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THE STRESS CORROSION RESISTANCE AND THE CRYOGENIC TEMPERATURE MECHANICAL BEHAVIOR OF 18-3 MN (NITRONIC 33) STAINLESS STEEL PARENT AND WELDED MATERIAL

Materials and Processes Laboratory

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16. ABSTRACT

This study describes the ambient and cryogenic temperature mechanical properties and the ambient temperature stress corrosion results of 18-3 Mn (Nitronic 33) stainless steel, longitudinal and transverse, as received and as welded (TIG) material specimens manufactured from 0.063 inch (0.160 Cm) thick sheet material.

The mechanical properties were evaluated at test temperatures from ambient to liquid hydrogen. The tensile test results indicate an increase in ultimate tensile and yield strengths with decreasing temperature. The elongation remained fairly constant to -200°F (-129.0°C) but below that temperature the elongation decreased to less than 6.0% at liquid hydrogen temperature.

The notched tensile strength (NTS) for the parent metal increased with decreasing temperature to liquid nitrogen temperature. Below -320°F (-190°C) the NTS decreased rapidly. The notched/unnotched (N/U) tensile ratio of the parent material specimens remained above 0.9 from ambient to -200°F (-129.0°C), and decreased to approximately 0.65 and 0.62, respectively, for the longitudinal and transverse directions at liquid hydrogen temperature.

Results of the MSFC non-corrosive atmosphere, alternate immersion, humidity, and salt spray tests on stressed and unstressed flat tensile specimens indicated that the alloy, in both the as received and in the as welded condition, had excellent resistance to stress corrosion cracking. After 180 days of testing in these media, only those specimens exposed to the salt spray indicated pitting and some degradation of mechanical properties.

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THE STRESS CORROSION RESISTANCE AND THE CRYOGENIC TEMPERATURE MECHANICAL BEHAVIOR OF 18-3 (NITRONIC 33) STAINLESS STEEL PARENT AND WELDED MATERIAL

SUMMARY

This report presents the ambient and cryogenic temperature mechanical properties and the ambient temperature stress corrosion resistance of as received (annealed) parent material and as welded (TIG) material specimens of 18-3 Mn (Nitronic 33) stainless steel alloy.

The mechanical properties were evaluated at test temperatures from ambient to liquid hydrogen. The tensile test results for longitudinal and transverse specimens of both as received and as welded material indicared excellent mechanical properties at test temperatures down to -200°F (-129.0°C). Below that temperature the elongation rapidly decreased to less than 6.0% at liquid hydrogen temperature.

The notched tensile properties (not applicable to as welded material) of the longitudinal and transverse parent metal specimens indicated a progressive increase in notched tensile strength (NTS) from ambient remperature to liquid nitrogen temperature. Below -320°F (-196.0°C) the NTS decreased rapidly. The notched/unnotched (N/U) tensile ratio of the longitudinal and transverse material specimens remained above 0.9 from ambient to -200°F (-129.0°C). Below that test temperature the N/U tensile ratio decreased steadily, yet remained above 0.6 at liquid hydrogen temperature for both longitudinal and transverse directions.

Stress corrosion tests were performed on the as received and on the as welded longitudinal and transverse material specimens in four different environments: MSFC non-corrosive atmosphere; alternate immersion in a 3.5% NaCl bath; humidity cabinet; and salt spray cabinet. Tensile tests made after 180 days exposure indicated that only the specimens exposed to the salt spray environment experienced pitting corrosion causing a degradation in mechanical properties. The angle of exposure proved to be more influential than the specimen direction (longitudinal or transverse) or the applied stress in determining the extent of degradation.

INTRODUCTION

The constant demand for improved corrosion resisting steels coupled with the recently increased emphasis on the conservation of strategic metals have prompted the development of a new family of stainless steels in which manganese and nitrogen are substituted for a portion of the usual nickel content. One such steel, 18-3 Mn (Nitronic 33) stainless contains approximately 18% chromium, 3.5% nickel, 0.05% carbon, 13.5% manganese, and 0.3% nitrogen. Compared to AISI 304 stainless steel which contains 8% nickel, 18-3 Mn is purported to offer the following advantages:

(1) yield strength in the annealed condition is approximately twice that of Type 304;

(2) resistance to stress corrosion cracking is better than Type 304;

(3) low magnetic permeability is retained even after severe cold working;

(4) strength and ductility at cryogenic temperatures are excellent;

(5) resistance to wear and galling much superior to the standard austenitic stainless steels;

(6) excellent high temperature properties.

The purposes of the present investigation were to evaluate the resistance of 18-3 Mn to stress corrosion cracking and to determine its mechanical properties at ambient and cryogenic temperatures. The results are presented in this paper.

MATERIAL PROCESSING

The chemical compositions of the as received material and the weld wire used in the investigation are shown in Tables Ia and Ib, respectively. The sheet material, 0.063-inch (0.160 cm) thick, from Armco Steel Co. Heat No. 300254 was utilized in the cold rolled annealed condition, and the weld wire (Nitronic 35W) 0.063-inch (0.160 cm) diameter mill coil was in the annealed and cold drawn condition from Armco Heat No. 032007.

The as received parent metal panels were joined by the Tungsten Inert Gas (TIG) process utilizing a 3/32-inch (0.0238 cm) diameter tungsten electrode; 80% argon-20% helium shield gas; a copper back-up bar; Nitronic 35W filler wire 0.063-inch (0.160 cm) diameter; a weld heat setting of 175 amps at 10 volts; and a travel speed of 13 inches (33 cm)/minute.

