-8930
BAR B
(NEW CUTTING)

2916 100# S/N 5	X-292 & 293 105#				2917 100#	2915 130#
	S/N 5	S/N 4	S/N 3	S/N 6	S/N 5	S/N 8

HOLD TO MTL TEST

CHANGE

RMI
804722
BAR T
(NEW CUTTING)

	2918 88#		2915 130#	2916 100#
S/N 18 17	16 15 14 13 12 11	S/N 12	S/N 11	S/N 6 S/N 7

CURRENT STATUS

- REACTIVATE RMI HEAT 804722
 - ▲ FORGE FROM 19 IN. SQ. TO 16 IN. OCT. AT 2000°F
 - ▲ REDETERMINE NOMINAL BETA TRANSUS
 - ▲ DETERMINE LAB FURNACE TEMP VARIATION
 - ▲ DETERMINE SHOP FURNACE(S) TEMP VARIATION(S)
- ESTABLISH MAX METAL TEMPERATURE
- FINISH FORGE AT OR BELOW MAX METAL TEMP
- REORDER TMCA HEAT AFTER SPECIFICATION CHANGE

INTERIM MATERIALS TEST PROGRAM

	70 ± 10°F/10 PSI GH ₂			-160 ± 10°F/1200 PSI GH ₂			-423 ^{+ 15} _{- 0} °F LH ₂		
	K _{Ic}	K _I /K _{Ic} = 0.5	SPARE	K _{Ic}	K _I /K _{Ic} = 0.5	SPARE	K _{Ic}	K _I /K _{Ic} = 0.5	SPARE
1138575 RING	1	1	1				1	1	1
1138576 RING				1	1	1	1	1	1
1138577 RING				1	1	1			
1138578 RING	1	1	1						
1138578 CENTR	1	1	1						
1138579 SLICE							1	1	1

TOTAL TESTS - 16 (PLUS 8 SPARES)

SPECIFICATION CHANGES

SPONGE - ANS 90296

NONE

BILLET - ANS 90295

CHANGE PRIMARY CYCLE VAC LEVEL TO 6000 MICRONS

MODIFY SECONDARY CYCLE VAC CONTROL

ADD FINISH FORGING TEMPERATURE LIMIT

CHANGE DYE PEN. CONTAMINATION LIMITS

CHANGE ULTRASONIC BACK REFLECTION LOSS LIMIT

*— make OK during
steady state portion of
the mch.*

FORGING - ANS 90297

CHANGE DYE PEN. CONTAMINATION LIMITS

AEROJET NUCLEAR SYSTEMS COMPANY

ARMCO 22-13-5 NOZZLE FORGING
MATERIALS DEVELOPMENT PROGRAM

PROBLEM - TO DATE, HAVE NOT BEEN SUCCESSFUL
IN PRODUCING 3 ARMCO 22-13-5 BILLETS WHICH WILL
MEET MIL-I-8950 LEVEL A (5/64-INCH) ULTRASONIC
CRITERIA.

SOLUTION - PRODUCE BILLETS USING ELECTRO SLAG
REMELT PROCESS.

ARMCO 22-13-5 ALLOY

I. INITIAL VACUUM ARC REMELT

- A. ONE 17-1/2 INCH BILLET PRODUCED.
- B. SHIPPED TO WYMAN-GORDON.
- C. REJECTED. ULTRASONIC INSPECTION REVEALED 5/64 INCH DEFECT.

II. VACUUM ARC REMELT

- A. TWO 17-1/2 INCH ROUND BILLETS PRODUCED.
- B. ALL HAD ULTRASONIC DEFECTS.
- C. ATTEMPT TO MELT THIRD INGOT RESULTED IN FURNACE EXPLOSION.
- D. PROBLEM WAS DIFFICULTY IN MAINTAINING ARC STABILITY WITH PARTIAL INERT GAS PRESSURES DURING VAR.
- E. TERMINATED EFFORT 14 JUNE 71 AND REQUESTED PROGRAM SCHEDULE SLIP.

