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AN EVALUATION OF THE MECHANICAL AND STRESS CORROSION PROPERTIES OF COLD WORKED A-286 ALLOY

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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

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16. ABSTRACT

This report presents the mechanical properties of cold worked, precipitation hardened, A-286 corrosion resistant bar stock manufactured by three different steel companies to the requirements of MSFC specification 145. Test specimens manufactured from approximately 1.0 inch (2.54 cm) diameter bar stock were tested at temperatures from 75°F (23.9°C) to -423°F (-253°C). The test data indicated excellent tensile strength, ductility, and impact properties.

Results of the alternate immersion stress corrosion tests on stressed and unstressed tensile specimens [0.125-inch (.3175 cm) diameter] and transverse "C" ring specimens [machined from 1.0 inch (2.54 cm) diameter bars] indicated that the material is not susceptible to stress corrosion cracking when tested in a 3.5 percent NaCl solution for 180 days.

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SUMMARY

The mechanical properties of 40 percent minimum cold worked, precipitation hardened, A-286 corrosion resistant bar stock were determined for the temperature range of 75°F (23.9°C) to -423°F (-253°C). The ultimate tensile and yield strengths of the material increased with decreasing temperatures, as did the elongation values. The percent reduction in area changed very little with decreasing temperature to -200°F (-129°C) and then gradually decreased in value down to liquid hydrogen temperature.

Results of the alternate immersion stress corrosion tests in stressed and unstressed longitudinal tensile specimens [0.125-inch (.3175 cm) diameter] and transverse "C"-ring specimens machined from approximately 1.0-inch (2.54 cm) diameter bars indicated that the material is not susceptible to stress corrosion cracking when tested in a 3.5 percent NaCl solution for 180 days.

INTRODUCTION

Due to the numerous problems associated with the thermal treatment, procurement, and processing of AM-355 stainless steel used in the manufacturing of MC-125 sleeves for space vehicle applications, the Materials Division (Astronautics Laboratory) has pursued an evaluation program to determine acceptable alloys for MC sleeves and similar space vehicle applications. Candidate materials were evaluated on the criteria of stress corrosion susceptibility, chemical composition, microstructure, microhardness, tensile and yield strength, elongation and reduction in area.

Information obtained from manufacturers relative to MC sleeve applications indicated that cold worked A-286 material was preferred over Unitemp 212, Waspaloy and Inconel 718, based on cost, and machinability.

Our initial evaluation of cold worked A-286 material consisted of studies made on 7/16 inch (1.111 cm), 9/16 inch (1.43 cm), 3/4 inch (1.90 cm) and 1.0 inch (2.54 cm) diameter round bar stock fabricated from consumable electrode vacuum melted ingot by the Universal Cyclops Steel Company. Additional studies have been made on Carpenter Steel Company's consumable electrode melted, cold worked bar stock and Armco Steel Company's vacuum-arc remelted cold worked bar stock material.

EQUIPMENT AND TEST SPECIMENS

The equipment used in this evaluation is described in reports by Miller (Ref. 1) and Williamson (Ref. 2). Fractured tensile test specimens are illustrated in Figure 1.

The chemical composition of the material used in the investigation is shown in Table I. Prior to machining into test specimens, the material was processed as follows:

Solution Treatment: 1800°F (982°C) - Two hours - Water quench
Mechanical Treatment: Cold drawn 40 percent minimum, straightened, centerless ground.
Aging Treatment: 1200°F (649°C) - 16 Hours - Air cool.

Microhardness readings as shown in Figure 2 indicated consistent cold work with little difference in hardness.

The stress corrosion investigation testing procedure is outlined below:

Company	Test Specimen	Stress (% of Y.S.)	Specimens per Stress Level
Armco	"C"-Ring	75, and 100	3
	Tensile	0, 75, and 100	6
Carpenter	"C"-Ring	50, 75, 90, and 100	4
	Tensile	75, 90, and 100	3
Universal-Cyclops	"C"-Ring	25, 50, 75, 90 and 100	3
	Tensile	0, 75, and 100	3

The "C"-ring specimens were stressed in the transverse direction by the constant deflection method explained in Appendix 1, and were placed in a 3.5 percent NaCl solution for 180 days of alternate immersion testing (10 minutes in solution, 50 minutes above solution). Longitudinal tensile specimens were also stressed up to 100 percent of the 0.2 percent yield strengths and subjected to the same stress corrosion test.

RESULTS AND DISCUSSION

The tensile test results of the ambient through cryogenic temperature mechanical properties evaluation are tabulated in Tables II, III, IV and VI, and are plotted in Figures 3 through 8. Table V contains double shear test data and Table VII contains charpy V-notched impact test data. These data indicate that cold worked A-286 material increases in ultimate tensile and yield strength with decreasing temperature. They also indicate good ductility and reduction in area at cryogenic temperatures. The notched to unnotched tensile ratio remains above 1.0 at testing temperatures of 75°F (23.9°C) to -423°C (-252.8°C) and the charpy V-notched impact strength remains fairly constant from ambient to liquid nitrogen test temperatures. Shear ultimate and shear yield (approximated by deflectometer measurement) increased with decreasing temperatures.

Typical test specimens as shown in Figures 9-13 indicated no evidence of stress corrosion in the "C"-rings or the tensile specimens after 180 days of alternate immersion testing. Tensile tests were made on the longitudinal tensile specimens after the 180 day alternate immersion test and these data are tabulated in Tables VIII to X. These data show no degradation of mechanical properties indicating excellent resistance to stress corrosion under the test conditions used in this program.

The microstructure of the test materials illustrated in Figures 14 to 16, indicates the effects of cold work. This type "herringbone" structure is discussed in detail in Ref. 3 and 4.

CONCLUSIONS

Based upon the results of this evaluation, A-286 precipitation hardenable alloy properties such as ultimate tensile, yield and shear strengths are increased over conventional solution treated and aged materials by cold working, and these properties are further enhanced by decreasing temperature. Elongation, reduction in area, and charpy V-notched values suffer somewhat due to the cold work; however, these values are still well within acceptable limits for cryogenic application when compared with other high strength steels.

The stress corrosion resistance of A-286, as evaluated by alternate immersion testing in a 3.5 percent NaCl solution, is not affected by cold working up to 53 percent cold reduction even when the test specimens are stressed to 100 percent of the 0.2 percent offset longitudinal yield strength.

This evaluation indicates that A-286 material (solution treated, cold worked, and aged) as tested in this program, is acceptable for MC-125 fittings and similar applications.

REFERENCES

1. Miller, P. C.: "Low Temperature Mechanical Properties of Several Aluminum Alloys and Their Weldments," MTP-S&E-M-61-16, October 1961.

2. Williamson, J. G.: "Stress Corrosion Studies of AM-355 Stainless Steel," NASA TM X-53317, August, 1961.

3. DMIC Memo 59, "Metallurgical Characteristics of A-286 Alloy," dated July 26, 1960.

4. Metcalf, Kenneth, "Solve Lamellar Phase Problems in A-286," Iron Age, Vol. 182, No. 1, July 3, 1958, pp 73-74.

APPENDIX 1

METHOD FOR STRESSING "C"-RING STRESS CORROSION SPECIMENS

The following is a procedure for stressing "C"-ring stress corrosion specimens:

1. Measure with a micrometer to the nearest 1/1000 of an inch the outside parallel to the stressing screw (averaging the two ends of the ring) and the wall thickness.

2. Set up a table to calculate the final diameter (OD_f) required to give the desired stress using the following equations:

$$OD_f = OD - \Delta$$

$$\Delta = \frac{f \cdot \pi \cdot D^2}{4 \cdot E \cdot t \cdot Z}$$

where
Δ = Change of OD giving desired stress, inches
f = Desired stress, psi
OD = Outside diameter, inches
t = Wall thickness, inches
D = Mean diameter (OD-t), inches
E = Modulus of elasticity
Z = Constant (function of ring D/t)

OD_f = Final outside diameter of stress "C"-ring, inches

3. To simplify calculations, certain terms in the above equation may be combined into a constant that will be applicable for a group of rings of the same alloy and size.

