Astronuclear
Laboratory

WANL-TME-1820
Revision 2
October, 1968

FINAL TEST SPECIFICATION

BERYLLIUM MATERIALS TEST, 37/W406

REVISION 2

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Unclassified

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DISCLAIMER

FINAL TEST SPECIFICATION
BERYLLIUM MATERIALS TEST, 37/W406
REVISION 1

WANL-TME-1820
Revision 2

I. EXPERIMENT IDENTIFICATION

A. EXPERIMENT DESIGN REFERENCE	37/W406, WANL-TME-1815
B. SPONSOR	WANL
C. TEST FACILITY	GD/FW (GTR-20)
D. TEST DATE	October, 1968

II. PURPOSE OF EXPERIMENT

Following are objectives for 37/W406:

For Group A-I determine:

1. 0.2% tensile yield strength
2. ultimate tensile strength
3. elongation
4. Nil ductility temperature

As a Function of:

1. temperature from 140 to 540°R
2. specimen orientation (longitudinal and transverse)
3. fast neutron fluence from 0 to 1 x 10^{19} nvt
4. two different cores

For Group A-II determine the annealing effect on:

1. 0.2% tensile yield strength
2. ultimate tensile strength
3. elongation

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As a Function of:

1. longitudinal and transverse specimen orientation
2. annealing times between 1 and 1000 minutes
3. two different cores
4. annealing temperatures between 273 and 540°R

For Group A-III determine:

1. the brittle fracture toughness

As a Function of:

1. temperatures between 140 and 540°R
2. longitudinal and transverse specimen orientation
3. fast neutron fluence from 0 to 1 x 10^{19} nvt

Examine the fractured surfaces of these specimens.

For Group A-IV determine:

1. the annealing effect on fracture toughness of specimens irradiated in LN_2 (140°R) to 5 x 10^{18} nvt

As a Function of:

1. annealing temperature from 273 to 540°R
2. annealing time from 10 to 1000 minutes

Examine the fractured surfaces of these specimens.

For Group A-V determine for specimens held under a tensile load:

1. 0.2% tensile yield strength
2. the ultimate tensile strength
3. the elongation

As a Function of:

1. fast neutron fluence from 0 to 5 x 10^{18} nvt
2. tensile load from 0 to 25 ksi
3. test temperature between 140 and 540°R

III. DRAWINGS

WANL'S DRAWING NUMBERS	DESCRIPTION
650A577	Round Tensile Specimen Be-IP
650A587	Biaxial Brittle Fracture Specimen
WT701590	Stressed Tensile Specimen

IV. EQUIPMENT LIST

A. TO BE PROVIDED BY WANL

1. Specimens
2. Tensile and Brittle Fracture Grips and Pull Rods
3. Cryogenic Temperature Control Coil(s)
4. Cryogenic Annealing Coil
5. Stressed Tensile Loading and Unloading Fixtures

B. TO BE PROVIDED BY TESTING AGENCY (GENERAL DYNAMICS/FORT WORTH)

1. Test Racks and Dewar for Holding Specimens During Irradiation
2. Instron Floor Model, Minimum Capacity 10,000 Pounds
3. Storage Dewar for Maintaining LN_2 Temperature
4. Instrumentation for Recording all Data
5. Transfer Devices to Transfer Specimens Under LN_2
6. LN_2 Test Cryostat(s)
7. Temperature Control (Cryogenic Range Compatible with Chromel-Alumel Thermocouple) and Recorders
8. Spring Constant Measuring Fixture (Stressed Beryllium Fixtures)
9. Strain Gage Readout Instrumentation

V. TEST ENVIRONMENT

A. TEMPERATURE	
1. IRRADIATION TEMPERATURE	LN_2 (-320°F)
B. PRESSURE	Ambient
C. HUMIDITY	Not Applicable
D. VIBRATION	Not Applicable
E. 1. UNPERTURBED FAST NEUTRON FLUX (E > 1.0 MeV)	4.6×10^{12} and 2.3×10^{12} nv*
2. UNPERTURBED THERMAL NEUTRON FLUX	As determined by experiment conditions
F. UNPERTURBED INTEGRATED DOSE	
1. Fast Neutron (E > 1.0 MeV)	1×10^{19} and 5×10^{18} nvt*, 2.5×10^{18}
2. Thermal Neutron	As determined by experiment conditions
G. FLUID ENVIRONMENT (During Irradiation)	LN_2
H. DURATION	~600 Hours

VI. ANALYTICAL

A. PREDICTED PERTURBED FLUXES

1. Any perturbation of neutron flux by specimens, etc. on other specimens shall be estimated and taken into account so that specimens will receive the specified fluence within ±5% of each other.

