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LOCKHEED NUCLEAR PRODUCTS

ER-7702

QUARTERLY PROGRESS REPORT No. 16

October 1964 through December 1964

Effect of Nuclear Radiation on materials at Cryogenic Temperatures

PREPARED UNDER

National Aeronautics/Space Administration Contract NASw-114

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PROJECT MANAGER

LOCKHEED
NUCLEAR
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FOREWORD

This quarterly report is submitted to the Office of Space Launch Vehicles of the National Aeronautics and Space Administration in accordance with the requirements of NASA Contract NASw-114.

TABLE OF CONTENTS

LIST OF TABLES

1 INTRODUCTION

This report describes the progress made on Contract NASw-114 during the final quarter, October through December of 1964.

Out-of-pile testing of 5 specimen sample lots were completed during this period. Previously unreported out-of-pile test results are included in this report. In several instances, principally casting alloys, defective specimens resulted in the generation of fewer than 5 reportable sets of test data for out-of-pile control tests. These cases are identified by footnotes in the compiled data.

All of the proposed tests of irradiated three specimen samples were completed during this period except for Aluminum Alloy 5083 and one specimen of Aluminum Alloy 5456. A reactor operational decision was made to remove the Mallory 1000 Gamma Shield early in 1965 due to the build-up of W^{187} activity in the primary coolant system. For this reason, the screening program was terminated without testing of these specimens. Compilation of test results for a summary report of the screening program was initiated.

The final report of the correlation program was completed during this period.

Repairs of test loop 201-003, initiated during the preceeding reporting period was completed.

Installation of the modified cask transfer equipment in the airlock penetration of the containment vessel was completed and transferral of the cask utilizing this equipment has proven the adequacy of the design.

Investigation of techniques for obtaining electron micrographs and x-ray diffraction patterns from failed tensile specimens were undertaken by NASA Plum Brook Metallurgical personnel during this period. If finished in time, the results of this investigation will be used in the radiation effects analysis section of the Summary Report of the screening program.

2 EQUIPMENT

2.1 TEST LOOPS

2.1.1 Repair of Test Loop 201-003

Repairs of test loop 201-003, damaged by the inadvertent closure of the beam port valve while the loop was still in HB-2 [1] were completed during this reporting period.

The identation resulting from the valve closure had essentially been corrected during the previous reporting period; [2] the effort during this period was directed at correction of an axial misalignment and an out-of-round condition in the area adjacent to the initial identation.

The misalingment was corrected by simple beam loading of the loop at several axial locations in an especially designed and built fixture. The out-of-round condition was corrected by circumferentially loading the surface of the loop against an internal forming die.

The test loop, after repair, still has a shallow, well-blended indentation and a slight axial misalingment. However, it is believed that further work on the loop with the available equipment and under the existing conditions would be likely to have a deleterious effect. The loop has not been given an operational check since being repaired. However, the remaining indentation is not considered sufficient to compromise the sealing action of the chevron seals in HB-2 and the minor remaining misalignment is not sufficiently great to effect the insertion of the loop into HB-2.

Following these repairs to loop 201-003, the loop was inspected for further internal damage using a mass spectrometer helium leak detector. It was found necessary to replace both extensometer instrument lead wires and one dynamometer instrument lead wire and to blank off the instrument lead tubes to the inoperative nuclear instrumentation. Subsequent mass spectrometer leak checks and heat leak checks using liquid nitrogen boil-off rates indicated that the loop is in operable condition.

(1) Quarterly Progress Report No. 13, ER-6929, page 13.
(2) Quarterly Progress Report No. 15, ER-7604, page 3.

2.1.2 Test Loop 201-002, Extensometer Leads

During operation of loop 201-002, in reactor cycle 26P of this reporting period, one bulkhead feed-through connector in an extensometer lead developed a helium leak. The leak was small enough to allow the continued use of loop 201-002 for the duration of the power cycle although extraordinary precautions during specimen changes were required to prevent the accumulation of moisture inside the test chamber.

The connector and leads were changed during reactor cycle 27S using a previously approved procedure.[3]

2.1.3 Test Loop Head Assemblies

Investigation of suitable techniques for re-evacuation of the test loop head assemblies was continued during this reporting period.[4]

A mock-up vessel with a volume approximating that of the evacuated volume in the test loop heads was fabricated to test evacuation and sealing procedures. An ionization gage was installed on this mock-up chamber to allow pressure measurements after evacuation and sealing for determination of the effectiveness of the seal.

Evacuation of the test vessel through an evacuation tube similar to that intended for the actual head assemblies is being investigated. This, however, and the proposed methods of sealing the tube by crimping and welding were not tested in this reporting period.

2.2 REMOTE HANDLING AND SAMPLE CHANGE EQUIPMENT

2.2.1 Carriages

Gradual increases in the time required for insertion of the test loop into HB-2 against primary coolant pressure were observed for carriages #2 and #4 during this reporting period.

The carriages were removed from the quadrant and disassembled for inspection. No component failures were observed. The deterioration in operational performance was due to a build-up of sedimentation deposits from the quadrant

(3) Quarterly Progress Report No. 15, ER-7604, page 3.
(4) Quarterly Progress Report No. 15, ER-7604, page 4.

water. The carriage parts were cleaned and reassembled, except for the bronze worm gear in carriage #4 which was replaced due to general wear on the teeth. The carriages were returned to service and operated without incident for the remainder of the reporting period.

2.2.1.1 Clevite 10HP Pump

The ten horse power Clevite pump, previously modified to prevent water-oil admixture, [5] has been operated some 200 hours since modification. The seals which separate the two fluids were replaced after approximately 120 operational hours; otherwise the pump functioned without incident.

A substitute pump previously available as an emergency replacement [6] from the manufacturer is no longer available. These pumps are specially manufactured to meet the requirements of this operation and replacement parts are not available except through special fabrication. Since disassembly and repair of the pump during an in-pile test exposure would create operational difficulties, a stand-by replacement pump is deemed advisable and was ordered.