EQUIPMENT AND MECHANICAL TEST SPECIMENS

The equipment used in the mechanical properties evaluation is described in a report by the author (Ref. 1). Tensile specimens, smooth and V-notched, are illustrated in Figures 1 a. and 1 b., respectively. The weld specimens, with weld beads machined flush, are identical in configuration to the smooth specimen illustrated in Figure 1 a.

STRESS CORROSION TEST PROCEDURE AND SPECIMENS

The equipment and the test procedure used in the Alternate Immersion (A.I.) stress corrosion test is described in a report by Humphries (Ref. 2). The A.I. bath is a 3.5% NaCl solution maintained at a pH of 6.5-7.2, a temperature of 80°F ± 2°F (27°C ± 1°C), and a water purity per ASTM-D-1193-7 Type II. The A.I. cycle is 10 minutes in solution and 50 minutes out of solution. The salt spray test utilized the procedures of ASTM-B-117-64, "Standard Method of Salt Spray (Fog) Testing" which specifies a 5% salt solution at a pH of 6.5-7.2 and a temperature of 95°F (35°C). The humidity test was conducted in a cabinet maintained at 98% relative humidity and a temperature of 95°F (35°C). The MSFC non-corrosive atmospheric conditions were 75°F (24°C) with a relative humidity of approximately 50%.

The flat tensile specimens illustrated in Figure 1 c. were degreased with acetone, stressed to 0 and 75% of the 0.2% yield strength (longitudinal and transverse directions) then re-cleaned with acetone prior to exposure in the corrosive environments.

RESULTS AND DISCUSSION

1. Mechanical Behavior

a. As Received Material

The tensile test results of the ambient through cryogenic temperature mechanical properties evaluation for as received material specimens are tabulated in Tables IIa and IIb and these properties are plotted in Figures 2 and 4.

Tables IIa and IIb contain test data on as received (annealed) 0.063-inch (0.160 cm) thick sheet material specimens tested in the longitudinal and transverse directions, respectively. The tensile test data indicate increasing ultimate tensile and 0.2% yield strengths with decreasing temperature for both longitudinal and transverse specimen directions. The elongation (measured in 4 x gage width) indicates excellent ductility from ambient temperature to -200°F (-129.0°C). However, at liquid nitrogen test temperature there is an approximate 50% loss in ductility, as compared to ambient temperature elongation, and at liquid hydrogen test temperature there is an approximate 90% loss in ductility.

The notched/unnotched (N/U) tensile ratios (average K_t = 9.4) for the longitudinal test specimen remained approximately 1.0 from ambient to -200°F (-129.0°C) while the transverse V-notched test specimen indicated a N/U tensile ratio above 0.90 over the same test temperature range. At liquid nitrogen and liquid hydrogen test temperatures the N/U tensile ratios for longitudinal and transverse specimen directions dropped to approximately 0.85 and 0.65, respectively. The notched tensile strength (NTS) for both specimen directions increased steadily from ambient test temperature to -320°F (-196.0°C) and then dropped sharply, yet remained well above the ambient temperature NTS.

b. As Welded Material

The tensile test results of the ambient through cryogenic temperature mechanical properties evaluation for as welded material specimens are tabulated in Tables IIIa and IIIb and these properties are plotted in Figure 3.

Tables IIIa and IIIb contain test data on as welded (TIG) 0.063-inch (0.160 cm) thick sheet material specimens, both longitudinal and transverse directions, with weld beads machined flush. The tensile test data indicate increasing ultimate tensile and 0.2% yield strengths with decreasing temperature for both test specimen directions. The elongation (measured in 4 x gage width) indicates excellent ductility from ambient temperature to -200°F (-129.0°C). However, at liquid nitrogen test temperature there is an approximate 60% loss

1. Mechanical Behavior (Cont'd)

b. As Welded Material (Cont'd)

in ductility, as compared to ambient temperature elongation, and at liquid hydrogen test temperature there is an approximate 90% loss in ductility.

The weld efficiency at all the test temperatures from ambient to liquid hydrogen temperature was greater than 97% indicating excellent weld properties. As indicated by the weld efficiency the mechanical properties including the 0.2% yield strength, modulus, and elongation are almost identical to those of the parent metal.

2. Stress Corrosion Susceptibility

a. As Received Material

Table IV contains test data prior to and after 180 days exposure to the following environments:

(1) MSFC Non-Corrosive Atmosphere - 75°F (24°C), 50% Relative Humidity.

(2) Alternate Immersion - 3.5% NaCl Bath, 80°F (27°C).

(3) Humidity Cabinet - 95°F (35°C), 98% Relative Humidity.

(4) Salt Spray Cabinet - 95°F (35°C).

These data indicate that the as received (annealed) parent material specimens were not susceptible to stress corrosion cracking, even when stressed to 75% of the 0.2% yield strength and exposed to the environments listed above. However, after 180 days exposure to the MSFC non-corrosive environment there was a slight increase in mechanical properties due, possibly, to aging.

Although there were no failures in any of the test specimens exposed to the above listed environments, there was some pitting corrosion on those specimens exposed to the salt spray. This corrosion is reflected in a minor degradation of the ultimate tensile strength of the transverse tensile specimens and in the elongation values of both longitudinal and transverse direction specimens.

Figure 5 illustrates the stressed parent metal specimens exposed for 180 days to the 3.5% NaCl alternate immersion bath. This figure also illustrates

2. Stress Corrosion Susceptibility (Cont'd)

a. As Received Material (Cont'd)

the stressed parent metal specimens exposed to the humidity cabinet environment. There was no staining or pitting on any of the specimens exposed to these two environments.