B. ACTIVATION LEVELS

1. Not Applicable

*See Appendix A for environment conditions on each specimen.

VII. FACILITY REQUIREMENTS

A. ELECTRICAL	110 Volts - 60 Cycles
B. PNEUMATIC	Not Applicable
C. HYDRAULIC	Not Applicable
D. SPECIAL FLUIDS	LN_2 for Irradiation - LN_2 for Testing

VIII. DOSIMETRY - (To be supplied by GD)

Thermal and fast neutron dosimetry at the front and rear of each experiment.

IX. DATA REQUIREMENTS

A. Accuracy Requirements

The neutron fluence for specimens with the same fluence requirement in any given group shall be within ±5%. Whenever a group has two required fluences (for example, group A-I has 24 specimens that require 5×10^{18} nvt and 12 specimens that require 1×10^{19} nvt) the ratio of high to low fluence shall be 2.00 ± 10%. Variation in fluence between groups shall be within ± 30%.

The gamma dose of all specimens shall be reported to within ± 50% to comply with the NERVA Trend Data Retrieval Program.

The Instron machine load shall be recorded with ± 0.5%.

The load on pre-stressed specimens shall be recorded within ± 1%.

Dimensional measurements of length shall be to the nearest 0.5 mils.

Room temperature shall be recorded to the nearest °R.

The Instron machine grip temperatures shall be monitored with thermocouples, and they should be recorded within ± 1°R. The specimen temperature shall be accurate to ± 5°R.

Annealing temperatures shall be accurate to ± 2°R in the cryogenic range and to ± 5°R at temperatures $\geq$ room temperature.

The annealing times shall be accurate to $\pm 1\%$.

X. TEST DESCRIPTION

A total of 124 specimens will be irradiated in a LN_2 environment. A description of the post-irradiation test conditions is itemized in Appendix A along with specimen numbers.

Specimen dimensions are approximated in the following table to demonstrate the space each specimen will occupy. The table also gives the drawing numbers(s) associated with each specimen for the exact dimensions. These drawings are Figures 1-3.

Specimen	Approximate Specimen Dimensions (Inches) Length	Width	Thickness or Diameter	Drawing Number(s)
Shoulder Loaded	2.0		0.49	650A577,
NOL	1.46	1.01	1.00	650A587
Stressed Tensile	8.86	-	2.35	WT701590

A. RECEIVING INSPECTION PROCEDURE

Upon receipt of specimens from WANL, all specimens will be visually inspected by GD/FW for possible damage due to handling and the results of this inspection recorded.

B. PRE-IRRADIATION CHECKOUT

Pre-irradiation checks will include (1) the measurement and recording of pre-test dimensions on all specimens by WANL and (2) identification of all specimens to be used in either the control or irradiation tests by WANL. The identification symbols assigned to each specimen, which are scribed on each end, together with a description of the material will be entered in a permanent log book, along with the recorded location of specimens and dosimetry as installed on racks in the test fixture by GD/FW.

Detailed procedures including operating check lists shall be prepared by General Dynamics and approved by WANL.

C. REACTOR INSTALLATION PROCEDURES

Upon initiation of LN_2 flow, all events affecting temperature of test specimens will be recorded.

D. IRRADIATION TEST PROCEDURE

The reactor shall be operated for 600 hours at 10 megawatts. There are no special requirements relating to reactor startup or shutdown procedures, except that the specimens irradiated must remain under LN_2 from the start of irradiation testing unless otherwise specified.

E. POST-IRRADIATION

The control specimens will be exposed to the same temperature environment including thermal cycling as the irradiated specimens. The specimens shall be maintained at LN_2 temperature throughout the complete program through post-irradiation testing, except those specifically warmed up, and not allowed to warm up above the test temperature. Procedures similar to those employed in GTR-16 will be required for the transfer of test specimens from the test dewar to the cryostat used in conjunction with the tests. GD/FW will concur with WANL on the use of load ranges for specific tests and materials.