2.2.2 Air Lock Penetration

NASA approval for the design modifications of the air lock transfer equipment to facilitate movement of the test loop transfer cask, or other objects of similar configuration, through the containment vessel was obtained during this reporting period. [7] The approved design, utilizing winches to move the cask, was fabricated and installed.

Transfer of a test loop in the transfer cask has been accomplished through the air lock penetration without difficulty. The modified design provides greater flexibility for the air lock and allows transfer of objects of varying configuration without compromising containment.

2.2.3 Hot Cave Port

The six polyurethane seals which were substituted for the teflon seals in the hot cave port during reactor cycle 24S [8] have operated satisfactorily for

(5) Quarterly Progress Report No. 14, ER-7352, page 6.
(6) Quarterly Progress Report No. 12, ER-6793, page 12.
(7) Quarterly Progress Report No. 15, ER-7604, page 5.
    Quarterly Progress Report No. 13, ER-6929, page 14.
(8) Quarterly Progress Report No. 5, ER-7604, page 5.

more than seventy (70) test loop insertions into the hot cave. There is no evidence of seal deterioration at this time.

2.2.4 Beam Port Valve

The six polyurethane chevron seals installed in the beam port coupling assembly during reactor cycle 24S [9] have withstood more than sixty (60) test loop insertions into HB-2 without visible deterioration. No schedule for routine replacement of these seals has been made; replacement requirements should be established by visual inspection of the seals each time quadrant "D" is drained or by observation of the rate of seal water flow during operation.

Two safety interlocks, both micro switches, became inoperative during reactor cycle 26P. The first malfunctioning limit switch was the beam port "thru seal" switch. This switch is activated by the front of the test loop as it emerges from the chevron seals in the beam port coupling assembly. The actuation of this switch stops the loop in a position where it, with the chevron seals, insures against admixture of primary and quadrant water and allows opening of the beam port gate valve. Re-activation of the switch upon test loop removal from HB-2 performs the reverse function, allowing closure of the valve while the loop seals primary from quadrant water.

The other switch malfunction was the hot cave "couple" interlock. This switch activates when the carriage coupling ring is attached to the hot cave valve. Without activation of this switch, the test loop cannot be inserted into the hot cave for specimen change.

Authorization was obtained from NASA to temporarily by-pass these interlocks, since a test operator routinely provides visual surveillance when test loops are moved in the beam port or hot cave port vicinity. The cycle was concluded without incident.

Both defective switches were replaced during reactor cycle 27S.

2.3 BEAM PORT SHIELD

The continuing build-up of W^{187} activity in the primary coolant system [10] led to the decision by NASA Reactor Operations that the entire shield assembly - both inner and outer shields - should be removed during reactor cycle 30S, which commenced on 19 December 1964.

(9) Quarterly Progress Report No. 15, ER-7604, page 6.
(10) Quarterly Progress Report No. 15, ER-7604, page 6.

The shield has provided a satisfactory level of gamma attenuation during the period of use. However, the increase of tungsten content in the primary coolant during service has led to the conclusion that the Mallory 1000 material is being removed from the shield through one or more failures in the nickel plate. This reflects on the structural integrity of the shield and replacement is indicated.

2.4 REFRIGERATION SYSTEM

During the period covered by this report, fifty-one (51) specimens were irradiated at 30° R. In two instances tests were aborted before the specimen received the required 1×10^{17} nvt exposure.

One abort was due to a shut down of the expansion engines caused by the closure of the isolation valve (V-9) which separates the cold-box portion of the refrigeration system located inside the containment vessel from the rest of the system. The valve closure was occasioned by the failure of a solenoid control valve. After replacement of the solenoid, the refrigerator was restarted and operated normally.

The second short exposure was due to an irrecoverable reactor scram.

There were two piston rod failures in the expansion engines during this reporting period. The failures were similar to those previously reported(11) and seem to be fatigue failures.

One failure caused the shut down of both sets of engines after 80% of the required specimen exposure. The loop was withdrawn from the high-flux zone during the re-starting of two of the undamaged engines. The temperature of the specimen (8 Ba 84) in this loop increased to approximately 70° R for about ten minutes before stabilization at 30° R. The loop was then reinserted for the remaining 20% of the exposure.

In the second instance of failure, the engines in pod #2 continued in operation and the test was completed with no loss of temperature control. This failed rod was replaced after completion of the test with a refrigerator down time of only 1 hour, 45 minutes. The total elapsed time from the completion of the preceeding test and the insertion of the subsequent test to the "full forward" position in HB-2 was 4 hours.

(11) Quarterly Progress Report No. 13, ER-6929, page 16.

Leakage of helium gas through the valve chest valves in the transfer lines coupled with an inability to close the shut-off valves in the refrigerator manifold allowed cold helium to escape from the forward end of the test loop during the time that the test loop head assembly was removed during specimen change. This cold gas lowered the temperature of the forward end of the loop, including the pull rod, to below the dew point of the ambient atmosphere, causing condensation of water (or frost) on the pull rod. This condensate was removed during head installation to prevent ice formation on the pull rod. However, in five instances condensate re-formed during head installation and five tests were invalidated after complete in-pile exposure due to the presence of ice on the pull rod.

The stuffing boxes of both expansion engine crosshead assemblies were rebuilt during this reporting period to replace failed "O" ring seals at the bottom of the distance pieces.

Oil carried over from the compressor collected in the heat exchanger, due to an inadequacy of the oil removal equipment. This resulted in reduced heat transfer across the heat exchanger and an excessive pressure drop across the heat exchanger both due to frozen oil impeding the helium flow. The system was flushed with freon to remove this oil and the heat exchanger has shown normal operating efficiency since this cleaning.(12)

(12) Quarterly Progress Report No. 14, ER-7352, page 10.

3 FLUX MAPPING

There was no activity with regard to the flux measurements in HB-2 during this reporting period.