ARMCO 22-13-5 ALLOY

III. AIR MELT INGOTS - PRIME

- A. THREE 39-INCH INGOTS MELTED FROM WHICH SIX 17-1/2 INCH BILLETS COULD BE PRODUCED.
- B. VENDOR MET SCHEDULE ON 23 JULY 1971.
- C. TWO 17-1/2 INCH BILLETS REJECTED - ULTRASONIC DEFECTS.
- D. PROBLEM DUE TO INADEQUATE PRESS CAPACITY AT ARMCO FOR CONVERTING THE INGOTS TO BILLETS.
- E. ONE 17-1/2 INCH BILLET MET ULTRASONIC CRITERIA BUT DID NOT MEET 3000-LB WEIGHT MINIMUM.
- F. TERMINATED EFFORT 1 AUGUST 1971.

IV. AIR MELT INGOTS - BACKUP

- A. THREE 22-INCH SQUARE BILLETS AVAILABLE FROM ORIGINAL 39-INCH INGOTS.
- B. SHIPPED TO LATROBE STEEL COMPANY WHICH HAS LARGER PRESS CAPACITY FOR CONVERSION TO 17-1/2 INCH BILLETS.
- C. THREE 17-1/2 INCH BILLETS REJECTED - ULTRASONIC DEFECTS.
- D. INADEQUATE AMOUNT OF WORK TO PRODUCE SOUND BILLETS.
- E. TERMINATED EFFORT 26 AUGUST 1971.

ARMCO 22-13-5 BILLET HISTORY

		<u>NUMBER PRODUCED</u>	<u>REASON FOR DEFECT</u>
I.	INITIAL VAC ARC REMELT	1	ARC INSTABILITY
II.	VAC ARC REMELT	3	ARC INSTABILITY
III.	AIR MELT 39-1/2 INCH INGOT CONVERTED AT ARMCO TO 17-1/2 INCH	3	2 EACH SHRINKAGE DEFECTS 1 EACH INADEQUATE WEIGHT
IV.	AIR MELT 39-1/2 INCH INGOT CONVERTED AT ARMCO TO 22 INCH THEN SENT TO LATROBE AND CONVERTED TO 17-1/2 INCH	3	3 EACH SHRINKAGE DEFECTS
	TOTAL BILLETS PRODUCED	<hr/> 10	

ULTRASONICALLY REJECTED 9 BILLETS
INADEQUATE WEIGHT REJECTED 1 BILLET

ELECTROSLAG REMELTING

CONSUMABLE ELECTRODE VACUUM MELTING

CHEMISTRY OF ARMCO 22-13-5
BEFORE AND AFTER ESR

AIR MELT
INGOT CHEMISTRY
ARMCO

INGOT CHEMISTRY
AFTER ELECTRO-SLAG
REMELT
LATROBE

<u>Element</u>	<u>Analysis</u>	<u>Analysis</u>		<u>Analysis</u>
C	0.052	0.052	-	0.052
Mn	5.26	5.29	-	5.26
P	0.019	0.019	-	0.020
S	0.006	0.004	-	0.004
Si	0.50	0.41	-	0.41
Cr	22.15	22.12	-	22.13
Ni	12.74	12.64	-	12.66
Mo	2.24	2.26	-	2.26
Cb	0.23	0.22	-	0.22
Ti	0.010	0.005	-	0.004
AL	0.010	0.010	-	0.011
V	0.26	0.25	-	0.25
N	0.34	0.33	-	0.33

*

ARMCO 22-13-5 ALLOY

V. ELECTRO SLAG REMELT

- A. ARMCO HAS RECEIVED A 24-INCH ESR REMELT INGOT FROM LATROBE. INGOT CONVERTED TO BILLET FORM AND BEING HELD AS A SPARE FOR ANSC ORDER.
- B. THE THREE 17-1/2 INCH BILLETS FROM IV WILL BE REMELTED USING ESR PROCESS AT LATROBE.
- C. SCHEDULE AT LATROBE:
 - 1. REMELT TO 24-INCH ESR INGOT - 22 SEPTEMBER.
 - 2. CONVERT TO 17-1/2 INCH - 29 SEPTEMBER.
 - 3. ULTRASONIC TEST - 5 OCTOBER.
 - 4. SHIP - 8 OCTOBER.