Specimens from A-II Beryllium-Plain Tensile-Annealing Study will be tested before A-I, and A-IV Beryllium-Brittle Fracture-Annealing Study will be tested before A-III.

The times to obtain temperatures will be determined and reported. Times referenced in annealing studies refer to times at temperature although this may be modified by WANL monitor depending on times taken to reach testing temperature. The specimens will be batch annealed and all specimens in A-II and A-IV will be tested at 140°R.

1. Tensile Tests - Detailed alignment checks on the tensile system used for beryllium will be made similar to that for GTR-18, Test No. 37/W403.

2. Biaxial Brittle Fracture Tests - The biaxial brittle fracture specimens will be tested in tension. Details will be specified by the cognizant WANL representative.

F. TENSILE TESTING (INSTRON MACHINE)

The Instron machine crosshead speed shall be 0.005 inches/min. for all beryllium tensile testing. Alignment checks shall be made intermittently during beryllium testing program. This shall be accomplished with three strain gages mounted 120° apart around the circumference of the gage section of a dummy specimen. The Materials Advisory Board recommends ≤5% misalignment for beryllium. The WANL monitor will determine whether the alignment of the system is such and note any deviation from this.

G. SPRING LOADED BERYLLIUM SPECIMENS

All 24 stressed specimens are to be strain gaged at WANL. Fixtures shall be shipped to GD/FW unloaded. They shall be assembled and proper alignment determined at GD/FW under WANL supervision as late as possible before insertion into irradiation dewars. The control specimens shall be held at LN_2 temperature during the irradiation. Before insertion into the dewar the spring compressed length shall

be measured. After irradiation the compressed length, free length, and spring constant of all springs shall be measured at LN_2 temperature. These 12 specimens will then be tested at the conditions given in Appendix A.

H. METALLOGRAPHY

Macrographs with a magnification of 2 to 4 shall be taken of the fractured surface of specimens numbered 2, 10, 11, 17, 74, 76, 77, 80, 81, 84, 85, and 87. (See Appendix A for specimen numbering.)

Electron fractographs (having suggested magnification 6000) of the fractured surface and microphotographs (having magnification 100 and 500) of the polished longitudinal area including the fracture shall be taken of specimens numbered 3, 4, 11, 15, 74, 76, 77, 80, and 119. WANL shall receive replicas of the electron fractographs.

Each beryllium brittle fracture specimen (numbers 73-104) shall have a macrograph and a microphotograph of the fractured surface taken after fracture. The macrograph shall have a magnification of 10, while the microphotograph shall have a magnification of 200.

XI. HAZARDS

A. PERSONNEL

No foreseeable hazard other than handling irradiated material for testing at high temperature.

B. FACILITY

No foreseeable hazards other than those connected with usual reactor operation.

XII. DATA REDUCTION

Data to be included in the report shall include ultimate and 0.2% offset yield tensile strength, the Instron chart elongation, the plastic elongation at maximum stress of WOL specimens, and the ultimate and yield strengths of stressed tensile specimens. Data shall be based on actual WANL reported gage length. Original or legible reproduced copies of all load-deflection curves, temperature recording curves, and raw data tabulations are to be made available to WANL as soon after testing as possible.

XIII. DISPOSITION OF SPECIMENS AND HARDWARE

Disposition of irradiated test specimens and/or equipment will be handled in accordance with current AEC regulations. The test specimens will be returned to WANL if specified. Obtain approval from WANL prior to disposition of any material or equipment.

XIV. SHIPPING AND RECEIVING INSTRUCTIONS

Specimens to be shipped to Mr. J. W. Allen at General Dynamics, Fort Worth, Texas.

APPENDIX A

The following pages give tabulation of all Beryllium specimens, the group number of each group, and the independent variables.

Test order 1 through 144.