Let $\frac{4 \cdot E}{\pi} = K$, a constant

Then $\Delta = \frac{f \cdot D^2}{K \cdot t \cdot Z}$

TABLE I

CHEMICAL COMPOSITION OF A-286 ALLOY BAR STOCK

	Fe	Ni	Cr	Ti	Mo	V	C	B	Mn	Si	P	S	Al
Armco Steel Analysis (1)	Bal	24.85	14.89	2.18	1.24	0.41	.044	.006	1.51	0.48	.009	.005	0.11
MSFC Analysis	Bal	25.04	14.90	2.20	1.03	0.36	.037	.008	1.55	0.50	-	-	0.11
Carpenter Steel Analysis (2)	Bal	25.40	14.20	2.05	1.33	0.25	.05	.004	1.51	0.50	.014	.004	0.25
MSFC Analysis	Bal	26.20	14.70	2.30	1.17	0.28	.06	.007	1.52	0.52	-	-	0.28
Universal Cyclops Analysis (3)	Bal	25.14	14.50	2.14	1.25	0.27	.07	.005	1.24	0.62	.022	.008	0.21
MSFC Analysis	Bal	25.20	15.08	2.40	1.20	0.37	.08	.006	1.25	0.58	< .02	.008	0.17
Universal Cyclops Analysis (4)	Bal	24.95	14.32	2.10	1.38	0.22	.045	.004	1.31	0.61	.020	.005	0.25
MSFC Analysis	Bal	25.26	14.91	2.03	1.32	0.24	.060	.006	1.57	0.54	< .02	.005	0.24

1. Armco Heat No. 2V0151
2. Carpenter Heat No. 68950
3. Universal Cyclops Heat No. G-1111-K-14 [7/16" (1.11 cm), 3/4" (1.90 cm), 1.0" (2.54 cm) Diameter]
4. Universal Cyclops Heat No. H.T. C-6256 KI [9/16" (1.428 cm) Diameter]

TABLE II -

LOW TEMPERATURE MECHANICAL PROPERTIES OF ARMCO A-286 TENSILE SPECIMENS
[.125-INCH (.3175 cm) DIAMETER] COLD WORKED 53 PERCENT AND AGED

Test Temp °F (°C)	U.T.S. ksi (GN/m^2)	.2% Offset Y.S. ksi (GN/m^2)	Elongation in 1/2 Inch (1.27 cm) (4D%)	Reduction of Area (Percent)	Number of Tests
75 (23.9)	208.2 (1.435)	193.4 (1.333)	14.0	42.32	2
-100 (-73.0)	222.2 (1.532)	212.4 (1.464)	14.0	41.28	2
-200 (.129.0)	230.6 (1.590)	219.0 (1.510)	18.3	41.83	3
-320 (-196.0)	258.3 (1.781)	229.5 (1.582)	21.0	41.44	3
-423 (-252.8)	285.4 (1.968)	247.8 (1.708)	23.3	38.93	3

TABLE III

LOW TEMPERATURE MECHANICAL PROPERTIES OF CARPENTER A-286 TENSILE SPECIMENS
[.250-INCH (.635 cm) DIAMETER] COLD WORKED 40 PERCENT MINIMUM AND AGED

Test Temp °F (°C)	U.T.S. ksi (GN/m^2)	.2% Offset Y.S. ksi (GN/m^2)	Elongation In 1/2-Inch (1.27 cm) (2D%)	Elongation In 1.0 Inch (2.54 cm) (4D%)	Reduction In Area (%)	Modulus X10^{-6} psi (N/m^2)	Number of Tests
75 (23.9)	197.0 (1.358)	183.1 (1.262)	19.7	14.0	43.7	30.8 (212.4)	5
0 (-17.8)	203.1 (1.400)	187.9 (1.295)	20.0	16.0	43.8	29.0 (199.9)	5
-100 (-73.0)	214.0 (1.475)	194.3 (1.340)	22.5	18.0	44.6	30.4 (209.6)	5
-200 (-129.0)	223.3 (1.539)	201.8 (1.391)	23.5	17.5	44.4	30.9 (213.0)	5
-320 (-196.0)	253.4 (1.747)	221.7 (1.528)	26.2	20.0	42.8	- -	5
-423 (-252.8)	281.2 (1.939)	237.5 (1.637)	24.8	19.0	36.0	- -	6

TABLE IV

LOW TEMPERATURE MECHANICAL PROPERTIES OF CARPENTER A-286 TENSILE SPECIMENS [.500-INCH (1.27 cm) DIAMETER] COLD WORKED 40 PERCENT MINIMUM AND AGED

Test Temp °F (°C)	U.T.S. ksi (GN/m^2)	.2% Offset Y.S. ksi (GN/m^2)	Elongation In 2.0 Inch (5.08 cm) (4D%)	R.A. (%)	Modulus $X10^{-6}$ psi (N/M^2)	N.T.S. Kt=10 ksi (GN/m^2)	N/U Ratio	Number of Tests
75 (23.9)	202.0 (1.393)	194.5 (1.341)	12.75	39.8	28.1 (193.7)	313.8 (216.3)	1.55	2
-320 (-196.0)	256.0 (1.765)	228.8 (1.577)	20.25	41.2	32.8 (226.1)	328.7 (226.6)	1.28	2
-423 (-252.8)	274.5 (1.893)	248.7 (1.715)	16.70	32.9	32.5 (224.1)	346.3 (238.8)	1.26	3

TABLE V

DOUBLE SHEAR TEST DATA FOR CARPENTER A-286 SHEAR SPECIMENS, [.312 -INCH (.7935 cm) DIAMETER] COLD WORKED 40 PERCENT MINIMUM AND AGED

Test Temp °F (°C)	Ultimate Shear Strength ksi (GN/m²)	0.2% Offset Shear Yield ksi (GN/m²)	Number of Tests
75 (23.9)	110.8 (0.764)	95.7 (0.660)	4
-320 (-196.0)	151.1 (1.042)	109.9 (0.758)	3

TABLE VI

LOW TEMPERATURE MECHANICAL PROPERTIES OF U-CYCLOPS A-286 TENSILE SPECIMENS
[.125-INCH (.3175 cm) DIAMETER] COLD WORKED 40 PERCENT MINIMUM AND AGED

Test Temp °F (°C)	U.T.S. ksi (GN/m^2)	0.2% Offset Y.S. ksi (GN/m^2)	Elongation In 1/2 Inch (1.27 cm) (4D%)	Reduction of Area (Percent)	Number of Tests
75 (23.9)	200.1 (1.379)	183.4 (1.264)	11.3	40.0	3
-100 (-73.0)	220.2 (1.518)	197.8 (1.364)	14.0	39.9	3
-200 (-129.0)	231.9 (1.599)	200.0 (1.379)	12.0	38.1	3
-320 (-196.0)	255.3 (1.760)	213.8 (1.474)	17.2	33.0	4
-423 (-252.8)	282.4 (1.947)	245.9 (1.695)	20.8	35.1	5

TABLE VII

CHARPY V-NOTCHED IMPACT TEST DATA FOR COLD WORKED A-286 BAR SPECIMENS

Company	Test Temp °F (°C)	Average Impact Energy Ft-Lb (Joules)	Impact Energy Range Ft-Lb (Joules)	Number of Tests
Armco	75 (23.9)	18.50 (25.08)	18.25-19.50 (24.74-26.44)	4
	-320 (-196.0)	18.40 (24.95)	18.00-19.50 (24.40-26.44)	4
Carpenter	75 (23.9)	29.00 (39.32)	27.50-30.00 (37.28-40.67)	3
	-320 (-196.0)	26.25 (35.59)	26.00-26.50 (35.25-35.93)	3
Universal-Cyclops	75 (23.9)	16.10 (21.83)	15.00-17.50 (20.34-23.73)	4
	-320 (-196.0)	15.90 (21.56)	14.50-19.50 (19.06-26.44)	4

TABLE VIII

MECHANICAL PROPERTIES OF ARMCO A-286 LONGITUDINAL TENSILE SPECIMENS [0.125 INCH (.3175 cm) DIAMETER] COLD WORKED 53 PERCENT, AGED, STRESSED, AND EXPOSED TO ALTERNATE IMMERSION TESTING IN A 3.5 PERCENT NaCl BATH

Exposure Time Days	Applied Stress Percent of Yield Strength	U.T.S. ksi (GN/m^2)	0.2% Offset Y.S. ksi (GN/m^2)	Elongation In 1/2 Inch (1.27 cm) (4D%)	R.A. (%)	Modulus $X10^{-6}$ psi (N/m^2)	Number of Tests
0	0	208.2 (1.435)	193.4 (1.333)	14.0	42.3	31.4 (216.5)	2
30	0	206.8 (1.426)	194.1 (1.338)	13.0	42.4	29.7 (204.8)	1
30	75	203.8 (1.405)	200.8 (1.384)	12.0	42.9	32.6 (225.8)	1
30	100	210.6 (1.452)	209.7 (1.446)	11.0	40.7	27.5 (189.6)	1
90	0	206.7 (1.425)	196.0 (1.351)	15.0	42.7	29.2 (201.3)	1
90	75	207.6 (1.431)	197.3 (1.360)	15.0	42.9	29.9 (206.1)	1
90	100	208.4 (1.437)	204.2 (1.408)	15.0	42.9	29.2 (201.3)	1
150	0	207.7 (1.432)	197.0 (1.358)	12.0	42.7	28.4 (195.8)	1
150	75	209.2 (1.442)	200.0 (1.379)	12.0	41.2	27.3 (188.2)	1
150	100	209.8 (1.446)	206.4 (1.423)	12.0	42.4	25.8 (177.9)	1
180	0	206.5 (1.424)	196.6 (1.355)	11.3	42.50	28.3 (195.1)	3
180	75	204.6 (1.411)	195.3 (1.346)	16.7	42.54	28.5 (196.5)	3
180	100	205.8 (1.419)	200.6 (1.383)	16.0	42.54	28.2 (194.4)	3

Manual Cross Head Movement = 0.025 Inch/Minute

TABLE IX

MECHANICAL PROPERTIES OF CARPENTER A-286 LONGITUDINAL TENSILE SPECIMENS
[.125-INCH (.3175 cm) DIAMETER] COLD WORKED 40 PERCENT MINIMUM, AGED, STRESSED, AND
EXPOSED TO ALTERNATE IMMERSION TESTING IN A 3.5 PERCENT NaCl BATH