4 TESTING PROGRAM

4.1 CORRELATION PROGRAM

The final report of the Correlation Program was completed during this reporting period and has been submitted to NASA for approval.

4.2 SCREENING PROGRAM

The in-pile portion of the screening program was conducted in reactor cycles 25P through 29P during this reporting period. The out-of-pile portion of the screening program was concluded with tensile and tensile notch tests being completed on all thirty-three (33) alloys at both room temperature and at 30° R.

A total of fifty-one (51) test specimens were inserted in-pile during this period. Of this number, 8 specimens were lost, one due to an irrecoverable reactor scram before complete exposure. The yield stress was not obtainable on another specimen due to the extensometer not operating properly. One specimen was invalidated because of a shut down of the refrigeration system as described in Section 2.4. An additional five (5) test specimens were invalidated due to an accumulation of ice forming on the pull rod and, consequently, indicating spurious results, as described in Section 2.4. Temperature control of one 1099 Aluminum specimen was temporarily lost due to shut down of the refrigerator as explained in Section 2.4. The exposure was completed, however, and the results are discussed further in Section 4.3.

Tensile tests for the 2024-T351 Aluminum Alloy were completed in this period and the results are given in Table 4. Specimens 1 Ba 71 and 1 Ba 72 were tested in the previous period but the results were not given because the sample lot was not completed in that period.

In addition to Aluminums 1099 and 2024, Aluminum Alloys 2014, 2219, 5083, 5086, 5456, 6061, 7079, 7178, X-250, B-750 and A 356 were tested in-pile during the period. The results from this testing along with out-of-pile test results, obtained in this period are presented and summarized with earlier out-of-pile results in Tables 1 through 29.

Steel alloys tested during this period were A-353, 17-7PH and T-450. The data obtained from these materials during this reporting period is given in Tables 30 through 34 and summarized with earlier out-of-pile data in Tables 35 through 37.

At the conclusion of this reporting period, testing of all the materials selected for the screening program was complete with the exception of 1 specimen of 5456-H321 Aluminum Alloy and 3 specimens of 5086 Aluminum Alloy. Since this remaining number of specimens is so low and with the anticipated removal of the beam port shield as stated in Section 2.3, the screening program is considered complete at the end of this period.

4.3 ALUMINUM 1099

The in-pile results from Aluminum 1099 presented in Table 1 deserve particular attention because of interesting effects arising from inadvertent variations in the test conditions within the 3 specimen sample. Also, this is a simple material that is likely to yield important fundamental information on nuclear-cryogenic effects and also one which shows unusually large irradiation effects. This is the only material included in the screening program to exhibit a decrease in yield strength on reduction of the testing temperature. This cryogenic effect is unusual and real, as verified by extra (unreported) tests on this particular material.

Specimen 8 Ba 87 was tested normally and the results from this specimen were the ones used in the summary of test results (Table 18). It shows unusually large increases in the ultimate and tensile yield strengths due to irradiation. Although part of the increase in the tensile yield strength due to irradiation is attributable to the unusual decrease in yield strength on reducing the temperature, the change with respect to the room-temperature-unirradiated test is also large (247%) compared with other materials, including Titanium 55A. Titanium 55A is the other relatively pure material in the testing program but exhibits only 147% increase in tensile yield from the room-temperature-unirradiated condition on irradiating and failing at 30° R.

Specimen 8 Ba 84 shows results affected by interrupting the refrigeration during irradiation and thus the effect of some annealing and diffusion of the irradiation induced defects. Both the ultimate tensile strength and the tensile yield strength are reduced by the annealing with the yield strength being reduced more than the ultimate strength.

If verified, this would indicate that the irradiation induced defects diffused to the grain boundaries rather than to dislocations or rather than to coagulate in such a manner as to act as barriers to dislocation motion. Such effects will be important eventually when it is necessary to consider temperature-irradiation histories in space hardware which are more complex than the histories used in the laboratory.

The stress-strain curve for specimen 8 Ba 80 indicated that only about one-half the total strain, as measured on the failed specimen, occurred during normal testing. Based on the experimental procedure, it was concluded that the specimen must have been accidentally prestrained before irradiation. The test results thus show that the ultimate tensile strength and yield strength are reduced by the presence of deformation induced defects such as additional dislocations or vacancies generated by dislocation motion. Effects of deformation prior to irradiation have been reported elsewhere, [13] and are important in the consideration of work hardened materials for nuclear cryogenic applications.

4.4 METALLOGRAPHIC STUDIES

Metallographic studies were continued during this reporting period.

Photo-micrographs of specimens tested during this period are not yet available and these will be presented, if available in time, in the forthcoming Summary Report on the screening program.

Analysis of photo-micrographs from specimens tested in the previous reporting period has continued but is incomplete. Some of this analysis will be presented in the Summary Report.

4.5 PRELIMINARY X-RAY STUDIES

Some x-ray work has been started with the objective being to determine the usefulness of standard x-ray techniques in observing differences in failed tensile specimens due either to cryogenic or irradiation effects.

The first attempts have been made to confirm effects that were observed in photo-micrographs. When confidence in the techniques is established, materials should be examined in which changes in mechanical properties do not correspond to differences in the photo-micrographs.

Of particular interest are the austenitic steels which are believed to exhibit at least partial phase transformation during deformation at low temperatures. This phase transformation should be altered by previous irradiation, yet such an effect is difficult to observe or measure by optical techniques and should

(13) D. S. Billington and S. Siegel, Met. Prog., 847 (Dec. 1950);
G. T. Murray and W. E. Taylor, Acta Metalorgica, Vol. 2, pp 52 (1954).

be relatively easy to measure by x-ray diffraction techniques.

Also, the degree of lattice distortion in deformed materials is observable with x-rays and such observations will help distinguish between boundary and lattice changes with respect to their effects on mechanical properties.