LATROBE CONVERSION OF ARMCO 22-13-5 INGOT

8-10,000 LB
ESR INGOT

UPSET

DRAW

ULTRASONIC &
CROP TO 3,000 LB

WYMAN GORDON CLOSED DIE FORGING OPERATION

ESR BILLET

BARREL

PANCAKE

CLOSED DIE

SUMMARY ARMC0 22-13-5 BILLETS

VAC ARC REMELT

- HIGH VAC (40MM INERT ATMOSPHERE)
 - LOSS OF NITROGEN AND MANGANESE
 - MARGINAL ARC STABILITY
- LOW VAC (100MM INERT ATMOSPHERE)
 - ARC INSTABILITY

AIR MELT

- INTERNAL SHRINKAGE DEFECTS EXCEED LEVEL "A" (5/64 INCH).
- PRESS CAPACITY INADEQUATE DURING INITIAL WORKING.

ELECTRO SLAG REMELT

- STABLE CHEMISTRY
- STABLE ARC
- INTERNAL SHRINKAGE MINIMIZED
- INTERNAL ULTRASONIC QUALITY TO BE DETERMINED

M-60 LH_2 , LN_2 , GH_2 CORRELATION

QUESTION: IS LH_2 OR GH_2 IRRADIATION TESTING NECESSARY TO EVALUATE
CRYOGENIC MECHANICAL PROPERTY DAMAGE TO NERVA MATERIALS

APPROACH: COMPARE TENSILE PROPERTY CHANGES AT HIGH NEUTRON FLUENCE
A LH_2 VS LN_2 AT 40 & 140°R
B GH_2 VS LN_2 AT 140°R

MATERIALS: HASTELLOY X SOLUTION HARDENED F.C.C.
Ti 5Al-2.5Sn (ELI) SOLUTION HARDENED H.C.P.
AA3061-T61 PRECIP. HARDENED F.C.C. - LOW M.P.

M-40 TEST MATRIX

IRRADIATION FLUID TEMPERATURE		LH ₂ 40°R		LN ₂ 140°R		GH ₂ 140°R
FLUENCE NVT		NONE	3×10^{18}	NONE	3×10^{18}	3×10^{18}
TENSILE TEST TEMPERATURE	40°R	X	X		X	
	140°R		X	X	X	X*

X = 4 UNNOTCHED & 4 NOTCHED SPECIMENS

X* = 7 UNNOTCHED & 3 NOTCHED GH₂ ENCAPSULATED SPECIMENS

M-23 STRESS, RADIATION & GH_2 SYNERGISTIC EFFECTS

QUESTION: ARE COMBINED VARIABLES MORE OR LESS DETRIMENTAL THAN EACH SEPARATELY

- NOTCH TENSILE SCREENING TESTS - A286, Ti, 301, 718

COMPARE RESULTS: IRRADIATION IN H_2O (NO STRESS) AND TEST IN GHe
IRRADIATION IN H_2O (NO STRESS) AND TEST IN GH_2
IRRADIATION IN GH_2 (NO STRESS) AND TEST IN GHe
IRRADIATION IN GH_2 (NO STRESS) AND TEST IN GH_2