Figure 6 illustrates parent metal specimens, unstressed and stressed, exposed to the salt spray. These photographs show the corrosion stains caused by the salt spray and also the mild pitting attack revealed by removing the stains. This pitting corrosion caused a slight degradation in the elongation properties as indicated in Table IV.

b. As Welded Material

Table V contains tensile test data prior to and after 180 days exposure to the various environments. These data indicate that the as welded sheet material specimens were not susceptible to stress corrosion cracking, even when stressed to 75% of the 0.2% yield strength.

Due to the limited amount of sheet material available for this evaluation, and because of inexperience in welding this new alloy, some of the weld panels contained imperfections. These imperfections are reflected in the erratic elongation values of the tensile specimens. Metallographic examination and electron microprobe analysis did not reveal any copper contamination which could have resulted from the utilization of a copper backup bar.

No failures were experienced in the as welded specimens exposed to the various environments; however, there was some pitting corrosion on the salt spray specimens. This pitting caused a greater degree of mechanical property degradation as compared to the parent metal specimen properties. This degradation is reflected in the ultimate tensile strength and in the elongation properties.

The angle of exposure of the test specimens evidently contributed to the pitting attack. Unstressed specimens exposed to the salt spray were supported, as specified in ASTM B-117, at a 15 to 30 degree angle in a plastic rack. The stressed specimens were in a separate stress jig and were arched to produce a given stress, therefore they were not exposed at the same angle as the unstressed specimens. The arched condition facilitated better drainage and prevented some

2. Stress Corrosion Susceptibility (Cont'd)

b. As Welded Material (Cont'd)

of the pitting corrosion that was experienced by the unstressed specimens. The tensile test results indicate superior ultimate tensile and elongation properties for the stressed specimens.

Figure 7 illustrates the typical as welded, longitudinal and transverse, stressed specimens exposed for 180 days to the 3.5% NaCl alternate immersion bath, and to the humidity cabinet environment of 95°F (35°C) and a relative humidity of 98%. There was no general corrosion or pitting on the as welded specimens exposed to these two environments.

Figure 8 indicates surface staining of the as welded, longitudinal and transverse, unstressed specimens exposed for 180 days to the 5% NaCl solution, 95°F (35°C) environment of the salt spray cabinet. Also shown are the same specimens with the stains removed, revealing a pitting attack on the specimen surfaces. Actually the attack on these unstressed specimens was more severe, due to the angle of exposure, than the attack on the stressed specimens shown in Figure 9.

Figure 9 shows surface staining of the as welded, longitudinal and transverse, stressed specimens exposed to the salt spray environment for 180 days. Pitting corrosion is also shown on the same specimens after removal of the stains.

3. Metallography

a. As Received Material

The metallography of the as received material illustrated in Figure 10 indicates an austenitic structure with a grain size smaller than per ASTM E 112-63. The longitudinal microstructure reveals stringers which were analyzed by Energy Dispersive Analysis of X-rays (EDAX) and found to contain the deoxidation additives, Aluminum and Calcium. Other elements present in the stringers were Iron, Chromium, and Manganese. The grains are free from any precipitated carbides and there is no evidence of banding.

b. As Welded Material

Figure 11 illustrates the microstructure of the 18-3 Mn (Nitronic 33) stainless steel, TIG welded with Nitronic 35W filler wire. The sample was

3. Metallography (Cont'd)

b. As Welded Material (Cont'd)

electrolytically etched with 10% Oxalic Acid and photographed at a magnification of 50X. There are no distinct heat affected zones and the immediate areas adjacent to the weld are free of carbide precipitation.

4. Fractography

a. As Received Material

Figures 12 through 13B are Scanning Electron Micrographs (SEM) of longitudinal tensile fractures at a magnification of 1000X. These SEM micrographs show the edge and center of the fractured specimens tensile tested at ambient, liquid nitrogen and liquid hydrogen temperatures.

In Figure 12, the ambient temperature fracture surface indicates excellent ductility while the fracture surfaces of the specimens tested at liquid nitrogen and liquid hydrogen temperatures vary from an edge ductile appearance to a center mixed mode of failure.

Figures 13A and 13B are fractographs of longitudinal V-notched tensile failures taken from the ductile fracture area and from the fracture initiation edges, respectively. The ductile fracture area represents the final rupture area of greatest ductility. This area retains some degree of ductility even at liquid hydrogen temperature. Note the contrast of the fractographs taken from the fracture initiation edges of the V-notched specimens. Only at ambient temperature is there any degree of ductility represented in these fracture initiation edges.

b. As Welded Material

Figure 14 illustrates the edge and center of the longitudinal as welded tensile fractures taken from ductile fracture areas. These fractures show some resemblance to the smooth parent metal fractures illustrated in Figure 12 except for the more brittle appearance at the center of the welds fractured at liquid hydrogen temperature.

CONCLUSIONS

Based upon the results of this evaluation of 18-3 Mn (Nitronic 33) stainless steel sheet material, tested in the as received and in the as welded (TIG) conditions, the following conclusions are drawn:

(1) The ultimate tensile and 0.2% yield strengths of the as received parent metal and the as welded metal, longitudinal and transverse, specimens increased with decreasing temperature.

(2) Elongation of parent and as welded tensile specimens remained above 40% at test temperatures from ambient to -200°F (-129.0°C).

(3) The mechanical properties of the as received and the as welded material were practically identical at all testing temperatures from ambient to liquid hydrogen temperature.

(4) The notched to unnotched tensile ratio (K_t = 9.4) for the parent material remained above 0.90 from ambient temperature to -200°F (-129.0°C).