Exposure Time Days	Applied Stress Percent of Yield Strength	U.T.S. ksi (GN/m^2)	.2% Offset Y.S. ksi (GN/m^2)	Elongation In 1/2 Inch (1.27 cm) (4D%)	R.A. (%)	Modulus $X10^{-6}$ psi (N/m^2)	Number of Tests
0	0	200.4 (1.382)	184.7 (1.273)	12.5	45.1	32.4 (223.4)	4
180	0	200.2 (1.380)	187.3 (1.291)	13.7	44.8	32.0 (220.6)	3
180	75	196.8 (1.357)	181.4 (1.251)	11.0	41.6	30.5 (210.3)	3
180	90	197.5 (1.362)	186.0 (1.282)	13.5	44.9	33.2 (228.9)	3
180	100	200.7 (1.384)	191.0 (1.317)	14.0	43.6	31.0 (207.5)	3

TABLE X

MECHANICAL PROPERTIES OF UNIVERSAL-CYCLOPS A-286 LONGITUDINAL TENSILE SPECIMENS [.125-INCH (.3175 cm) DIAMETER] COLD WORKED 40 PERCENT MINIMUM, AGED, STRESSED, AND EXPOSED TO ALTERNATE IMMERSION TESTING IN A 3.5 PERCENT NaCl BATH

Exposure Time Days	Applied Stress Percent of Yield Strength	U.T.S. ksi (GN/m^2)	0.2% Offset Y.S. ksi (GN/m^2)	Elongation In 1/2 Inch (1.27 cm) (4D%)	R.A. (%)	Modulus X10^{-6} psi (N/m^2)	Number of Tests
0	0	200.1 (1.379)	183.4 (1.264)	11.3	40.0	26.1 (179.95)	3
180	0	200.7 (1.384)	183.2 (1.263)	12.0	39.7	26.8 (184.78)	3
180	75	201.8 (1.391)	185.8 (1.281)	14.0*	38.4	28.6 (197.19)	3
180	90	202.5 (1.396)	196.4 (1.344)	13.7	39.0	27.6 (190.29)	3

* Two Tests Valid for Elongation

Manual Cross Head Movement = 0.05 Inch/Minute

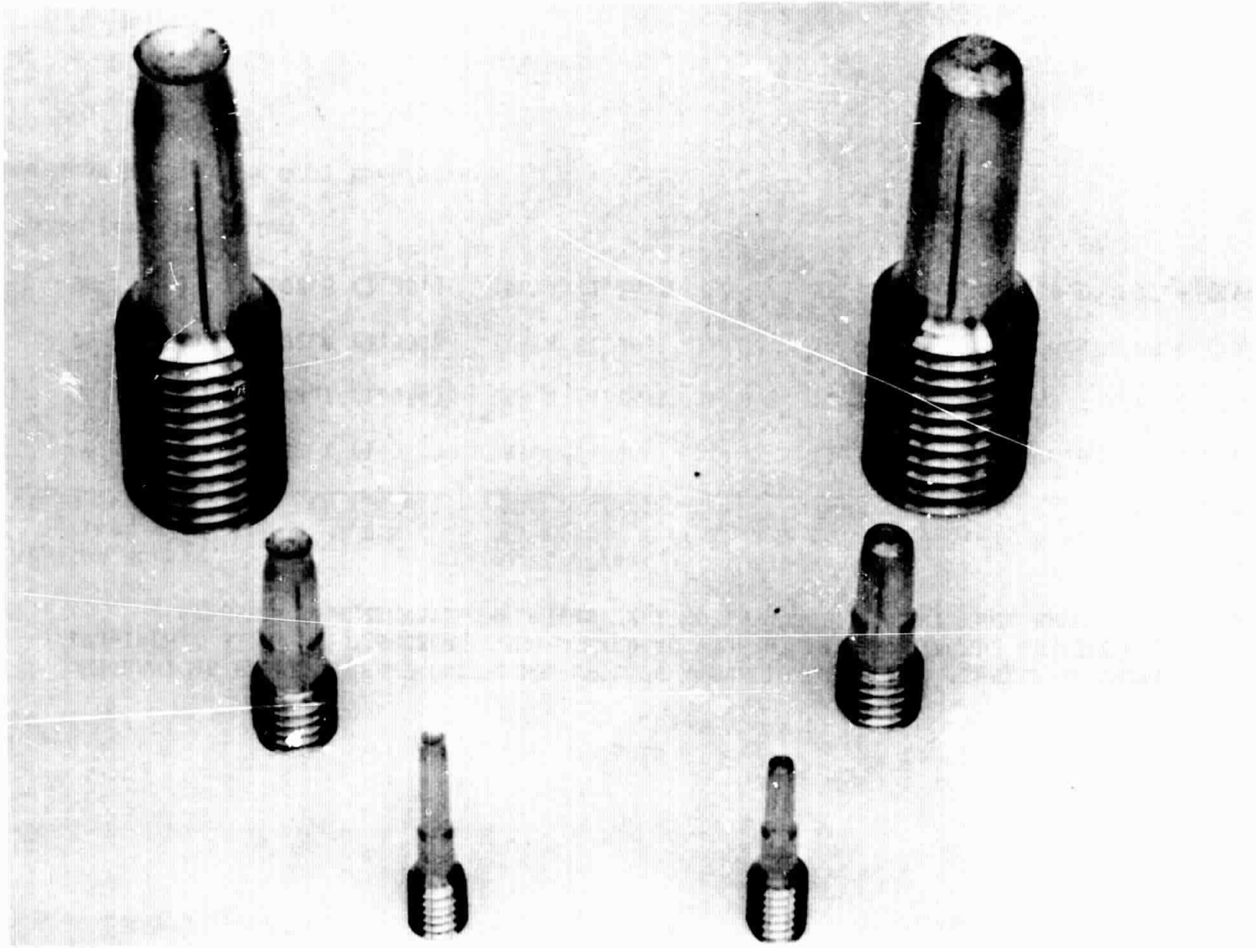


FIGURE 1-CARPENTER A-286 STAINLESS STEEL LONGITUDINAL TENSILE SPECIMENS TESTED AT AMBIENT TEMPERATURE

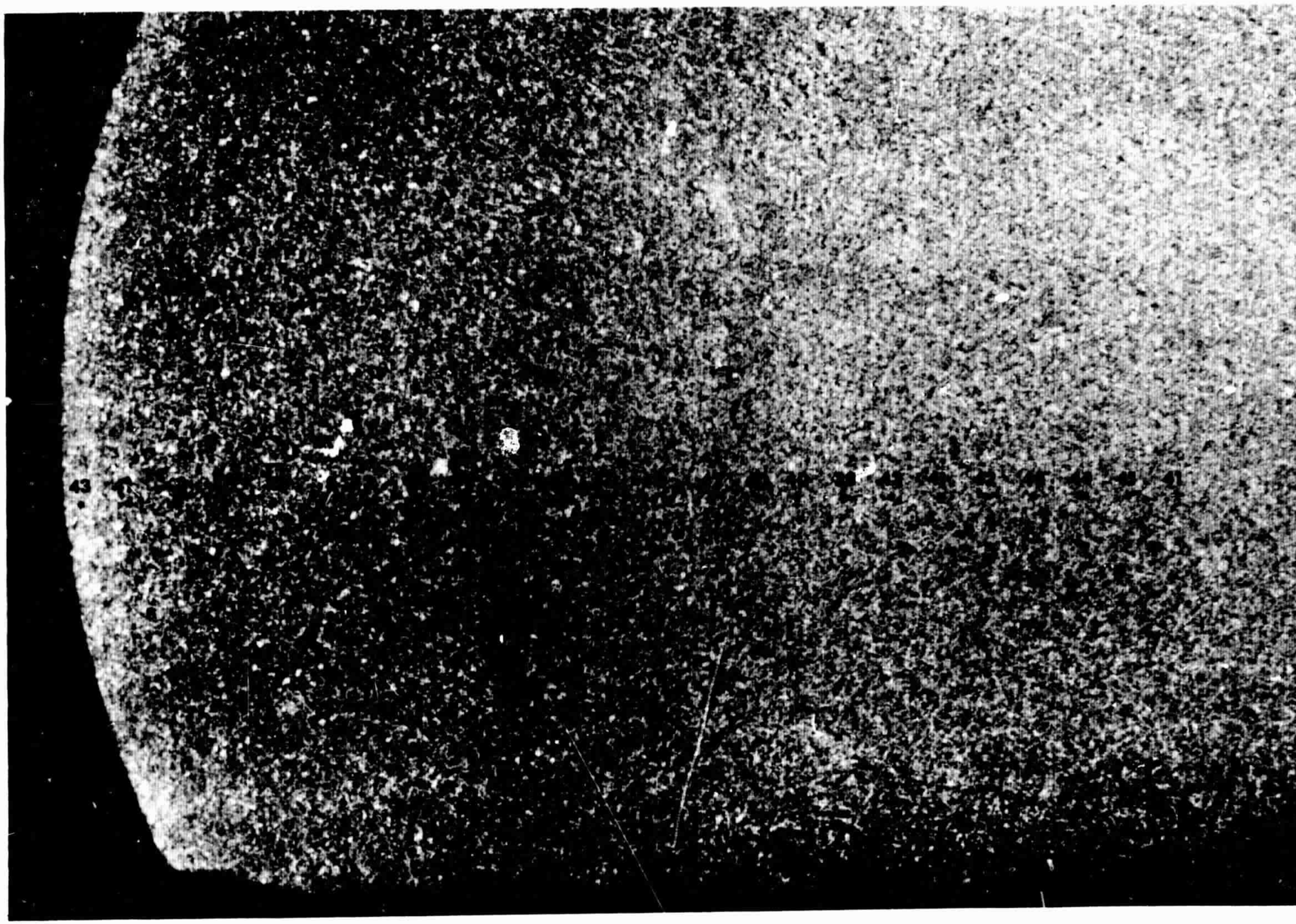


FIGURE 2 - CARPENTER A-286 S.S. BAR (0.88 INCH DIAMETER) SOLUTION TREATED, C.W. 40%, AND AGED ROCKWELL "C" HARDNESS (CONVERTED FROM D.P.H.) MAG. 5X