4.6 PRELIMINARY ELECTRON MICROGRAPH STUDIES

Effort on electron micrograph studies to date has gone into trying standard replication techniques to observe failed specimens as etched for photo-micrograph studies. The trial replicas from one stainless steel and two titanium alloys were observed and photographs were made at 16,000x and 27,000x. The replication technique is quite satisfactory, showing much surface detail.

The problem now is to establish proper etching techniques to be used before replication in order to show the most important cryogenic or irradiation effects.

In addition to looking for gross differences in the deformed materials, the shoulders of the test specimens should be examined, in anticipation of seeing defects or defect clusters introduced directly by irradiation followed by annealing. Such observations would be of real value in attempting to determine the fundamental causes of nuclear cryogenic effects so far observed.

TABLE 1

IN-PILE TEST RESULTS, ALUMINUM 1099 (H-14)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
8 Ba 87	1×10^{17}	49, 200	43, 300	41	54	87, 400
8 Ba 84	1×10^{17} (a)	45, 900 (a)	33, 500 (a)	43 (a)	56 (a)	89, 500 (a)
8 Ba 80	1×10^{17} (b)	45, 800 (b)	31, 000 (b)	46 (b)	67 (b)	107, 000 (b)
		(c)	(c)	(c)	(c)	(c)

(a) interruption of refrigeration at 80% of total accumulated dose caused specimen temperature to increase to about 70° R for about 10 minutes
(b) apparently strained, before irradiation, to about one-half of total elongation
(c) not averaged due to non-identical test conditions

TABLE 2

IN-PILE TEST RESULTS, ALUMINUM 2014 (T-651)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
1 Ba 65	1×10^{17}	81,300	64,900	13	13	93,400
1 Ba 71	1×10^{17}	90,600	78,200	13	21	103,000
1 Ba 72	1×10^{17}	81,900	72,200	12	21	108,000
Average		84,600	71,770	12.7	18.3	101,500

TABLE 3

OUT-OF-PILE TEST RESULTS, ALUMINUM 2014 (T-651)

TEST TEMPERATURE: 30°R

Specimen Number	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST					
1 Ba 49	91,600	56,700	(d)	(d)	(e)
1 Ba 63	92,900	63,100	(d)	(d)	(e)
1 Ba 67	87,100	71,200	16	28	114,000
1 Ba 68	89,100	72,300	19	26	115,000
1 Ba 70	94,800	78,100	18	25	122,000
Average	91,100	68,280	17.6	26.3	117,000
TENSILE NOTCH TEST					
1 Ba 54	101,000	Notch-Unnotched Ratio			
1 Ba 55	98,800				
1 Ba 57	102,000	Avg ÷ Avg 1.11			
1 Ba 58	102,000	High ÷ Low 1.17			
1 Ba 61	102,000	Low ÷ High 1.04			
Average	101,200				

(d) not available
(e) not recorded

TABLE 4

IN-PILE TEST RESULTS, ALUMINUM 2024 (T-351)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
7 Ba 6	1×10^{17}	112,000	(e)	18	16	133,000
7 Ba 9	1×10^{17}	90,600	79,200	15	14	105,000
7 Ba 25	1×10^{17}	100,000	90,600	16	24	133,000
Average		100,900	84,900	16.3	18.0	123,700

(e) Not recorded

TABLE 5

IN-PILE TEST RESULTS, ALUMINUM 2219 (T-87)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
2 Ba 58	1×10^{17}	93, 500	76, 200	15	15	109, 000
2 Ba 61	1×10^{17}	96, 000	77, 200	15	19	113, 000
2 Ba 70	1×10^{17}	91, 700	68, 800	16	21	112, 000
Average		93, 730	74, 070	15.3	18.3	111, 300

TABLE 6

IN-PILE TEST RESULTS, ALUMINUM 5086 (H-32)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
11 Ba 40	1×10^{17}	92,500	61,100	21	18	112,000
11 Ba 68	1×10^{17}	98,600	60,400	27	25	134,000
11 Ba 72	1×10^{17}	91,600	56,900	22	20	115,000
Average		94,230	59,470	23.3	21.0	120,300

TABLE 7

OUT-OF-PILE TEST RESULTS, ALUMINUM 5086 (H-32)

TEST TEMPERATURE: $30^{o}R$

Specimen Number	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST					
11 Ba 50	88,400	31,800	30	29	125,000
11 Ba 51	91,700	39,300	(d)	(d)	(e)
11 Ba 64	97,200	37,000	28	24	128,000
11 Ba 66	91,800	36,600	31	25	122,000
11 Ba 73	90,700	36,200	31	22	116,000
Average	91,960	36,180	30.0	25.0	122,800
TENSILE NOTCH TEST					
		Notch-Unnotched Ratio			
11 Ba 20	70,600	Avg ÷ Avg	0.74		
11 Ba 21	58,600	High ÷ Low	0.86		
11 Ba 22	75,700	Low ÷ High	0.60		
11 Ba 23	68,400				
11 Ba 24	68,700				
Average	68,400				

(d) not available
(e) not recorded

TABLE 8

IN-PILE TEST RESULTS, ALUMINUM 5456 (H-321)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
5 Ba 39	1×10^{17}	90,900	68,900	14	15	107,000
5 Ba 47	1×10^{17}	95,400	64,500	14	18	116,000
(f)						
Average		93,150	66,700	14	16.5	111,500

(f) Screening program ended before completion of normal 3 specimen sample

TABLE 9

IN-PILE TEST RESULTS, ALUMINUM 6061 (T-6)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
12 Ba 61	1×10^{17}	68,100	62,000	30	36	(e)
12 Ba 66	1×10^{17}	64,400	63,700	30	36	100,000
12 Ba 69	1×10^{17}	61,200	52,400	30	32	88,600
Average		64,570	59,370	30	34.7	94,300