(5) Considering the mechanical properties obtained in this evaluation it would be reasonable to consider sheet material in either the annealed condition or the as welded (TIG) condition for cryogenic application to -200°F (-129.0°C).

(6) Fractographic analysis indicates the transition from ductility to brittleness of the parent metal and of the as welded metal specimens fractured at liquid nitrogen temperature and the increasing brittleness of the fractures at liquid hydrogen test temperature.

(7) 18-3 Mn (Nitronic 33) stainless steel alloy sheet material in the annealed condition and in the as welded (TIG) condition, as tested in this evaluation, is not susceptible to stress corrosion cracking, even when stressed to 75% of the 0.2% yield strength and exposed to 180 days of moisture and chloride environments. Lengthly exposure to the salt spray environment does cause some pitting corrosion, especially in the as welded material specimens.

REFERENCES

1. Montano, J. W.: "A Mechanical and Stress Corrosion Evaluation of Custom 455 Stainless Steel Alloy," TMX-64682, August 2, 1972.

2. Humphries, T. S.: "Procedures for Externally Loading and Corrosion Testing Stress Corrosion Specimens," TMX-53483, June 29, 1966.

TABLE Ia

Chemical Composition of 18-3 Mn (Nitronic 33) Stainless Steel Alloy Sheet

Analysis	Fe	Cr	Mn	Ni	Si	C	P	S	N
MSFC	Main	17.61	13.41	3.70	0.83	0.046	0.011	0.004	0.26
ARMCO	Main	17.83	13.87	3.34	0.50	0.046	0.018	0.006	0.29

ARMCO Steel Co. Heat No. 300254.
Cold Rolled Annealed - 0.063- Inch (0.160 cm) Thick.

TABLE Ib

Chemical Composition of 18-3 Mn (Nitronic 35W) Weld Wire

Analysis	Fe	Cr	Mn	Ni	Si	C	P	S	N
ARMCO	Main	18.11	12.37	4.96	0.41	0.041	0.007	0.005	0.18

ARMCO Steel Co. Heat No. 032007.
Annealed and Cold Drawn - 0.063- Inch (0.160 cm) Mill Coil.

TABLE IIa

LOW TEMPERATURE MECHANICAL PROPERTIES OF 18-3 MN STAINLESS STEEL PARENT METAL
LONGITUDINAL FLAT TENSILE SPECIMENS 0.063-INCH (0.160 CM) THICK

Test Temperature		Ultimate Tensile Strength		.2% Offset Yield Strength		Elongation 2.00 in. (5.08 cm)	Modulus X10^{-6}		N/U* Tensile Ratio	No. of Tests
°F	(°C)	KSI	(GN/m^2)	KSI	(GN/m^2)	(%)	PSI	(GN/m^2)		
75	(+23.9)	113.0	(0.779)	65.6	(0.452)	48.4	28.7	(0.198)	1.01	4
0	(-17.8)	132.4	(0.913)	81.1	(0.559)	49.9	29.0	(0.200)	0.99	4
-100	(-73.0)	147.6	(1.018)	95.5	(0.658)	46.9	28.8	(0.197)	1.05	4
-200	(-129.0)	167.6	(1.155)	117.0	(0.807)	41.6	28.8	(0.197)	1.06	4
-320	(-196.0)	224.7	(1.549)	160.5	(1.107)	23.5	29.3	(0.202)	0.87	4
-423	(-252.8)	259.3	(1.788)	206.8	(1.424)	5.8	28.4	(0.196)	0.62	3

* Average Stress Concentration Factor K_t = 9.5

TABLE IIb

LOW TEMPERATURE MECHANICAL PROPERTIES OF 18-3 MN STAINLESS STEEL PARENT METAL
TRANSVERSE FLAT TENSILE SPECIMENS 0.063-INCH (0.160 CM) THICK

Test Temperature		Ultimate Tensile Strength		.2% Offset Yield Strength		Elongation 2.00 In. (5.08 cm)	Modulus X10^{-6}		N/U* Tensile Ratio	No. of Tests
°F	(°C)	KSI	(GN/m^2)	KSI	(GN/m^2)	(%)	PSI	(GN/m^2)		
75	(+23.9)	113.6	(0.783)	62.6	(0.432)	47.5	28.7	(0.198)	0.92	4
0	(-17.8)	130.5	(0.900)	77.9	(0.537)	47.0	28.4	(0.196)	0.94	4
-100	(-73.0)	150.2	(1.035)	95.9	(0.661)	45.5	28.6	(0.197)	0.98	4
-200	(-129.0)	168.1	(1.159)	118.7	(0.818)	41.1	28.3	(0.195)	1.03	4
-320	(-196.0)	230.7	(1.591)	165.5	(1.141)	27.6	29.9	(0.206)	0.85	4
-423	(-252.8)	259.0	(1.786)	211.4	(1.457)	4.3	28.6	(0.197)	0.65	3

* Average Stress Concentration Factor K_t = 9.3

TABLE IIIa

LOW TEMPERATURE MECHANICAL PROPERTIES OF 18-3 MN STAINLESS STEEL TIG WELDS
LONGITUDINAL FLAT TENSILE SPECIMENS 0.063-INCH (0.160 CM) THICK