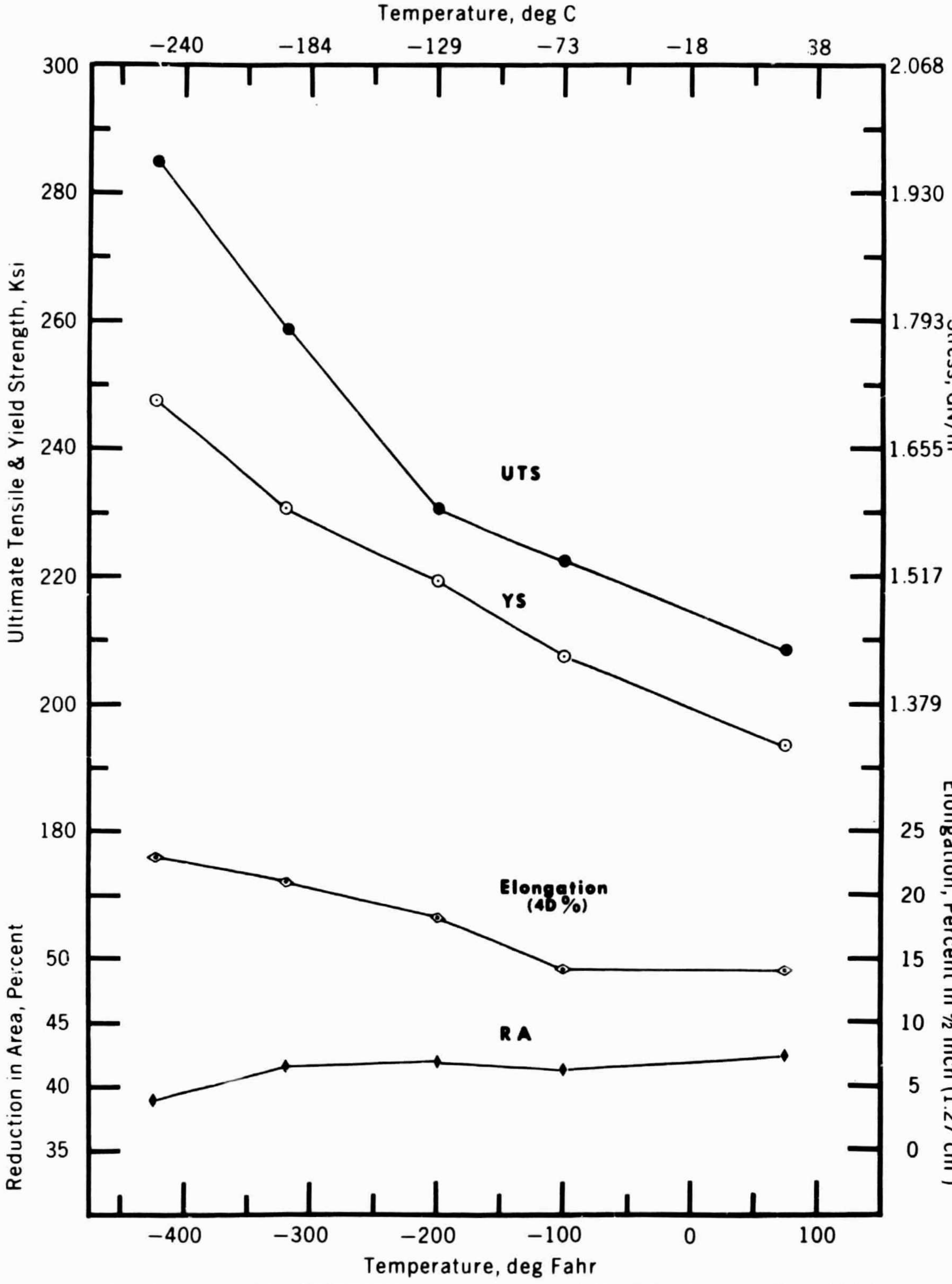


FIGURE 3 - LOW TEMPERATURE MECHANICAL PROPERTIES OF ARMCO A–286 S.S. (53% C.W.) LONGITUDINAL TENSILE SPECIMENS (0.125" DIAMETER)

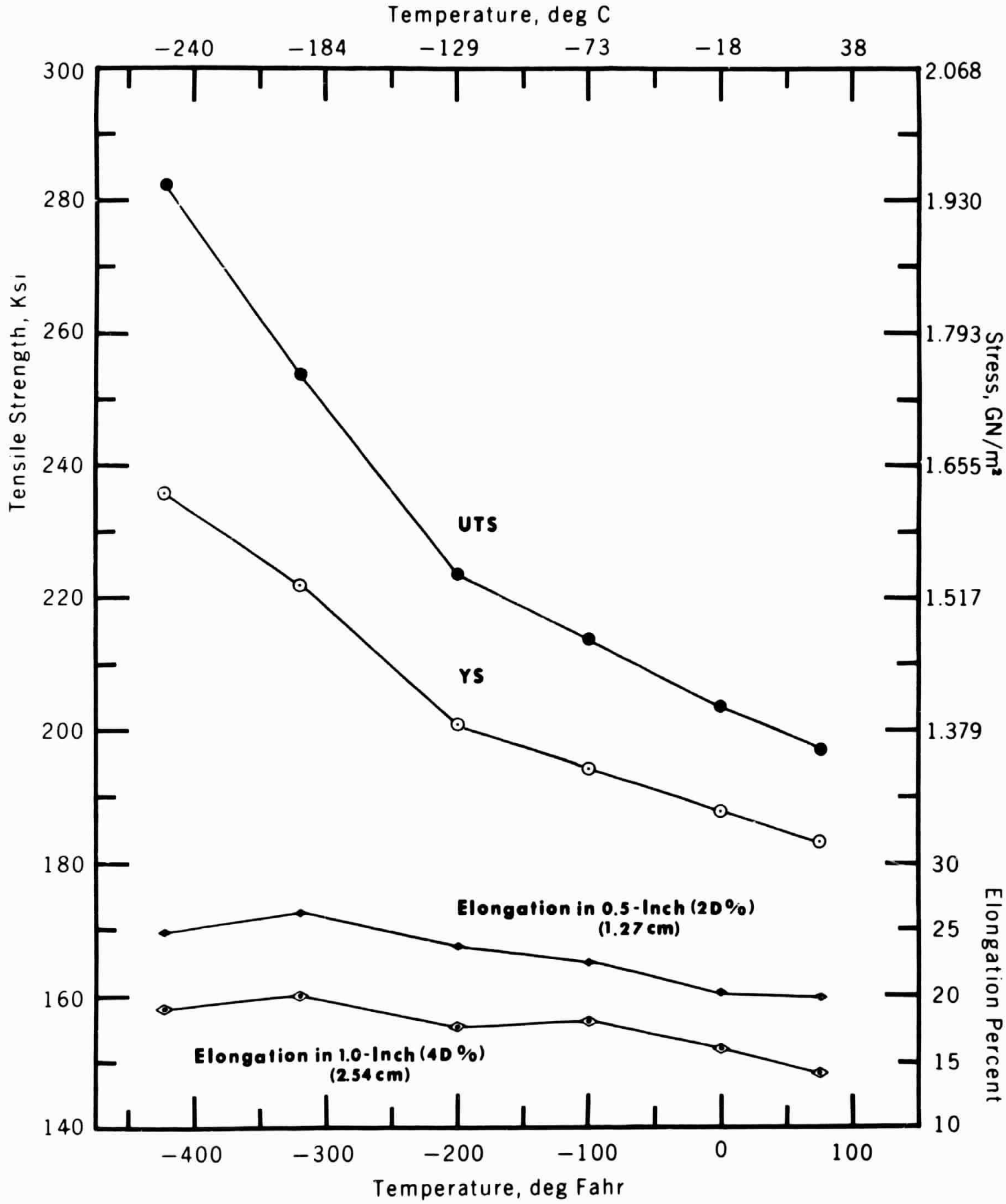


FIGURE 4 - LOW TEMPERATURE MECHANICAL PROPERTIES OF CARPENTER A-286 S.S. (40% C.W.) LONGITUDINAL TENSILE SPECIMENS (0.250" DIAMETER)