- CRACK GROWTH RATE AND K_{TH} (STRESS INTENSITY OF CRACK ARREST) -
- A286, Ti, 9310, 718

COMPARE RESULTS: AIR AND STRESS
 GH_2 AND STRESS
 GH_2 , STRESS AND IRRADIATION

ENCAPSULATED COMPACT TENSION SPECIMEN

DRM MANUAL MAINTENANCE

DRM MANUAL DESCRIPTION

INTRODUCTION CONTAINS:

- PURPOSE OF MANUAL
- NUMBERING SYSTEM FOR DRM'S
- CLASSIFICATION CRITERIA FOR DATA CATEGORIES
- ORGANIZATION OF DRM CONTENT
- CRITERIA FOR USING DRM DATA

ORGANIZATION

- DRM IDENTIFICATION

DRM 02.08

REV. NO. 2

SEPARATE SECTION INDEX NUMBER
FOR EACH MAJOR MATERIAL

SEQUENTIAL NUMBER IDENTIFYING
EACH DRM IN A SECTION

REVISION REPLACING ORIGINAL ISSUE

SECTION INDEX NUMBER IDENTICAL TO RELATED TEST PLAN NUMBER

- AISI 347 - TEST PLAN M-2 - MANUAL SECTION 02
- Ti 5Al-2.5Sn ELI - TEST PLAN M-4 - MANUAL SECTION 04

SUMMARY OF MATURITY OF MATERIALS DATA

<u>MATERIAL</u>	<u>NO. OF DRM'S</u>	<u>DATA CATEGORY DISTRIBUTION</u>			
		<u>A</u>	<u>or B</u>	<u>C</u>	<u>D</u>
ALLOY 718	10	2		5	3
AISI 347	10	7		2	1
AA 7039	5	2 1/2		2	1/2
Ti 5Al-2.5Sn ELI	5	4		1	
ALLOY A-286	5	1		4	
AG CARB-101	4			3	1
AA 6061	4	1		2 1/2	1/2
Ti 6Al-4V	1	1			
AA 7075	2	1		1	
ARMCO 22-13-5	<u>1</u>	<u>—</u>		<u>1</u>	<u>—</u>
SUBTOTAL	47	19 1/2		21 1/2	6
MISC.	<u>27</u>	<u>—</u>		<u>18 1/2</u>	<u>8 1/2</u>
TOTALS	74	19 1/2		40	14 1/2

Enclosure (6)
27 September 1971
TAR:mc:N8130R:71-0160

MATERIALS REVIEW 21-22 SEPTEMBER 1971 FOR SNSO

HANDOUT MATERIALS

BOTTOM OF "T4" BILLET

100X TRANSF'D α

UPSET, DRAWN AND
DIE FORGED

100X

RIM

100X

CENTER

FIGURE 2

P/N 1138575 S/N 2 (FIRST TRYOUT)

2ND IMPELLER, SHOWING EFFECT OF CROSS AND DIE FORGING ON MICROSTRUCTURE OF SEMI-FINISHED PART. HUBS WERE CUT OFF FOR INSPECTION AND TO FACILITATE SECTIONING. FORGED MICROSTRUCTURE IS CONSIDERED EQUIAXED ALPHA WITH DISTORTION IN RIM.

BOTTOM OF "T"

100X TRANSF'D α

UPSET, DRAW AND
DIE FORGE

100X

RIM

100X

CENTER

FIGURE 3

P/N 1138576 S/N 1 (FIRST TRY-OUT) 1ST IMPELLER
SHOWING EFFECT OF FORGING ON CHANGING MICRO-
STRUCTURE TO EQUIAXED.

TOP OF "T"
BILLET

MIXED α

100X

EQUIAXED α

UPSET, DRAW, PANCAKED
AND DIE FORGE

100X

RIM

100X

CENTER

FIGURE 4

P/N 1138578 S/N 1 (FIRST TRY-OUT) 2ND ROTOR
SHOWING ACCEPTABLE EQUIAXED MICROSTRUCTURE IN
BILLET AND FORGING.