Test Temperature °F	(°C)	Ultimate Tensile Strength KSI	(GN/m^2)	.2% Offset Yield Strength KSI	(GN/m^2)	Elongation 2.00 In. (5.08 cm) (%)	Modulus X10^{-6} PSI	(GN/m^2)	Weld* Eff. (%)	No. of Tests
75	(+23.9)	115.3	(0.795)	66.8	(0.460)	44.2	28.3	(0.195)	100.0	6
0	(-17.8)	128.9	(0.889)	79.1	(0.545)	44.8	28.2	(0.194)	97.3	6
-100	(-73.0)	148.4	(1.023)	94.7	(0.653)	43.5	28.9	(0.199)	100.0	6
-200	(-129.0)	169.2	(1.166)	116.1	(0.800)	39.8	28.4	(0.196)	100.0	6
-320	(-196.0)	224.5	(1.548)	158.9	(1.096)	18.5	28.9	(0.199)	99.9	5
-423	(-252.8)	252.9	(1.744)	201.7	(1.391)	5.3	29.0	(0.200)	97.6	6

* Weld to Parent Metal Ultimate Tensile Strength Ratio for Longitudinal Specimens (Weld-Beads Removed)

TABLE IIIb

LOW TEMPERATURE MECHANICAL PROPERTIES OF 18-3 MN STAINLESS STEEL TIG WELDS
TRANSVERSE FLAT TENSILE SPECIMENS 0.063-INCH (0.160 CM) THICK

Test Temperature °F	(°C)	Ultimate Tensile Strength KSI	(GN/m^2)	.2% Offset Yield Strength KSI	(GN/m^2)	Elongation 2.00 In. (5.08 cm) (%)	Modulus X10^{-6} PSI	(GN/m^2)	Weld* Eff. (%)	No. of Tests
75	(+23.9)	116.3	(0.800)	66.6	(0.459)	43.1	28.1	(0.194)	100.0	6
0	(-17.8)	128.9	(0.889)	78.6	(0.542)	42.4	28.1	(0.194)	98.8	6
-100	(-73.0)	149.8	(1.033)	97.0	(0.669)	41.8	28.6	(0.197)	99.7	6
-200	(-129.0)	170.1	(1.173)	120.2	(0.829)	36.4	28.9	(0.199)	100.0	5
-320	(-196.0)	225.9	(1.557)	164.6	(1.135)	17.1	28.6	(0.197)	97.9	6
-423	(-252.8)	252.3	(1.739)	212.6	(1.466)	3.5	28.3	(0.195)	97.4	5

* Weld to Parent Metal Ultimate Tensile Strength Ratio for Transverse Specimens (Weld Beads Removed)

TABLE IV

Mechanical Properties of Parent Metal 18-3 Mn (Nitronic 33) Stainless Steel Tensile Specimens*
0.063 Inch (0.160 cm) Thick Sheet
Exposed to Various Environments

Specimen Direction	Exposure Time Days	Applied Stress Percent of Yield Strength	Ultimate Tensile Strength KSI	Ultimate Tensile Strength (GN/m^2)	0.2% Offset Yield Strength KSI	0.2% Offset Yield Strength (GN/m^2)	Elongation 2.00-In. (5.08 cm) [4 x Gage Width]	Modulus $X10^{-6}$ PSI	Modulus $X10^{-6}$ (GN/m^2)
			Exposed to MSFC - Non-Corrosive Environment 75°F (24°C)						
Long.	0	0	112.8	(0.778)	65.8	(0.454)	50.9	28.7	(0.198)
	180**	0	115.5	(0.796)	66.6	(0.459)	54.5	28.5	(0.196)
Trans.	0	0	112.6	(0.776)	63.8	(0.440)	48.6	28.3	(0.195)
	180**	0	116.2	(0.801)	65.0	(0.448)	52.0	28.9	(0.199)
			Exposed to Alternate Immersion Testing in a 3.5 Percent NaCl Bath 80°F (27°C)						
Long.	180	0	115.7	(0.798)	67.0	(0.462)	52.5	27.8	(0.192)
	180	75	115.6	(0.797)	66.2	(0.456)	53.8	28.1	(0.194)
Trans.	180	0	115.7	(0.798)	63.5	(0.438)	53.0	27.2	(0.187)
	180	75	115.9	(0.799)	65.6	(0.452)	52.0	27.9	(0.192)
			Exposed to Humidity Cabinet 95°F (35°C) 98% R.H.						
Long.	180	0	115.5	(0.796)	66.8	(0.460)	53.0	28.2	(0.194)
	180	75	116.0	(0.800)	66.8	(0.460)	53.7	28.6	(0.197)
Trans.	180	0	115.4	(0.796)	64.0	(0.441)	53.3	27.8	(0.192)
	180	75	115.4	(0.796)	64.6	(0.445)	52.2	28.0	(0.193)
			Exposed to Salt Spray Cabinet 95°F (35°C)						
Long.	180	0	116.2	(0.801)	67.1	(0.463)	53.5	28.4	(0.196)
	180	75	115.7	(0.798)	66.0	(0.455)	54.0	27.9	(0.192)
Trans.	180	0	115.9	(0.799)	65.0	(0.448)	46.7	27.9	(0.187)
	180	75	113.8	(0.785)	64.3	(0.443)	40.2	27.7	(0.191)

* Values represent an average of 4 Specimen Blanks tested prior to exposure and 3 Specimens tested per Stress Level after 180 days exposure.