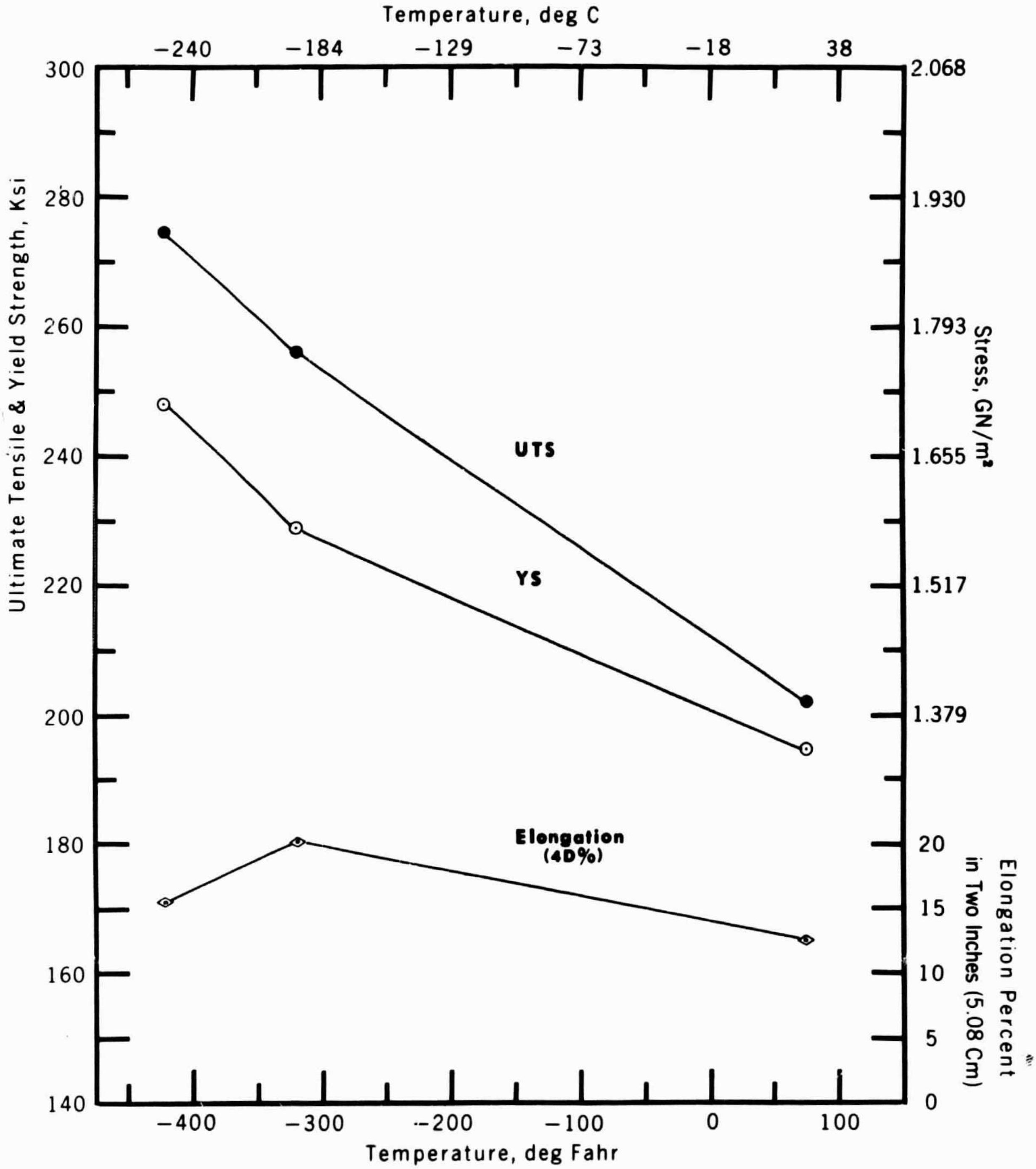


FIGURE 5 - LOW TEMPERATURE MECHANICAL PROPERTIES OF CARPENTER A-286 S.S. (40% C.W.) LONGITUDINAL TENSILE SPECIMENS (0.500" DIAMETER)

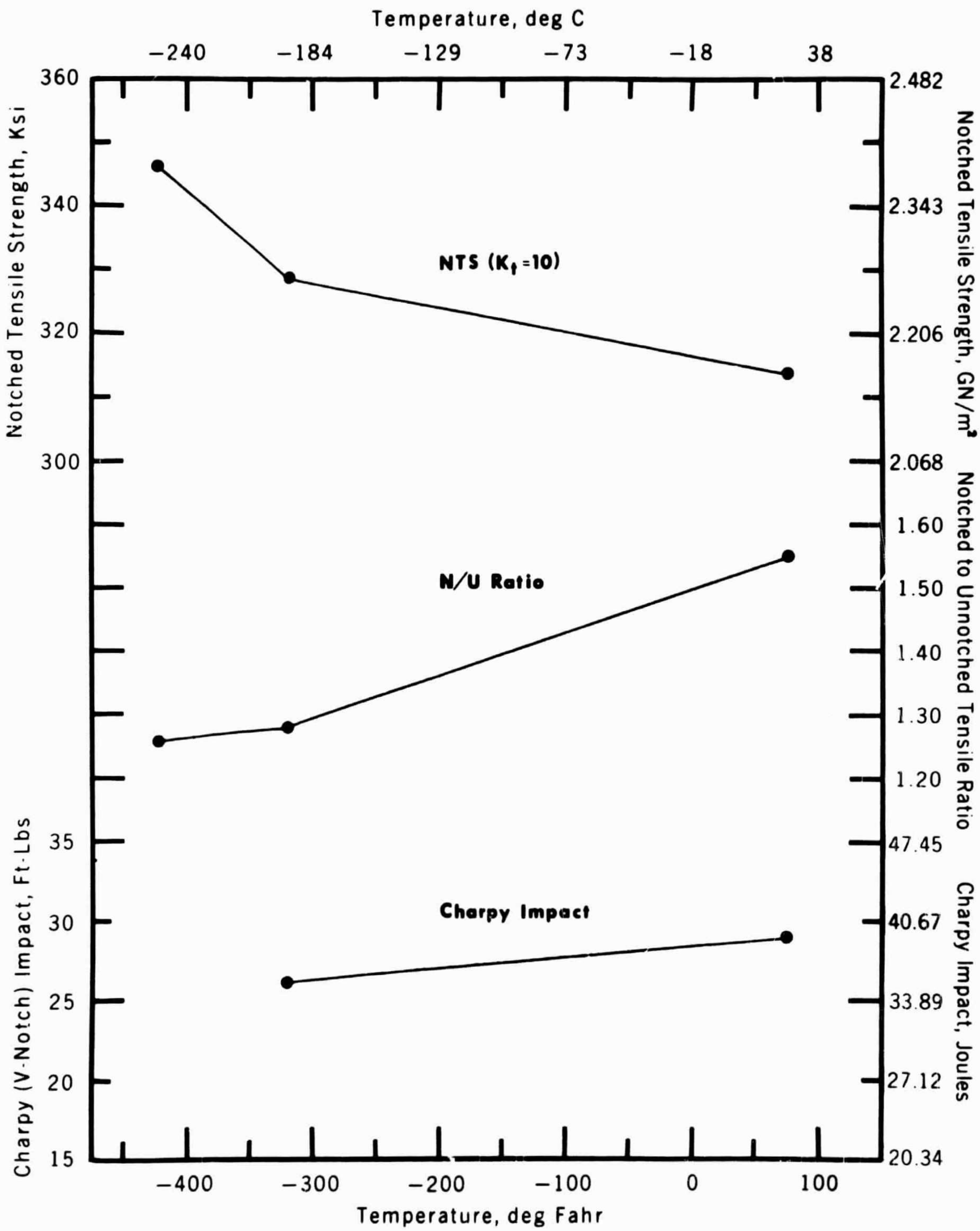


FIGURE 6 - LOW TEMPERATURE NOTCHED PROPERTIES OF CARPENTER A-286 S.S. (40% C.W.) LONGITUDINAL TENSILE SPECIMENS (0.500" DIAMETER) AND CHARPY IMPACT SPECIMENS