(e) Not recorded

TABLE 10

IN-PILE TEST RESULTS, ALUMINUM 7079 (T-6)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
13 Ba 22	1×10^{17}	145,000	138,000	5	3	150,000
13 Ba 25	1×10^{17}	128,000	123,000	5	6	137,000
13 Ba 36	1×10^{17}	128,000	122,000	6	4	133,000
Average		133,700	127,700	5.3	4.3	140,000

TABLE 11

OUT-OF-PILE TEST RESULTS, ALUMINUM 7079 (T-6)

TEST TEMPERATURE: 30°R

Specimen Number	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST					
13 Ba 10	145,000	127,000	9	7	155,000
13 Ba 11	143,000	128,000	8	6	152,000
13 Ba 15	150,000	135,000	7	5	158,000
13 Ba 18	147,000	130,000	2	5	155,000
13 Ba 27	141,000	129,000	3	6	147,000
Average	145,200	129,800	5.8	5.8	153,400
TENSILE NOTCH TEST					
13 Ba 31	142,000	Notch-Unnotched Ratio			
13 Ba 58	156,000				
13 Ba 59	149,000	Avg ÷ Avg 1.05			
13 Ba 62	161,000	High ÷ Low 1.14			
13 Ba 65	151,000	Low ÷ High .95			
Average	151,800				

TABLE 12

IN-PILE TEST RESULTS, ALUMINUM 7178 (T-651)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
10 Bb 135	1×10^{17}	138,000	127,000	7	1	140,000
10 Bb 141	1×10^{17}	130,000	118,000	6	6	139,000
10 Bb 143	1×10^{17}	135,000	119,000	6	6	164,000
Average		134,300	121,300	6.3	4.3	147,700

TABLE 13

IN-PILE TEST RESULTS, ALUMINUM X-250 (T-4)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
4 Ba 12	1×10^{17}	49, 900	(g)	nil	nil	49, 900
4 Ba 14	1×10^{17}	50, 500	(g)	nil	nil	50, 500
4 Ba 23	1×10^{17}	45, 900	(g)	nil	nil	45, 900
Average		48, 770				48, 770

(g) Failed at less than .2% plastic strain

TABLE 14

OUT-OF-PILE TEST RESULTS, ALUMINUM X-250 (T-4)

TEST TEMPERATURE: 30°R

Specimen Number	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST					
4 Ba 16	35,900	(g)	nil	nil	35,900
4 Ba 27	55,800	49,600	nil	nil	55,800
4 Ba 29 (j)	54,400	47,300	(d)	(d)	(d)
4 Ba 40	57,300	50,200	nil	nil	57,300
4 Ba 41	44,600(h, i)	44,600	nil	nil	44,200
Average	49,600	47,930	nil	nil	48,300
TENSILE NOTCH TEST					
		Notch-Unnotched Ratio			
4 Ba 3	51,400	Avg ÷ Avg	1.07		
4 Ba 4	53,200 (h, i)	High ÷ Low	1.52		
4 Ba 5	51,000	Low ÷ High	.89		
4 Ba 22	54,700				
4 Ba 30	53,900				
Average	52,840				

(d) not available
(g) failed at less than .2% plastic strain
(h) failed outside of gage length
(i) casting defect at fracture
(j) previously reported in Quarterly Progress Report No. 9, ER-6219

TABLE 15

IN-PILE TEST RESULTS, ALUMINUM B-750 (T-5)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
6 Ba 51	1×10^{17}	44,200	40,800	4	1	44,600
6 Ba 79	1×10^{17}	48,800	43,900	3	2	50,000
6 Ba 81	1×10^{17}	45,000	42,400	3	1	45,600
Average		46,000	42,400	3.3	1.3	46,700

TABLE 16

IN-PILE TEST RESULTS, ALUMINUM A356 (T-61)

TEST TEMPERATURE: 30^{o} R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
14 Ba 10	1×10^{17}	61, 200	47, 000	9	8	66, 400
14 Ba 48	1×10^{17}	63, 300	46, 000	7	7	68, 100
14 Ba 69	1×10^{17}	61, 800	45, 400	10	10	68, 400
Average		62, 100	46, 130	8.7	8.3	67, 630

TABLE 17

OUT-OF-PILE TEST RESULTS, ALUMINUM A356 (T-61)

TEST TEMPERATURE: $30^{\circ}R$

Specimen Number	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST					
14 Ba 15	59,700	31,200	12	16	71,100
14 Ba 74	67,500	37,200	12	10	75,100
14 Ba 77	75,600	43,100	15	12	86,000
14 Ba 90	65,300	40,500	12	7	70,500
14 Ba 93	54,600	35,900	7	2	55,600
Average	64,540	37,580	11.6	9.4	71,660
TENSILE NOTCH TEST					
14 Ba 32	76,500	Notch-Unnotched Ratio			
14 Ba 35	61,800				
14 Ba 43	58,900	Avg ÷ Avg	1.02		
14 Ba 46	67,800	High ÷ Low	1.40		
14 Ba 68	64,100	Low ÷ High	.78		
Average	65,820				

TABLE 18

SUMMARY OF TEST RESULTS, ALUMINUM 1099 (H-14)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated (j, l)		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of One Test	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	13, 220	34, 160	+158%	49, 200 (p)	+44%
Tensile Yield Strength, F_{ty}, psi	12, 480	7, 950	-36%	43, 300 (p)	+445%
F_{ty}/F_{tu} Ratio	0.94	0.23	-76%	0.88 (p)	+283%
Tensile Notch (K_t = 6), psi	16, 120	47, 160	+192%	(q)	(q)
Notched-Unnotched Ratio	1.22	1.38	+13%	(q)	(q)
Fracture Stress, psi	(e)	110, 000	(e)	87, 400 (p)	-21%
Elongation in 1/2" (4D), %	22.8	61.4	+169%	41 (p)	-33%
Reduction of Area, %	78.8	71.2	-10%	54 (p)	-24%

(e) not recorded
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(p) one test only
(q) test deleted from screening program