** One Specimen, each direction, tested after 180 days exposure to MSFC Non-Corrosive Environment.

TABLE V

Mechanical Properties of Welded 18-3 Mn (Nitronic 33) Stainless Steel Tensile Specimens
0.063 Inch (0.160 cm) Thick Sheet
Exposed to Various Environments

Specimen Direction	Exposure Time Days	Applied Stress Percent of Yield Strength	Ultimate Tensile Strength KSI	(GN/m²)	0.2% Offset Yield Strength KSI	(GN/m²)	Elongation 2.00-In. (5.08 cm) 4 x Gage Width	Modulus X10⁻⁶ PSI	(GN/m²)	Number of Tests
			MSFC - Non-Corrosive Environment 75°F (24°C)							
Long.	0	0	113.8	(0.785)	66.7	(0.460)	42.7	28.7	(0.198)	9
	180	0	116.6	(0.804)	67.7	(0.467)	49.3	28.6	(0.197)	5
Trans.	0	0	111.5	(0.769)	66.2	(0.456)	31.0	27.9	(0.192)	9
	180	0	111.9	(0.771)	66.6	(0.459)	31.9	27.6	(0.190)	6
			Alternate Immersion - 3.5 Percent NaCl Bath 80°F (27°C)							
Long.	180	0	116.2	(0.801)	67.3	(0.464)	47.2	28.5	(0.196)	3
	180	75	117.0	(0.807)	67.3	(0.464)	48.2	28.2	(0.194)	3
Trans.	180	0	116.4	(0.802)	67.3	(0.464)	48.7	28.5	(0.196)	4
	180	75	117.3	(0.809)	68.0	(0.469)	48.5	28.7	(0.198)	4
			Humidity Cabinet 95°F (35°C) 98% R.H.							
Long.	180	0	115.4	(0.796)	66.8	(0.460)	48.0	28.3	(0.195)	3
	180	75	115.4	(0.796)	66.6	(0.459)	46.7	28.1	(0.194)	3
Trans.	180	0	115.8	(0.798)	67.0	(0.462)	47.6	28.1	(0.194)	4
	180	75	115.3	(0.795)	67.3	(0.464)	46.0	28.5	(0.196)	4
			Salt Spray Cabinet 95°F (35°C)							
Long.	180	0	95.5	(0.658)	67.5	(0.465)	18.7*	28.4	(0.196)	3
	180	75	112.7	(0.777)	66.1	(0.456)	50.7*	28.1	(0.194)	3
Trans.	180	0	98.6	(0.680)	65.5	(0.452)	19.6	28.4	(0.196)	4
	180	75	106.0	(0.731)	65.9	(0.454)	23.6	28.4	(0.196)	4

* Only two valid Elongation measurements.

NOTE: Salt Spray Test Results - the attack on the unstressed specimens was more severe, due to the angle of exposure, than the attack on the stressed specimens.