BOTTOM OF "T2" BILLET

X292/X293
UPSET AND
DRAW
ONLY

100X

RIM

100X

CENTER

100X TRANSF'D α

UPSET, DRAW AND
DIE FORGE

100X

RIM

100X

CENTER

FIGURE 7

P/N 1138577 S/N 1 and P/N 1138579 S/N 1 (FIRST TRY-OUTS) SHOWING TH. EFFECT OF CROSS-FORGING ON THE DEGREE OF MICROSTRUCTURAL IMPROVEMENT STRUCTURES ARE CONSIDERED EQUIAXED WITH VARIOUS DEGREES OF DISTORTION

BOTTOM OF "T4" BILLET

100X TRANSF'D α

UPSET, DRAW AND
DIE FORGE

100X

SMALL HUB

100X

LARGE HUB

100X

RIM

100X

CENTER

FIGURE 8

P/N 1138575 S/N 3 (2ND TRY-OUT) 2ND IMPELLER SHOWING UNIFORM, FINE EQUITAXED ALPHA MICROSTRUCTURE COMPARED TO TRANSFORMED ALPHA MICROSTRUCTURE OF STARTING BILLET.

ENGINEERING OPERATIONS PROCEDURE

SUBJECT: PRELIMINARY MATERIALS DATA RELEASE

PURPOSE: To define procedures for providing preliminary materials property data for component design prior to completion of the entire test program and publication of the DRM.

APPLICABILITY: Materials property data generated within the Materials Section which the NERVA Project Design Groups consider sufficiently critical to require immediate transmittal of test results.

INSTRUCTIONS: Department Managers will periodically review the Material Priority and Maturity Status Report and the bi-monthly revisions thereto and ascertain whether the data to be generated on any line item is critical to their design activity.

The classification of "critical" means that preliminary data is required as soon as generated, rather than held for completion of the test program and publication of a DRM.

The Department Manager shall give the Materials Section a list of critical line items.

The Materials Section shall inform the Department Manager when a sufficient amount of data becomes available to meet the design requirement. It is important that this notification is given when the smallest amount of data which will provide useful information is available.

When critically-needed data suitable for pre-release becomes available, the Project or Department Manager shall request pre-release through the Manager, Engineering Operations.

Manager, Engineering Operations shall convene a Data Pre-Release Meeting with representatives of the following:

Project
Applied Mechanics
Materials
Reliability

Upon review by the representatives and approval of the Manager, Engineering Operations, the available data shall be released.

If preliminary results of any materials tests, not only critical line items, appear to contradict the generally anticipated results sufficiently that in the estimation of the Materials Section Manager it is important that the Project Design Group have the results, the appropriate Department Manager shall be notified immediately. He shall determine whether the implication of these results is of sufficient

consequence to warrant data pre-release. If so, he shall request consideration by the Data Pre-Release Representatives.

FORMAT:

The data shall be released in a DRM. This DRM shall be marked plainly as follows:

"Preliminary Data - Use With Caution. This DRM will be updated when complete test results become available."

The data shall be statistically analyzed to the extent possible and an appropriate data category assigned.

IMPLEMENTATION: Immediate.

II. INDEX OF DIM SECTION NUMBERS BY MATERIAL CLASSIFICATION

	<u>SECTION NO.</u>
A. <u>NICKEL ALLOYS</u>	
718	01
K-Monel 500	42
B. <u>ALUMINUM ALLOYS</u>	
7039	03
6061	07
2024	08
5083	20
7075	21
Aluminum, Pure	25
C. <u>STAINLESS STEELS</u>	
347	02
A-286	05
301, 302, 303	10
440C	19
310	29
21-6-9	36
22-13-5	38
D. <u>ALLOY STEELS</u>	
Maraging Steel, Grade 250	16
9310	31
Invar 36	41
3% Si Transformer Steel	45
E. <u>TITANIUM ALLOYS</u>	
Ti 5Al-2.5Sn ELI	04
Ti 6Al-4V	09
F. <u>OTHER METALS</u>	
Lead, Pure	27
Bronze Bearing Alloys/Brass 268	32
Phosphor Bronze	37
Beryllium Copper	39