A-I Beryllium - Plain Tensile

Test Conditions

Specimen No.	Core	Orientation	Fluence (Fast) (nvt)	Test Temperature (°R)	Test Order
11	No. 4	Long.	0	140	43
29				406	63
15			5×10^{18}	140	47
36			2.5×10^{18}	273	58
27			5×10^{18}	406	70
3			2.5×10^{18}	540	37
31			10^{19}	273	54
7				540	40
395			5×10^{18}	273	57
396			5×10^{18}	540	36
33		Trans.	0	273	55
2				540	35
14			2.5×10^{18}	140	46
39			5×10^{18}	273	62
21			2.5×10^{18}	406	65
8			5×10^{18}	540	41
399			5×10^{18}	140	45
400			5×10^{18}	406	64
20			10^{19}	140	52
22				406	66
32	No. 7	Long.	0	273	53
4				540	38
19			2.5×10^{18}	140	51
34			5×10^{18}	273	56

A-I Beryllium - Plain Tensile (Continued)

Test Conditions

Specimen No.	Core	Orientation	Fluence (Fast) (nvt)	Test Temperature (°R)	Test Order
30	No.7	Long.	2.5×10^{18}	406	72
5	↓	↓	5×10^{18}	540	39
403	↓	↓	5×10^{18}	140	50
404	↓	↓	5×10^{18}	406	71
17	↓	↓	10^{19}	140	48
26	↓	↓	↓	406	69
18	↓	Trans	0	140	49
25	↓	↓	↓	406	68
12	↓	↓	5×10^{18}	140	44
37	↓	↓	2.5×10^{18}	273	69
23	↓	↓	5×10^{18}	406	67
1	↓	↓	2.5×10^{18}	540	34
407	↓	↓	5×10^{18}	273	59
408	↓	↓	5×10^{18}	540	33
38	↓	↓	10^{19}	273	61
10	↓	↓	↓	540	42

Spare Specimens

A-I Beryllium - Plain Tensile

Specimen No.	Core	Orientation	Fluence(nvt)
397	No. 4	Long.	5×10^{18}
398			10^{19}
401		Trans.	5×10^{18}
402			5×10^{18}
405			5×10^{18}
406			10^{19}
409			5×10^{18}
410			5×10^{18}

A-II Beryllium - Plain Tensile - Annealing Study
5 x 10^{18} nvt Fast Fluence

Test Conditions

Specimen No.	Core	Orientation	Annealing Temperature (°R)	Annealing Time Minutes	Test Order
42	#4	Long.	273	1 (1)	1
71				100 (3)	24
70			406	10 (2)	15
55				1000 (4)	30
64			540	1 (1)	6
52				10 (2)	10
65				100 (3)	21
41				1000 (4)	25
57		Trans.	273	10 (2)	11
62				1000 (4)	32
67			406	1 (1)	7
61				100 (3)	20
43			540	1 (1)	2
72				10 (2)	16
44				100 (3)	17
50				1000 (4)	28
48	#7	Long.	273	10 (2)	9
49				1000 (4)	29

A-II Beryllium - Plain Tensile - Annealing Study
5×10^{18} nvt Fast Fluence
(Continued)

Test Conditions

Specimen No.	Core	Orientation	Annealing Temperature (°R)	Annealing Time Minutes	Test Order
68	#7	Long.	406	1 (1)	8
66				100 (3)	22
59			540	1 (1)	5
63				10 (2)	14
54				100 (3)	18
56				1000 (4)	31
51		Trans.	273	1 (1)	4
58				100 (3)	19
45			406	10 (2)	12
47				1000 (4)	26
46			540	1 (1)	3
60				10 (2)	13
69				100 (3)	23
53				1000 (4)	27

A-III Beryllium - Brittle Fracture

Test Conditions

Specimen No.	Orientation	Fluence (Fast) (nvt)	Test Temperature (°R)	Test Order
77	Long.	0	140	91
81			406	97
80		5×10^{18}	140	96
85			273	102
84			406	100
76			540	90
88		10^{19}	273	104
75			540	88
87	Trans.	0	273	101
74			540	86
79		5×10^{18}	140	95
86			273	103
82			406	98
73			540	85
78		10^{19}	140	93
83			406	99
91	Trans.	2.5×10^{18}	540	87
89	Long.	2.5×10^{18}	540	89
100	Trans.	2.5×10^{18}	140	94
97	Long.	2.5×10^{18}	140	92