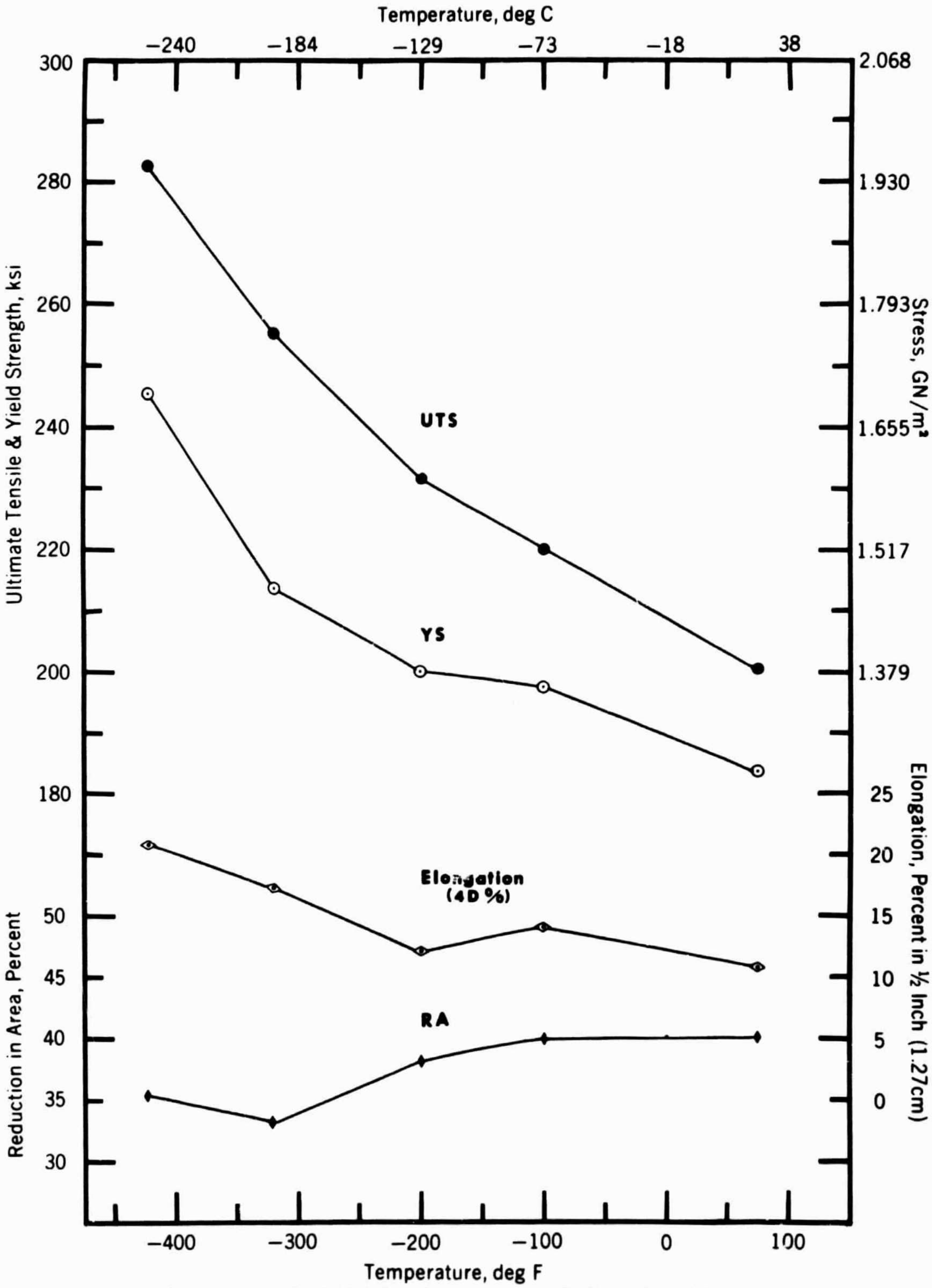


FIGURE 7 - LOW TEMPERATURE MECHANICAL PROPERTIES OF U–CYCLOPS A–286 S.S. (40% MIN. C.W.) LONGITUDINAL TENSILE SPECIMENS (0.125" DIAMETER)

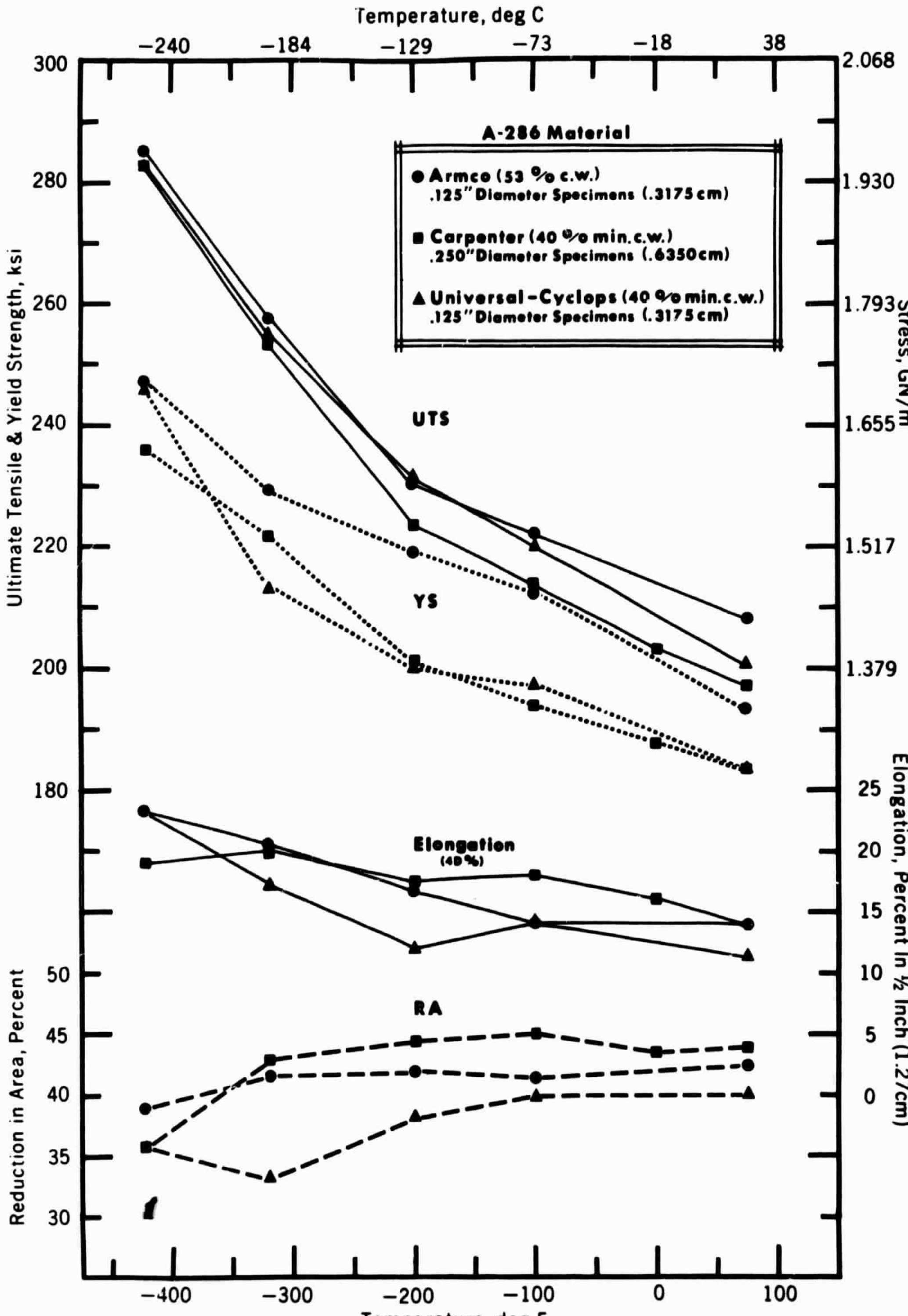
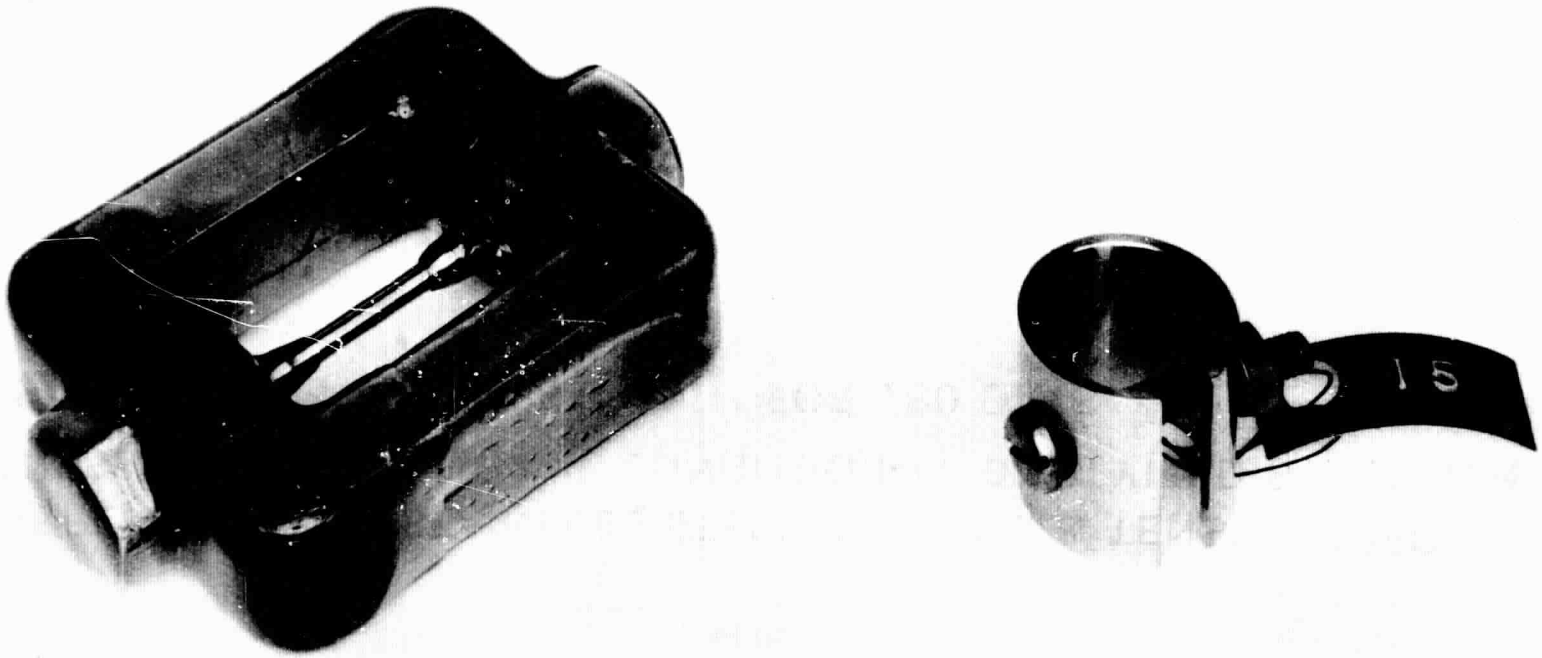