G. NON-METALLICS

AGCarb-101	06
Al ₂ O ₃	24
Graphite - 3% B	28
LiH	33

H. MISCELLANEOUS PROPERTIES

Coefficients of Friction	11
Vapor Pressures, Contaminant Limits	26

MATERIAL	CONDITION *	FORM	DIRECTION *	PROPERTIES						TEST TEMPERATURES °F*	DATA CATE-CORY	ISSUE DATE	DRM NO.
				MECHANICAL	FATIGUE	FRACTURE	THERMOPHYSICAL	RADIATIVE	OTHER				
Alloy 718	HEAT TREAT B	SHEET	L	X						RT	C	1-14-70	01.01
Alloy 718	HEAT TREAT B	WELDED SHEET	ACROSS WELD	X						RT	C	2-18-70	01.02
Alloy 718	AS SPECIFIED	-	-					X		-60, 40, 140	D	4-1-70	01.03
Alloy 718	SOL. TREAT & AGED	SHEET	F		X					-423, -320, RT	C	4-14-70	01.04
Alloy 718	SOL. TREAT & AGED	BAR	A, RB		X					-423, -320, RT	C	4-14-70	01.05
Alloy 718	HEAT TREAT A & B	ALL	ALL				X			-423 to 2000	D	6-12-70	01.06
Alloy 718	HEAT TREAT B	FORGING	C			X				-423	A	7-15-70	01.07
Alloy 718	HEAT TREAT B	ALL	ALL				X			-423 to 0	D	8-7-70	01.08
Alloy 718	COLD WORKED & AGED	BAR	A	X						-423, -320, RT	C	11-4-70	01.09
Alloy 718	HEAT TREAT B	FORGING	T	X						-423, -320, RT	A	1-18-70	01.10
AISI 347	TRIPLE BRAZED	FORGING	A, C	X						-100, RT, 600, 1200	B	3-4-70	02.01
AISI 347	WROUGHT	ALL	ALL				X	X		-459 to 2241	D	6-22-70	02.02
AISI 347	SIMULATED BRAZE	SHEET	T, L	X						-320 to 2000	C	7-30-70	02.03
AISI 347	TRIPLE BRAZED	FORGING	A, C,	X						-100, RT, 600, 1200	A	8-7-70	02.04
AISI 347	SIMULATED BRAZE	SHEET	T, L	X						-320 to 2000	A,B	12-17-70	02.05
AISI 347	ANNEALED	FORGING	L, LT	X						RT	A	1-5-71	02.06
AISI 347	ANNEALED & BRAZED	SHEET & FORGING	ALL				X			-423 to 1840	B	1-7-71	02.07
AISI 347	ANNEALED & BRAZED	FORGING	A, C	X						-320 to 1200	A,B	1-11-71	02.08
AISI 347	ANNEALED	SHEET	T		X					-423	C	2-15-71	02.09
AISI 347	ANNEALED, BRAZED	ALL	ALL				X			-440 to 2040	A	2-18-71	02.10
AA 7039	ALL	ALL	ALL				X			-460 to 440	B,D	6-10-70	03.01
AA 7039	T-63	FORGING	L, C	X						-320 to 300	A	6-22-70	03.02
AA 7039	T-63	FORGING	C			X				-320, RT	C	7-16-70	03.03
AA 7039	T-63	FORGING	C, A, ST			X				-320, -100, RT	A	11-3-70	03.04
AA 7039	T-63	FORGING	A		X					150	C	11-9-70	03.05
Ti 5Al-2.5Sn ELI	ANNEALED	FORGING(RING)	C, R	X						-320, RT	A	9-1-70	04.01
Ti 5Al-2.5Sn ELI	ANNEALED	FORGING(PANCAKE)	T, R	X						-423, -320, RT	A,B	11-23-70	04.02
Ti 5Al-2.5Sn ELI	ANNEALED	FORGING(RING)	T, R	X						-320, RT	A	12-1-70	04.03
Ti 5Al-2.5Sn ELI	ANNEALED	FORGING(PANCAKE)	T, R	X						-423	B	2-17-70	04.04