Specimens

A-III Beryllium Brittle Fracture - Ring Pressing Material

Specimen Number	Core	Orientation	Fluence (nvt)
415	#4	Long.	0
416			5×10^{18}
417			10^{19}
418		Trans.	0
419			5×10^{18}
420			10^{19}
421	#7	Long.	0
422			5×10^{18}
423			10^{19}
424		Trans.	0
425			5×10^{18}
426			10^{19}

A-IV Beryllium - Brittle Fracture - Annealing Study
5×10^{18} nvt Fast Fluence

Test Conditions

Specimen No.	Orientation	Annealing Temperature (°R)	Annealing Time (min.)	Test Order
92	Long.	406	10	73
94		406	100	77
103		406	1000	84
96		540	10	74
102		540	100	80
95		540	1000	83
104	Trans.	406	10	76
101		406	100	79
90		406	1000	81
98		540	10	75
99		540	100	78
93		540	1000	82

A-V Beryllium - Stressed Tensile

Test Conditions

Specimen No.	Load KSI	Fluence (Fast) (nvt)	Test Temperature (°R)	Test Order
120	12.5	0	140	132
128			340	140
108			540	120
118			140	130
117			340	135
111			540	123
113		5×10^{18}	140	125
126			340	138
112			540	124
123			140	129
124			340	136
107			540	119
132	25.0	0	140	128
121			340	133
109			540	121
115			140	127
125			340	137
105			540	117

A-V Beryllium - Stressed Tensile

Test Conditions

Specimen No.	Load KSI	Fluence (Fast) (nvt)	Test Temperature (°R)	Test Order
114	25.0	5×10^{18}	140	126
127	↓	↓	340	139
110	↓	↓	540	122
119	↓	↓	140	131
122	↓	↓	340	134
106	↓	↓	540	118
129	0	↓	140	141
130	↓	↓	140	142
131	↓	↓	140	143
116	↓	↓	140	144

GTR-20 TEST ORDER

BERYLLIUM

Specimen No.	Test Order
42	1
43	2
46	3
51	4
59	5
64	6
67	7
68	8
48	9
52	10
57	11
45	12
60	13
63	14
70	15
72	16
44	17
54	18
58	19
61	20
65	21
66	22

GTR-20 TEST ORDER
(continued)

BERYLLIUM

Specimen No.	Test Order
69	23
71	24
41	25
47	26
53	27
50	28
49	29
55	30
56	31
62	32
408	33
1	34
2	35
396	36
3	37
4	38
5	39
7	40
8	41
10	42
11	43
12	44

GTR-20 TEST ORDER
(continued)

BERYLLIUM

Specimen No.	Test Order
399	45
14	46
15	47
17	48
18	49
403	50
19	51
20	52
32	53
31	54
33	55
34	56
395	57
36	58
407	59
37	60
38	61
39	62
29	63
400	64
21	65
22	66
23	67

GTR-20 TEST ORDER
(continued)

BERYLLIUM

Specimen No.	Test Order
25	68
26	69
27	70
404	71
30	72
92	73
96	74
98	75
104	76
94	77
99	78
101	79
102	80
90	81
93	82
95	83
103	84
73	85
74	86
91	87
75	88
89	89

GTR-20 TEST ORDER
(continued)

BERYLLIUM

Specimen No.	Test Order
76	90
77	91
97	92
78	93
100	94
79	95
80	96
71	97
82	98
83	99
84	100
87	101
85	102
86	103
88	104
423	105
418	106
426	107
416	108
417	109
420	110
422	111
425	112

GTR-20 TEST ORDER
(continued)