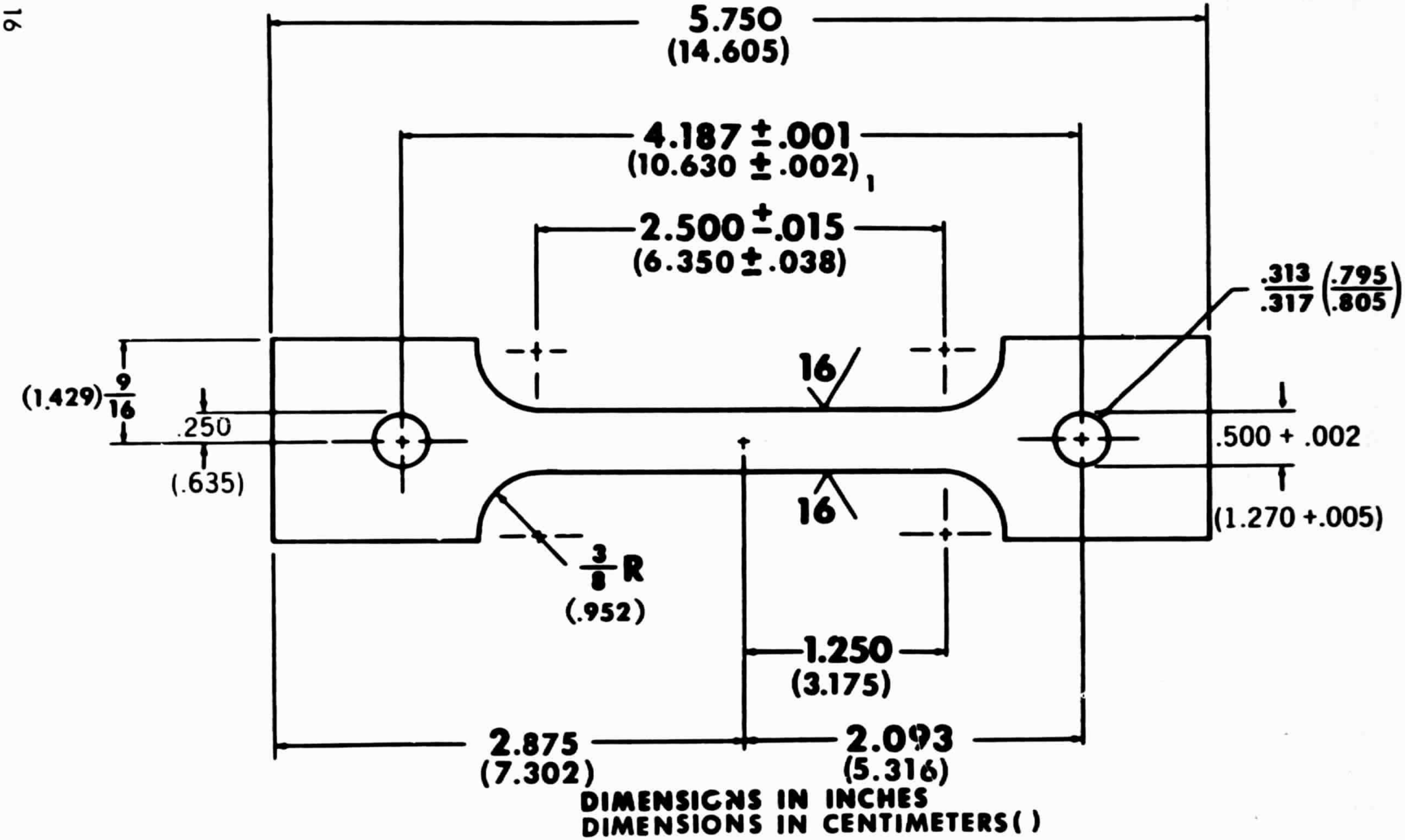


FIGURE 1A - FLAT TENSILE TEST SPECIMEN CONFIGURATION

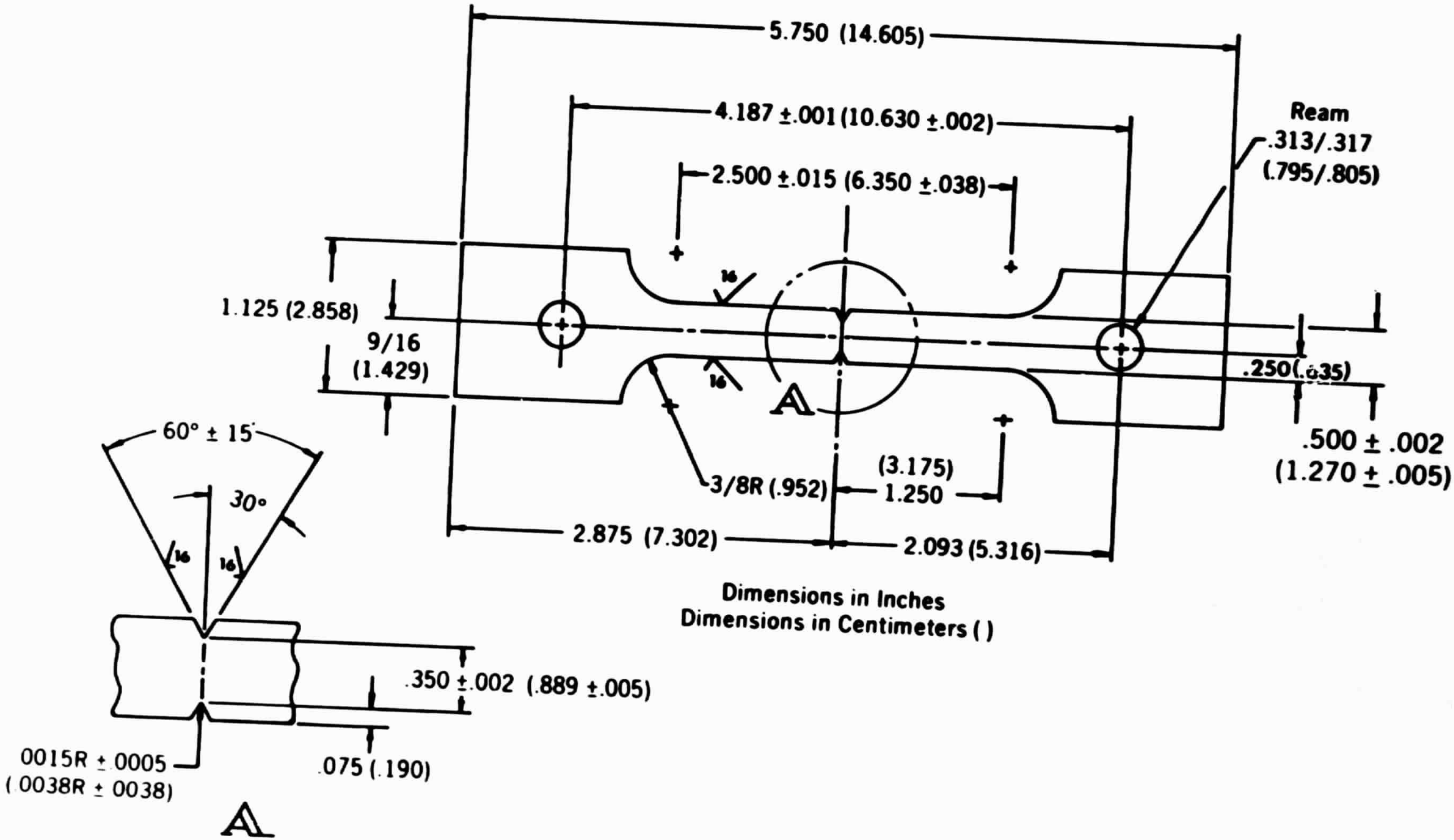
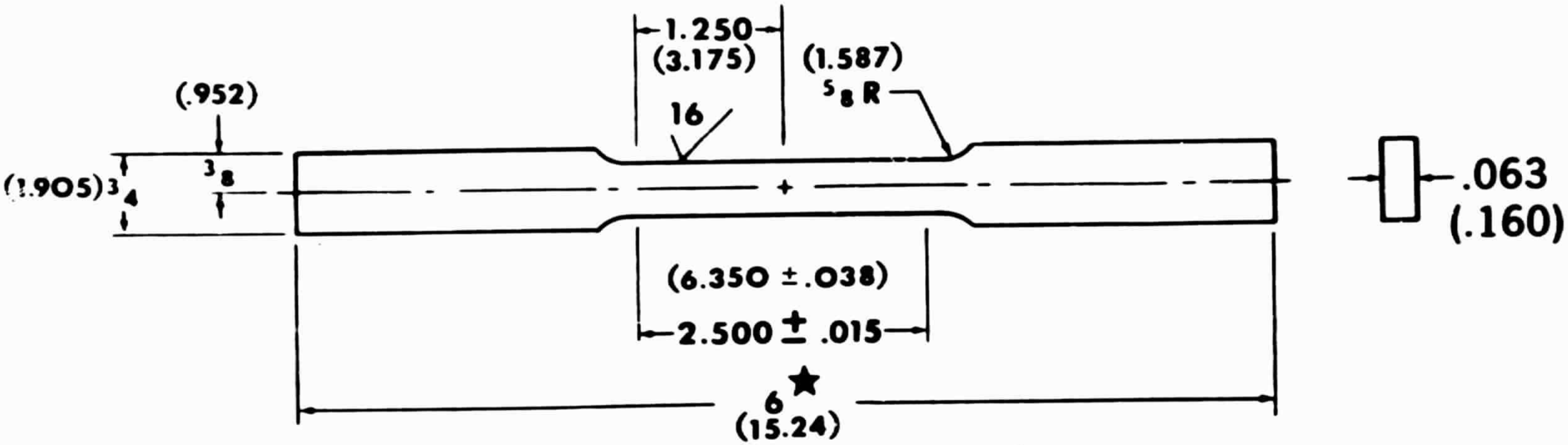