MATERIAL	CONDITION *	FORM	DIRECTION *	PROPERTIES						TEST TEMPERATURES °F*	DATA CATE-GORY	ISSUE DATE	DRM NO.
				MECHANICAL	FATIGUE	FRACTURE	THERMOPHYSICAL	RADIATIVE	OTHER				
Alloy A-286	SOL. TREATED & AGED	FORGING	T, R	X			X			-423, -320, 100, RT	C	2-16-70	05.01
Alloy A-286	COLD WORKED & AGED	BOLTS	L	X						-423, -320, RT	C	2-24-70	05.02
Alloy A-286	N/A	ALL	ALL				X			-300 to 400	C	8-3-70	05.03
AG CARB-101	N/A	N/A	AS SPECIFIED	X	X	X	X			RT, 1000, 2000, 3000	C	12-19-69	06.01
AG CARB-101	N/A	N/A	ALL					X		70 to 4000	D	3-23-70	06.02
AG CARB-101	N/A	N/A	ALL				X			-100 to 3000	C	9-9-70	06.03
AA 6061	T-6	SHEET & PLATE	L, LT	X						-423, -320, 70	C	3-18-70	07.01
AA 6061	T-6	WROUGHT	ALL	X	X		X	X		-423 to 500	C,D	3-18-70	07.02
AA 6061	T-6	FORGINGS	L, T, ST	X						-423, -320, 70, 300	B	9-3-70	07.03
AA 6061	T-6	SHEET	F		X					RT	C	1-20-71	07.04
AA 2024	N/A	WROUGHT	ALL					X		-60 to 140	D	6-16-70	08.01
Ti 6Al-4V	ANNEALED	SHEET	L, T	X						-320, -100, 70, 200	B	1-15-70	09.01
AISI 301	1/4 HARD	SHEET	L, T	X			X			-423, -320, 70	C	1-14-70	10.01
AISI 302	ALL	ALL	ALL				X			-300 to 400	C	8-3-70	10.02
AISI 303	ALL	ALL	ALL				X			-300 to 400	C	8-3-70	10.03
COEFFICIENTS OF FRICTION (VARIOUS PAIRS OF MATERIALS)								X		-420 to 160	D	5-22-70	11.01
MARAGING STEEL (GR 250)	N/A	ALL	ALL				X	X		-200 to 400	D	3-23-70	16.01
AISI 440C	QUENCH & TEMPERED	BAR	ALL	X			X			-423, RT	C	11-4-70	19.01
AA 5083	H323	SHEET	L, LT	X						-423, -320, RT	C	1-23-70	20.01
AA 7075	T-73	ALL	ALL				X			-320 to 300	B,C,D	12-7-70	21.01
AA 7075	T-73	FORGING	ST, L, LT	X						-423	B,C	12-18-70	21.02