TABLE 19

SUMMARY OF TEST RESULTS, ALUMINUM 2014 (T-651)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	65,280	91,100	+ 40%	84,600	-7%
Tensile Yield Strength, F_{ty}, psi	60,340	68,280	+ 13%	71,770	+ 5%
F_{ty}/F_{tu} Ratio	0.92	0.75	-18%	0.85	+13%
Tensile Notch (K_t = 6), psi	79,500	101,200 (j, l)	+ 27%	(q)	(q)
Notched-Unnotched Ratio	1.22	1.11	-9%	(q)	(q)
Fracture Stress, psi	(e)	117,000 (n)	(e)	101,500	-13%
Elongation in 1/2" (4D), %	12.2	17.6 (n)	+ 44%	12.7	-28%
Reduction of Area, %	35.0	26.3 (n)	-24%	18.3	-30%

(e) not recorded
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(n) three tests only
(q) test deleted from screening program

TABLE 20

SUMMARY OF TEST RESULTS, ALUMINUM 2024 (T-351)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated (j, l)		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	67,080	106,600	+ 59%	100,900	-5%
Tensile Yield Strength, F_{ty}, psi	50,300	77,200	+ 53%	84,900 (o)	+ 10%
F_{ty}/F_{tu} Ratio	0.75	0.72	-4%	0.79	+ 10%
Tensile Notch ($K_t = 6$), psi	72,820	95,640	+ 31%	(q)	(q)
Notched-Unnotched Ratio	1.45	1.24	-14%	(q)	(q)
Fracture Stress, psi	(e)	(e)	(e)	123,700	(e)
Elongation in 1/2" (4D), %	21.2	22.3 (m)	+ 5%	16.3	-27%
Reduction of Area, %	28.2	20.3 (m)	-28%	18.0	-11%

(e) not recorded
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(m) four tests only
(o) two tests only
(q) test deleted from screening program

TABLE 21

SUMMARY OF TEST RESULTS, ALUMINUM 2219 (T-87)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated (j, l)		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	59,040	95,860	+62%	93,730	-2%
Tensile Yield Strength, F_{ty}, psi	48,020	68,180	+42%	74,070	+9%
F_{ty}/F_{tu} Ratio	0.81	0.71	-12%	0.79	+11%
Tensile Notch (K_t = 6), psi	74,680	98,100	+31%	(q)	(q)
Notched-Unnotched Ratio	1.26	1.02	-19%	(q)	(q)
Fracture Stress, psi	52,400 (p)	(e)	(e)	111,300	(e)
Elongation in 1/2" (4D), %	13.8 (m)	16.4	+19%	15.3	-7%
Reduction of Area, %	32.2	27.2	-16%	18.3	-33%

(e) not recorded
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(p) one test only
(q) test deleted from screening program
(m) four tests only

TABLE 22

SUMMARY OF TEST RESULTS, ALUMINUM 5086 (H-32)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	45,460	91,960	+102%	94,230	+2%
Tensile Yield Strength, F_{ty}, psi	32,080	36,180	+ 13%	59,470	+64%
F_{ty}/F_{tu} Ratio	0.71	0.39	-45%	0.63	+62%
Tensile Notch ($K_t = 6$), psi	52,880	68,400 (j)	+ 29%	(q)	(q)
Notched-Unnotched Ratio	1.16	0.74	-36%	(q)	(q)
Fracture Stress, psi	56,400 (n)	122,800 (m)	+118%	120,300	-2%
Elongation in 1/2" (4D), %	10	30 (m)	+200%	23.3	-22%
Reduction of Area, %	23.4	25 (m)	+ 7%	21.0	-16%

(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(m) four tests only
(n) three tests only
(q) test deleted from screening program

TABLE 23

SUMMARY OF TEST RESULTS, ALUMINUM 5456 (H-321)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, 1)	30° R, Unirradiated (j, l)		30° R, Irradiated to 1 x 10^{17} nvt Fast Neutrons (f)	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	49,900	92,200	+85%	93,150	+ 1%
Tensile Yield Strength, F_{ty}, psi	34,000	43,860	+29%	66,700	+52%
F_{ty}/F_{tu} Ratio	0.68	0.48	-29%	0.72	+50%
Tensile Notch (K_t = 6), psi	59,580	69,100	+16%	(q)	(q)
Notched-Unnotched Ratio	1.19	0.75	-37	(q)	(q)
Fracture Stress, psi	(e)	113,000 (p)	(e)	111,500	-1%
Elongation in 1/2" (4D), %	12.8	18.2	+ 4%	14	-23%
Reduction of Area, %	10.4	16.8	+62%	16.5	- 2%

(e) not recorded
(f) screening program ended before completion of normal 3 specimen sample
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(p) one test only
(q) test deleted from screening program

TABLE 24

SUMMARY OF TEST RESULTS, ALUMINUM 6061 (T-6)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated (j, l)		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	43,360	68,140	+57%	64,570	-5%
Tensile Yield Strength, F_{ty}, psi	40,000	50,420	+26%	59,370	18%
F_{ty}/F_{tu} Ratio	0.92	0.74	-20%	0.92	+24%
Tensile Notch (K_t = 6), psi	51,740	72,960	+41%	(q)	(q)
Notched-Unnotched Ratio	1.19	1.07	-10%	(q)	(q)
Fracture Stress, psi	(e)	(e)	(e)	94,300 (o)	(e)
Elongation in 1/2" (4D), %	18.8	30.4	+62%	30.0 (o)	-1%
Reduction of Area, %	48.3 (m)	40.6	-16%	34.0 (o)	-16%

(e) not recorded
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(m) four tests only
(o) two tests only
(q) test deleted from screening program

TABLE 25

SUMMARY OF TEST RESULTS, ALUMINUM 7079 (T-6)