FIGURE 8 · LOW TEMPERATURE MECHANICAL PROPERTIES OF COLD WORKED A–286 LONGITUDINAL TENSILE SPECIMENS

FIGURE 9-ARMCO A-286 S.S. (53% C.W.) LONGITUDINAL TENSILE SPECIMENS STRESSED TO 0, 75, & 100% OF THE 0.2% Y.S. - 180 DAYS A.I. EXPOSURE

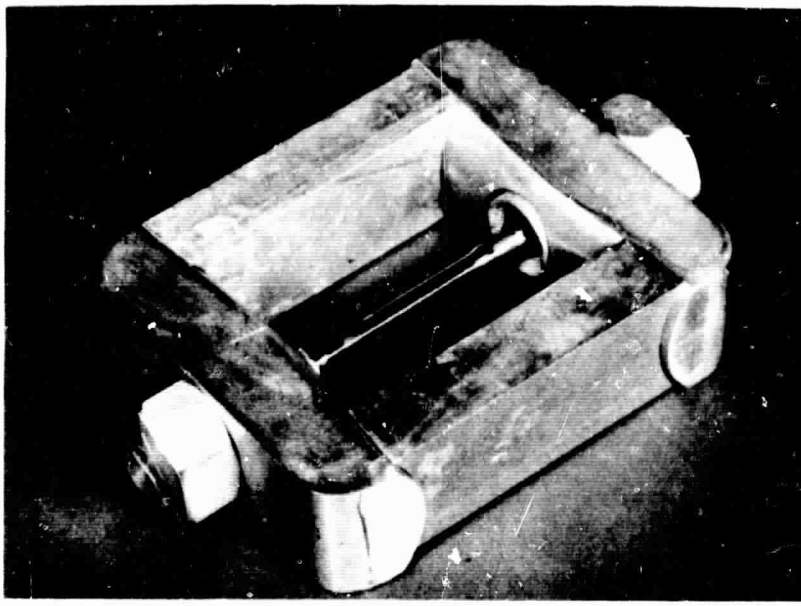


ARMCO A-286 S.S. (53% C.W.) SPECIMENS STRESSED TO 100% OF YIELD STRENGTH

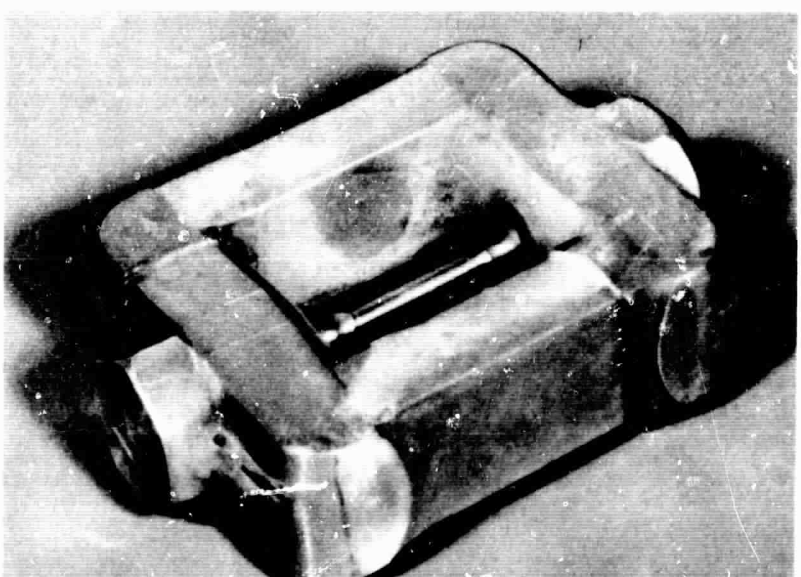
FIGURE 10

CARPENTER A-286 STAINLESS STEEL "C"-RING & TENSILE SPECIMEN
STRESSED TO 100% OF THE LONGITUDINAL 0.2% YIELD STRENGTH
TESTED IN A 3.5% NACL A.I. BATH FOR 180 DAYS

FIGURE-11

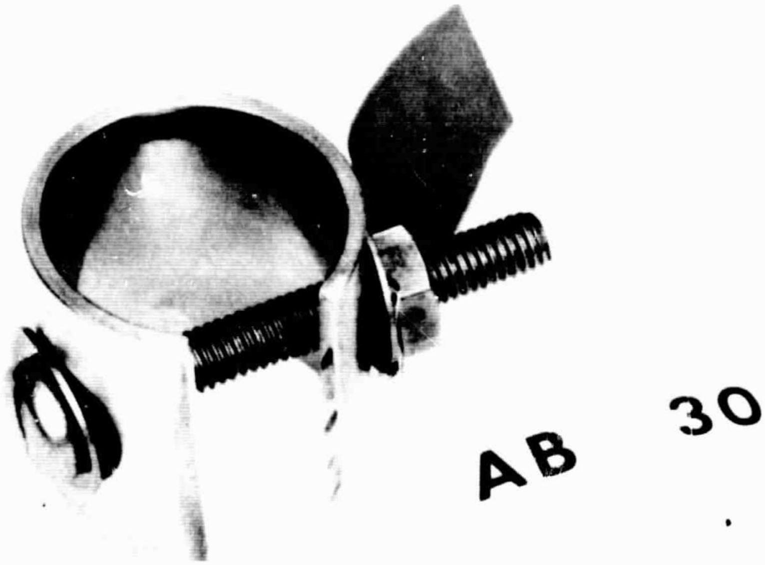


PRIOR TO TESTING

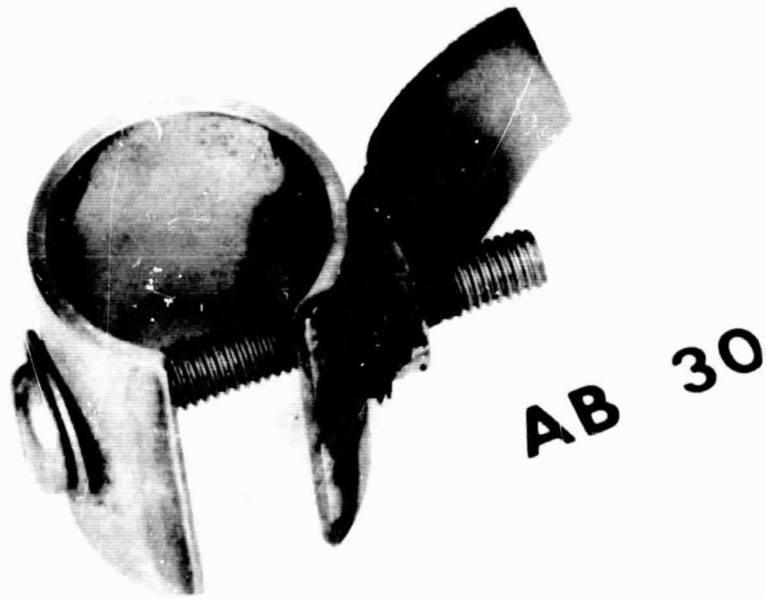


AFTER 180 DAY TEST

FIGURE-12 A-286 TENSILE SPECIMEN STRESSED TO 100% OF YIELD STRENGTH (U-CYCLOPS)