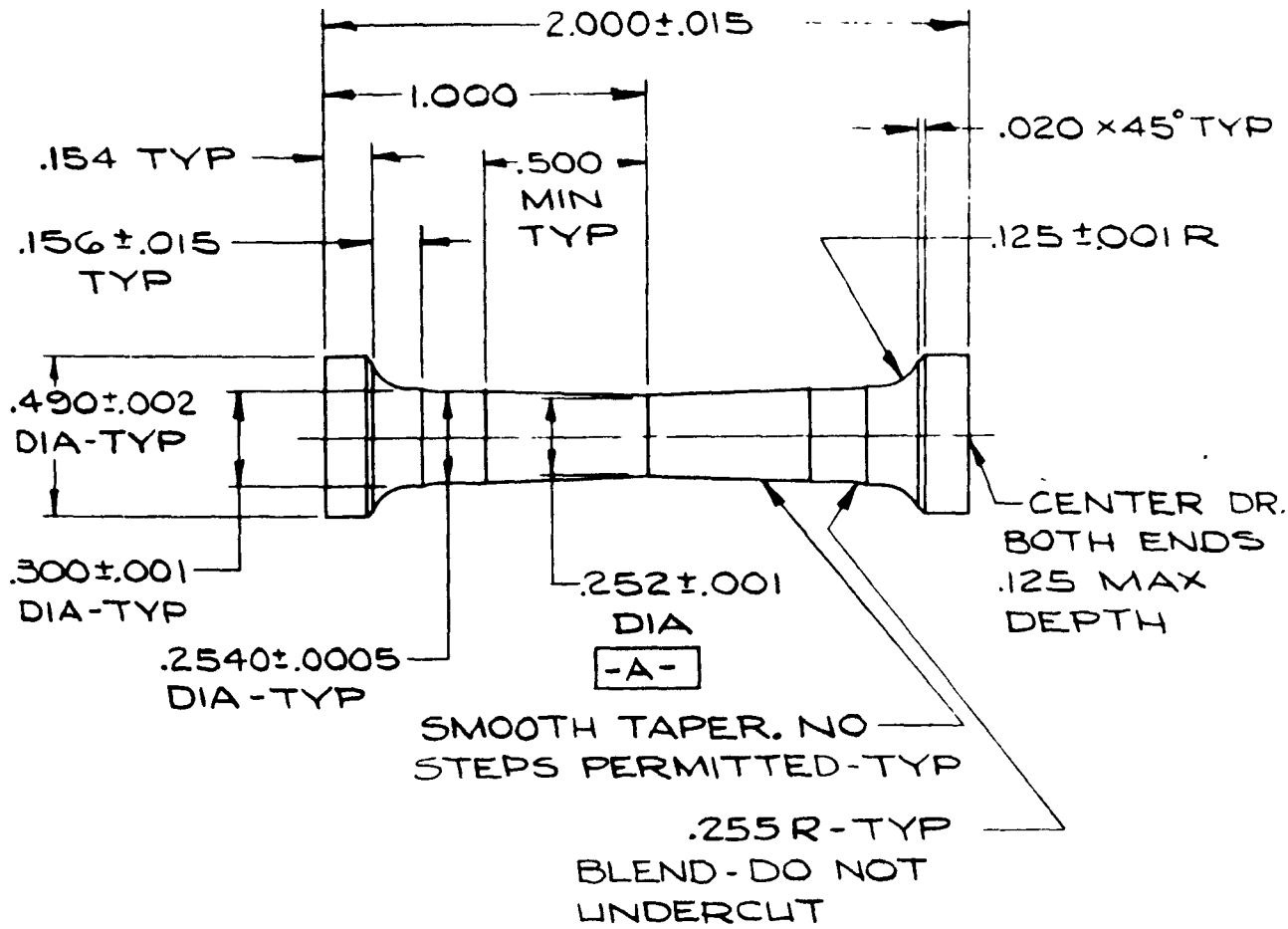
BERYLLIUM

Specimen No.	Test Order
415	113
424	114
421	115
419	116
105	117
106	118
107	119
108	120
109	121
110	122
111	123
112	124
113	125
114	126
115	127
132	128
123	129
118	130
119	131
120	132
121	133
122	134

GTR-20 TEST ORDER
(continued)

BERYLLIUM

Specimen No.	Test Order
117	135
124	136
125	137
126	138
127	139
128	140
129	141
130	142
131	143
116	144