MATERIAL	CONDITION *	FORM	DIRECTION *	PROPERTIES						TEST TEMPERATURES °F*	DATA CATE-GORY	ISSUE DATE	DRM NO.
				MECHANICAL	FATIGUE	FRACTURE	THERMOPHYSICAL	RADIATIVE	OTHER				
Al ₂ O ₃	FLAME OR PLASMA SPRAYED	COATING	N/A					X		-60,40,140	C	1-6-71	24.01
ALUMINUM, PURE	N/A	BASE MTL OR COATING	ALL					X		-320 to 300	D	3-31-70	25.01
VAPOR PRESSURE AND CONTAMINANT LIMITS (VARIOUS MATERIALS)								X		VARIOUS	D	5-21-70	26.01
LEAD, PURE	ANNEALED	ALL	ALL					X		-460 to 620	D	5-22-70	27.01
GRAPHITE-3%B	N/A	MOLDED	AS SPECIFIED					X		-460 to 1070	D	6-17-70	28.01
ABI 310	ANNEALED	BAR, SHEET	ALL	X						-423,-320,RT	C	6-11-70	29.01
AISI 9310	QUENCHED & TEMPERED	BAR	ALL	X		X				-423 to RT	C	11-9-70	31.01
BEARINGS, BRONZE	CAST	N/A	N/A	X		X		X		RT	C	7-15-70	32.01
BRASS ALLOY 268	ANNEALED	ALL	ALL				X			80,170,260,350	C	12-22-70	32.02
L1 H	N/A	AS SPECIFIED	N/A				X			-420 to 810	C	7-17-70	33.01
21-6-9 SS	TRIPLE BRAZED	SHEET	L, T	X						-423 to 1600	C	8-7-70	36.01
21-6-9 SS	TRIPLE BRAZED	FORGING	C, R	X						-423 to 600	C	8-7-70	36.02
PHOSPHOR BRNZ	ALL	ALL	ALL				X			-423,-320,0,80	D	8-3-70	37.01
BRONZE	ANNEALED	ALL	ALL				X			-42,-320,572	C,C,D	2-2-71	37.02
22-13-5 SS	ANNEALED	BAR	ALL	X						-320 to 1500	C	8-7-70	38.01
BeCu	SOL ANNEALED & AGED	ALL	ALL				X			80 to 350	C	12-22-70	39.01
INVAR 36	ANNEALED	BAR PLATE	L	X			X			-423,-320,-100,RT	C	11-23-70	41.01
K-MONEL 500	COLD DRAWN & AGED	WIRE	N/A	X						-423,-320,RT		12-8-70	42.01
K-MONEL 500	ANNEALED & AGED	ROD & BAR	L	X						-423,-320,-100,RT	C	12-14-70	42.02
3% Si TRANS-FORMER STEEL	ANNEALED	SHEET	ALL				X			80 to 350	C	12-22-70	45.01

* ABBREVIATIONS USED IN INDEX

SOL. = SOLUTION
 N/A = NOT APPLICABLE
 RT = ROOM TEMPERATURE

DIRECTIONS:

A = AXIAL
 C = CIRCUMFERENTIAL
 L = LONGITUDINAL
 LT = LONG TRANSVERSE
 R = RADIAL

ST = SHORT TRANSVERSE
 T = TRANSVERSE
 F = FLEXURAL
 RB = ROTATING BEAM

MANUAL OF MATERIALS DATA RELEASE MEMORANDA, SUPPLEMENT I, 15 JULY 1971

LISTING OF INCLUDED DRM'S

<u>MATERIAL</u>	<u>CONDITION</u>	<u>FORM</u>	<u>DIRECTION</u>	<u>PROPERTIES</u>	<u>TEST TEMPERATURES, °F</u>	<u>DATA CATEGORY</u>	<u>ISSUE DATE</u>	<u>DRM NO.</u>
Ti-5Al-2.5Sn ELI	ANNEALED	BAR	A, RB	FATIGUE	-423, -320, RT	C	4-21-71	04.05
ALLOY A-286	ANNEALED & AGED	SHEET	F	FATIGUE	-423, -320, RT	C	4-21-71	05.04
Alloy A-286	SOL. TREATED & AGED	FORGINGS	TANG	MECHANICAL	-423, -110, RT	B	5-24-71	05.05
AG CARB-101	IRRADIATED & ANNEALED	N/A	N/A	MECHANICAL	RT	C	7-2-71	06.04

FOR ABBREVIATIONS, SEE PAGE 3 OF DRM MANUAL