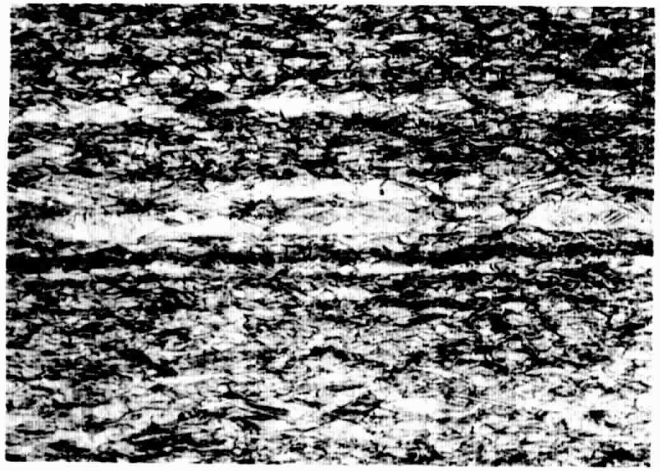


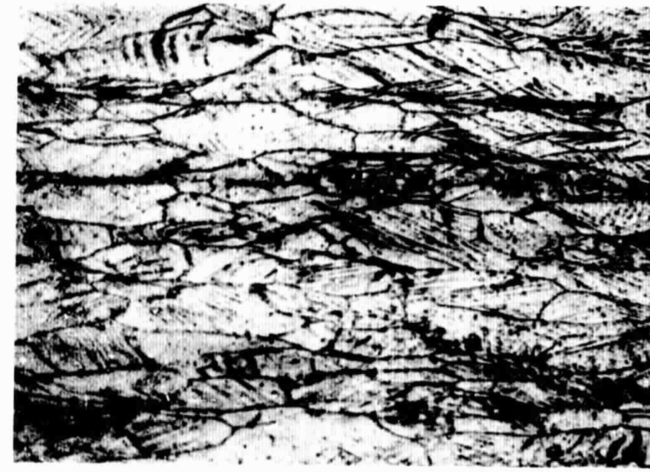
PRIOR TO TESTING



AFTER 180 DAY TEST

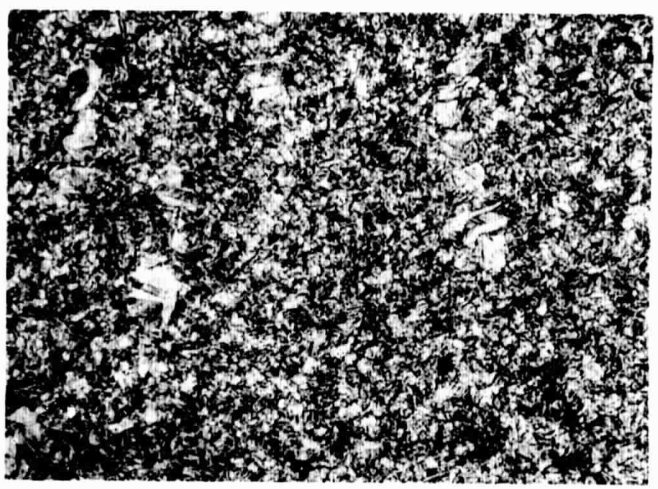
FIGURE-13 A-286 C-RING SPECIMEN AB-30 STRESSED TO 100% OF YIELD STRENGTH (U-CYCLOPS)

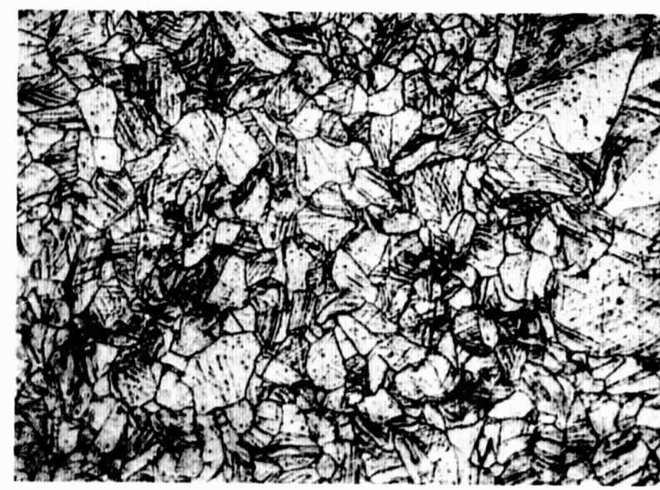




Mag 100X

Longitudinal





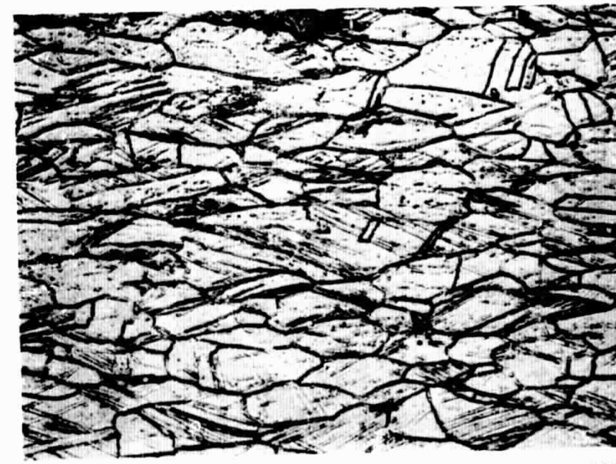
Mag 100X

Transverse

Mag 500X

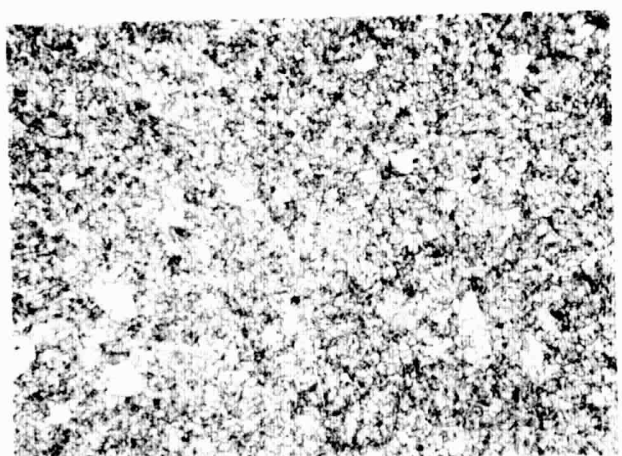
Figure 14 - Armco A-286 Bar (1.0-Inch (2.54 cm) Diameter) Solution Treated, Cold Worked 53 Percent, and Aged Hardened Microstructure Oxalic Acid Etch

MAG. 100X

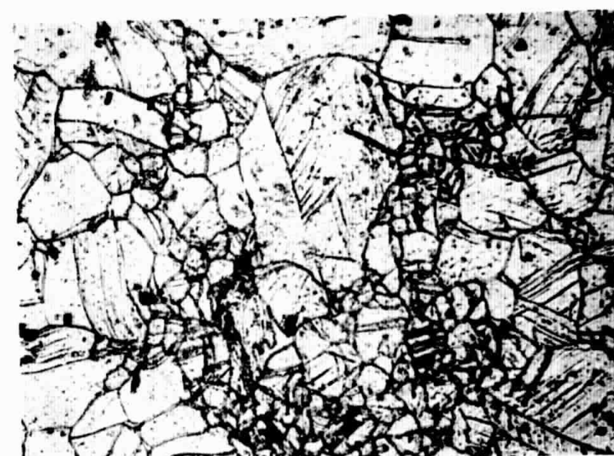


MAG. 500X

LONGITUDINAL



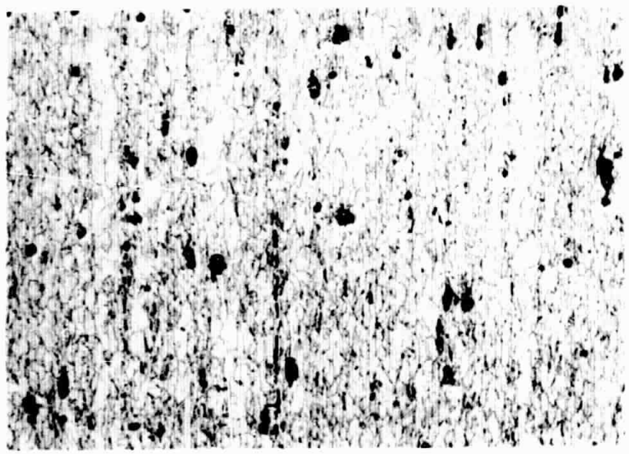
MAG. 100X



MAG. 500X

TRANSVERSE

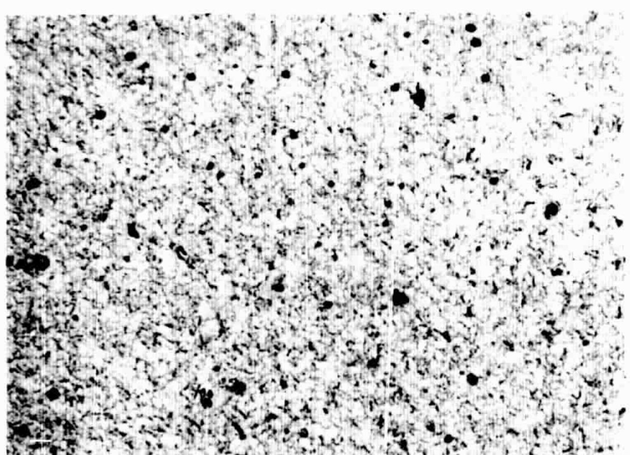
FIGURE 15 - Carpenter A-286 Bar (.88-Inch Diameter) Solution Treated, Cold-Worked 40 Percent Minimum, and Aged Hardened Microstructure Oxalic Acid Etch

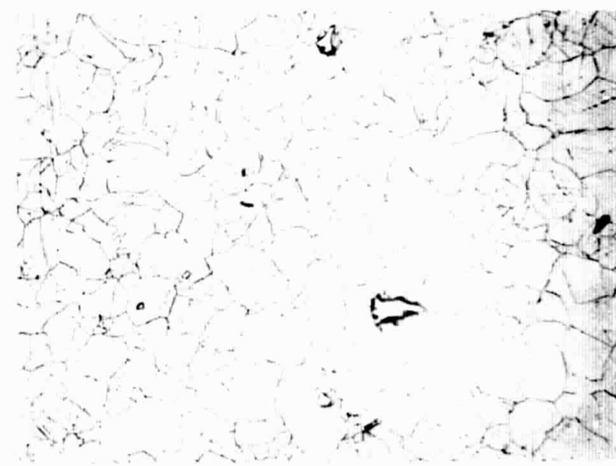


Mag. 100X

Longitudinal

Mag. 500X





Mag. 100X

Transverse

Mag. 500X

Figure 16 - Universal Cyclops A-286 Bar 1.0-Inch (2.54 cm) Diameter Solution Treated, 40 Percent Minimum Cold Worked, and Aged Hardened Microstructure Oxalic Acid Etch

APPROVAL

AN EVALUATION OF THE MECHANICAL AND STRESS CORROSION PROPERTIES OF COLD WORKED A-286 ALLOY

By

J. W. Montano

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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