Property	Test Conditions				
	Room Temperature, Unirradiated (k, l)	30° R, Unirradiated		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	93,920	145,200	+55%	133,700	-8%
Tensile Yield Strength, F_{ty}, psi	90,160	129,800	+44%	127,700	-2%
F_{ty}/F_{tu} Ratio	0.96	0.89	-7.2%	0.96	+8%
Tensile Notch ($K_t = 6$), psi	108,200	151,800	+40%	(q)	(q)
Notched-Unnotched Ratio	1.15	1.05	-9%	(q)	(q)
Fracture Stress, psi	103,500 (o)	153,400	+48%	140,000	-9%
Elongation in 1/2" (4D), %	11.4	5.8	-49%	5.3	-9%
Reduction of Area, %	25.0	5.8	-78%	4.3	-26%

(k) previously reported in Quarterly Progress Report No. 13, ER-6929

(l) some differences due to additional testing or refinement of data

(o) two tests only

(q) test deleted from screening program

TABLE 26

SUMMARY OF TEST RESULTS, ALUMINUM 7178 (T-651)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated (j, l)		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	87,680	129,000	+ 47%	134,300	+ 4%
Tensile Yield Strength, F_{ty}, psi	80,480	108,000	+ 34%	121,300	+ 12%
F_{ty}/F_{tu} Ratio	0.92	0.84	-9%	0.90	+7%
Tensile Notch (K_t = 6), psi	100,300	128,200	+ 28%	(q)	(q)
Notched-Unnotched Ratio	1.14	0.99	-13%	(q)	(q)
Fracture Stress, psi	(e)	(e)	(e)	147,700	(e)
Elongation in 1/2" (4D), %	12.0	12.4	+3%	6.3	-49%
Reduction of Area, %	22.8	13.0	-43%	4.3	-67%

(e) not recorded
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(q) test deleted from screening program

TABLE 27

SUMMARY OF TEST RESULTS, ALUMINUM X-250 (T-4)

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated (j, l)		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	55,600	49,600	-11%	48,770	-2%
Tensile Yield Strength, F_{ty}, psi	32,460	47,930 (m)	+48%	(g)	(e)
F_{ty}/F_{tu} Ratio	0.58	0.97	+67%	(e)	(e)
Tensile Notch (K_t = 6), psi	58,540	52,840	-10%	(q)	(q)
Notched-Unnotched Ratio	1.05	1.07	+ 2%	(q)	(q)
Fracture Stress, psi	(e)	48,300	(e)	48,770	+ 1%
Elongation in 1/2" (4D), %	21.5 (m)	nil	-100%	nil	nil
Reduction of Area, %	18.0	nil	-100%	nil	nil

(e) not recorded
(g) failed at less than .2% plastic strain
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(m) four tests only
(q) test deleted from screening program

TABLE 28

SUMMARY OF TEST RESULTS, ALUMINUM B-750

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R, Unirradiated (j, l)		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	29,360	42,580	+ 45%	46,000	+ 8%
Tensile Yield Strength, F_{ty}, psi	19,460	25,180	+ 29%	42,400	+ 68%
F_{ty}/F_{tu} Ratio	0.66	0.59	-9%	0.92	+ 56%
Tensile Notch (K_t = 6), psi	31,100 (m)	31,150 (m)	nil	(q)	(q)
Notched-Unnotched Ratio	1.06	0.73	-31%	(q)	(q)
Fracture Stress, psi	(e)	(e)	(e)	46,700	(e)
Elongation in 1/2" (4D), %	8.8	7.0 (n)	-20%	3.3	-53%
Reduction of Area, %	10.4	4.0 (m)	-62%	1.3	-68%

(e) not recorded
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(m) four tests only
(n) three tests only
(q) test deleted from screening program

TABLE 29

SUMMARY OF TEST RESULTS, ALUMINUM A-356

Property	Test Conditions				
	Room Temperature, Unirradiated (k, l)	30° R, Unirradiated		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	44,100	64,540	+ 46%	62,100	-4%
Tensile Yield Strength, F_{ty}, psi	30,300	37,580	+ 24%	46,130	+ 23%
F_{ty}/F_{tu} Ratio	0.69	0.58	-16%	0.74	+ 28%
Tensile Notch (K_t = 6), psi	51,360	65,820	+ 28%	(q)	(q)
Notched-Unnotched Ratio	1.16	1.02	-12%	(q)	(q)
Fracture Stress, psi	54,520	71,660	+ 31%	67,630	-6%
Elongation in 1/2" (4D), %	14.6	11.6	-21%	8.7	-25%
Reduction of Area, %	18.4	9.4	-49%	8.3	-12%

(k) previously reported in Quarterly Progress Report No. 13, ER-6929

(l) some differences due to additional testing or refinement of data

(q) test deleted from screening program

TABLE 30

IN-PILE TEST RESULTS, STAINLESS STEEL A-353

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
5 Ca 29	1×10^{17}	209,000	183,000	16	20	255,000
5 Ca 36	1×10^{17}	220,000	194,000	12	9	241,000
5 Ca 45	1×10^{17}	218,000	193,000	19	35	285,000
Average		215,700	190,000	15.6	21.3	260,300

TABLE 31

IN-PILE TEST RESULTS, STAINLESS STEEL 17-7 PH (RH-950)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
11 Ca 28	1×10^{17}	260,000	260,000	2	nil	260,000
11 Ca 32	1×10^{17}	256,000	254,000	2	nil	256,000
11 Ca 46	1×10^{17}	238,000	238,000	2	nil	238,000
Average		251,300	250,700	2.0	nil	251,300

TABLE 32

OUT-OF-PILE TEST RESULTS, STAINLESS STEEL 17-7 PH (RH-950)