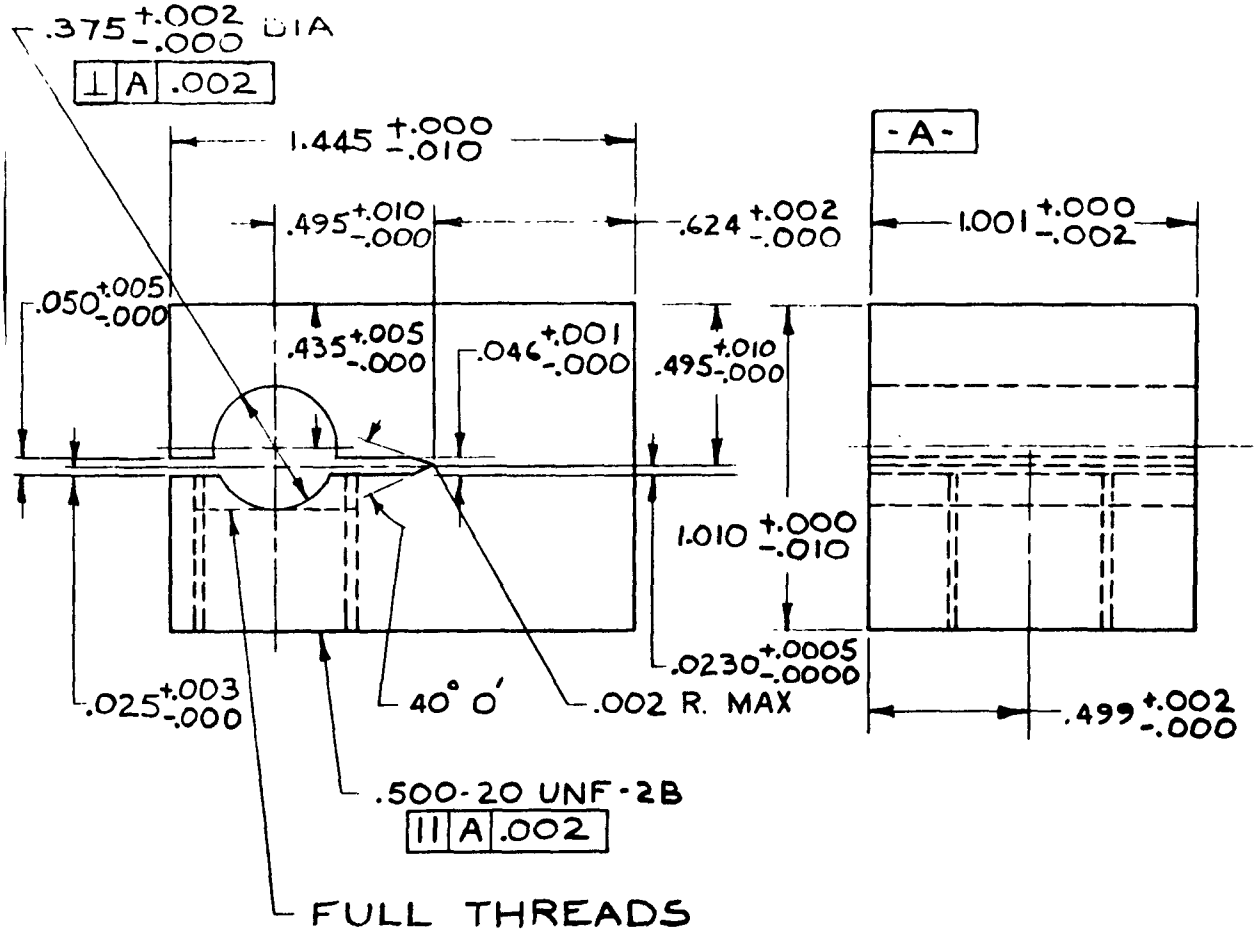


2- ALL DIAMETERS ⌀ A .005 TIR

1- UNLESS OTHERWISE SPECIFIED TOLERANCES ARE:
.XXX = ±.005

CODE 3

FIGURE 1 Beryllium Shoulder Loaded Tensile Specimen



1 ALL SIDES ⊥ .002

CODE 3

FIGURE 2 Beryllium Brittle Fracture (WOL) Specimen

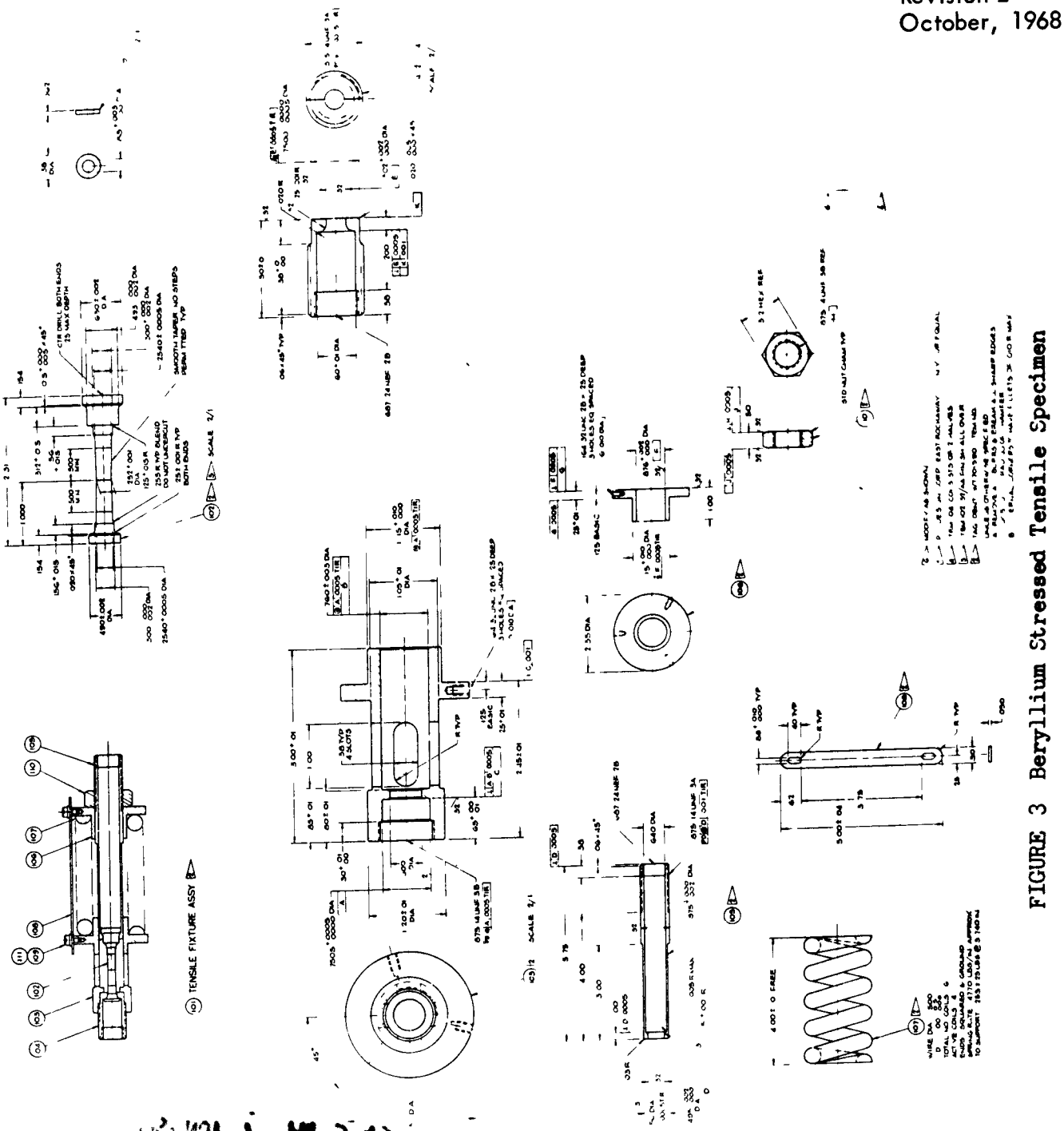


FIGURE 3 Beryllium Stressed Tensile Specimen

REVISED GTR-20 PRE-LOADED BERYLLIUM SPECIMEN MATRIX

Load	Fluence	Test Temperature	Specimen Number	Spring Number	Test Order
12.5 (K.S.I.)	0 n/cm.^{2}	140 °R	118	25	130
		140	117	38	129
		340	128	29	137
		540	108	32	119
		540	111	22	122
	5×10^{18}	140	113	6	125
		140	123	15	131
		340	124	7	134
		340	126	20	136
		540	112	34	123
		540	130	2	124
25	0	140	115	5	127
		140	132	27	133
		340	121	8	140
		340	125	10	135
		540	105	4	117
		540	109	9	120
	5×10^{18}	140	114	37	126
		140	116	14	128
		340	122	23	139
		340	119	30	141
		540	106	39	118
		540	110	24	121
0		140	131	-	132
		140	129	-	138