TEST TEMPERATURE: 30°R

Specimen Number	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST					
11 Ca 12	342,000	333,000	(d)	(d)	(d)
11 Ca 29	340,000	334,000	2	1	345,000
11 Ca 30	324,000	319,000	3	nil	(e)
11 Ca 31	332,000	327,000	3	nil	(e)
11 Ca 39	327,000	326,000	3	4	342,000
Average	333,000	327,800	2.8	1.2	343,500
TENSILE NOTCH TEST					
11 Ca 10	182,000	Notch-Unnotched Ratio			
11 Ca 18	193,000				
11 Ca 21	220,000	Avg ÷ Avg	0.55		
11 Ca 33	169,000	High ÷ Low	0.68		
11 Ca 35	149,000	Low ÷ High	0.44		
Average	182,600				

(d) not available
(e) not recorded

TABLE 33

IN-PILE TEST RESULTS, AUSTENITIC MANGANESE STEEL (T-450)

TEST TEMPERATURE: 30° R

Specimen Number	Total Accumulated Fast Neutron Dose (nvt)	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST						
1 Eb 24	1×10^{17}	193,000	92,400	32	28	270,000
1 Eb 28	1×10^{17}	194,000	92,400	30	30	276,000
1 Eb 49	1×10^{17}	191,000	92,000	29	31	277,000
Average		192,700	92,270	30.3	29.7	274,300

TABLE 34

OUT-OF-PILE TEST RESULTS, AUSTENITIC MANGANESE STEEL (T-450)

TEST TEMPERATURE: 30°R

Specimen Number	Ultimate Tensile Strength (F_{tu} in psi)	Tensile Yield Strength (F_{ty} in psi)	Elongation in 1/2" (4 Dia.), %	Reduction of Area, %	Fracture Stress, psi
TENSILE TEST					
1 Eb 4	210,000	105,000	28	24	275,000
1 Eb 10	190,000	81,000	30	26	258,000
1 Eb 18	194,000	92,400	32	30	277,000
1 Eb 31	193,000	89,500	30	29	274,000
1 Eb 34	199,000	89,400	36	27	273,000
Average	197,200	91,460	31.2	27.2	271,400
TENSILE NOTCH TEST					
		Notch-Unnotched Ratio			
1 Eb 9	222,000				
1 Eb 13	236,000	Avg ÷ Avg	1.09		
1 Eb 23	216,000	High ÷ Low	1.24		
1 Eb 44	191,000	Low ÷ High	0.91		
1 Eb 46	207,000				
Average	214,400				

TABLE 35

SUMMARY OF TEST RESULTS, STAINLESS STEEL A-353

Property	Test Conditions				
	Room Temperature, Unirradiated (j, l)	30° R Unirradiated (j, l)		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	110,600	201,600	+ 82%	215,700	+ 7%
Tensile Yield Strength, F_{ty}, psi	88,600	174,800	+ 97%	190,000	+ 9%
F_{ty}/F_{tu} Ratio	0.80	0.87	+ 9%	0.88	+ 1%
Tensile Notch (K_t = 6), psi	137,000	180,200	+ 32%	(q)	(q)
Notched-Unnotched Ratio	1.24	0.89	-28%	(q)	(q)
Fracture Stress, psi	(e)	(e)	(e)	260,300	(e)
Elongation in 1/2" (4D), %	26.4	20.3 (m)	-23%	15.6	-23%
Reduction of Area, %	69.4	47.8 (m)	-31%	21.3	-55%

(e) not recorded
(j) previously reported in Quarterly Progress Report No. 9, ER-6219
(l) some differences due to additional testing or refinement of data
(m) four tests only
(q) test deleted from screening program

TABLE 36

SUMMARY OF TEST RESULTS, STAINLESS STEEL 17-7PH (RH-950)

Property	Test Conditions				
	Room Temperature, Unirradiated (k, l)	30^{o} R, Unirradiated		30^{o} R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Three Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	234,800	333,000	+ 42%	251,300	-25%
Tensile Yield Strength, F_{ty}, psi	226,600	327,800	+ 45%	250,700	-24%
F_{ty}/F_{tu} Ratio	0.97	0.98	+ 1%	1.00	+ 2%
Tensile Notch (K_t = 6), psi	266,600	182,600	-32%	(q)	(q)
Notched-Unnotched Ratio	1.14	.55	-52%	(q)	(q)
Fracture Stress, psi	284,000 (o)	343,500 (o)	+ 21%	251,300	-27%
Elongation in 1/2" (4D), %	13.8	2.8 (m)	-80%	2.0	-29%
Reduction of Area, %	41.6	1.2 (m)	-97%	nil	-100%

(k) previously reported in Quarterly Progress Report No. 13, ER-6929
(l) some differences due to additional testing or refinement of data
(m) four tests only
(o) two tests only
(q) test deleted from screening program

TABLE 37

SUMMARY OF TEST RESULTS, AUSTENITIC MANGANESE STEEL (T-450)

Property	Test Conditions				
	Room Temperature, Unirradiated (k, l)	30° R, Unirradiated		30° R, Irradiated to 1×10^{17} nvt Fast Neutrons	
	Test Data, Average of Five Tests	Test Data Average of Five Tests	Net Change Due to Temperature	Test Data Average of Five Tests	Net Change Due to Irradiation
Ultimate Tensile Strength, F_{tu}, psi	112,200	197,200	+76%	192,700	-2%
Tensile Yield Strength, F_{ty}, psi	36,340	91,460	+152%	92,270	+ 1%
F_{ty}/F_{tu} Ratio	0.32	0.46	+ 44%	0.48	+ 4%
Tensile Notch (K_t = 6), psi	120,200	214,400	+ 78%	(q)	(q)
Notched-Unnotched Ratio	1.07	1.09	+ 2%	(q)	(q)
Fracture Stress, psi	385,500 (o)	271,400	-30%	274,300	+ 1%
Elongation in 1/2" (4D), %	70.2	31.2	-56%	30.3	-3%
Reduction of Area, %	71.0	27.2	-62%	29.7	+ 9%

(k) previously reported in Quarterly Progress Report No. 13, ER-6929
(l) some differences due to additional testing or refinement of data
(o) two tests only
(q) test deleted from screening program

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