FIGURE 1B - FLAT TENSILE V–NOTCH SPECIMEN CONFIGURATION



DIMENSIONS IN INCHES
Dimensions in Centimeters ( )

★ NOTE: - OVERALL DIMENSION WILL VARY WITH THE STRENGTH AND THE DESIRED STRESS LEVEL

FIGURE 1C - FLAT TENSILE SPECIMEN CONFIGURATION FOR STRESS CORROSION TEST

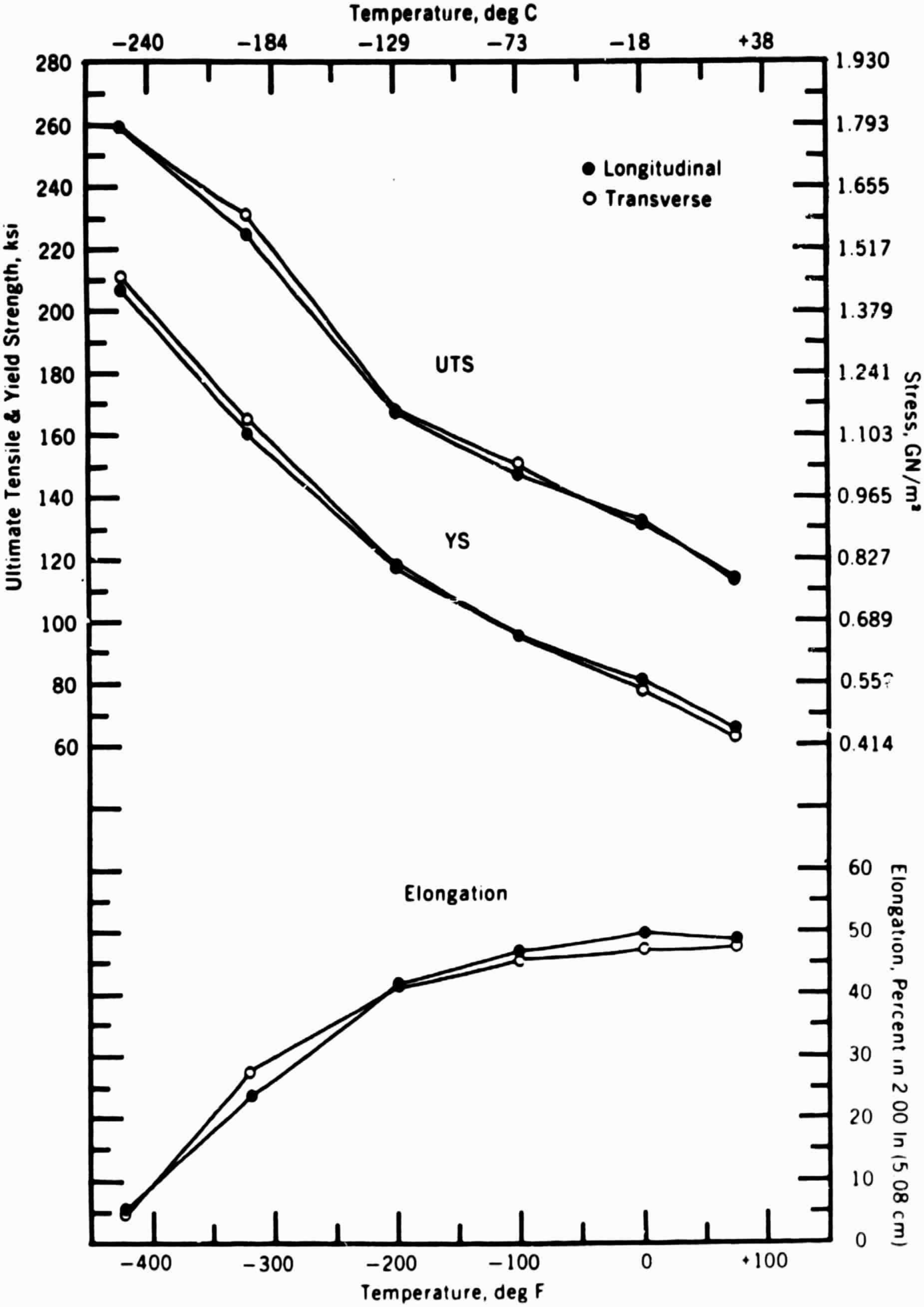


FIGURE 2 · LOW TEMPERATURE MECHANICAL PROPERTIES OF ANNEALED 18-3 MN STAINLESS STEEL PARENT METAL SHEET SPECIMENS

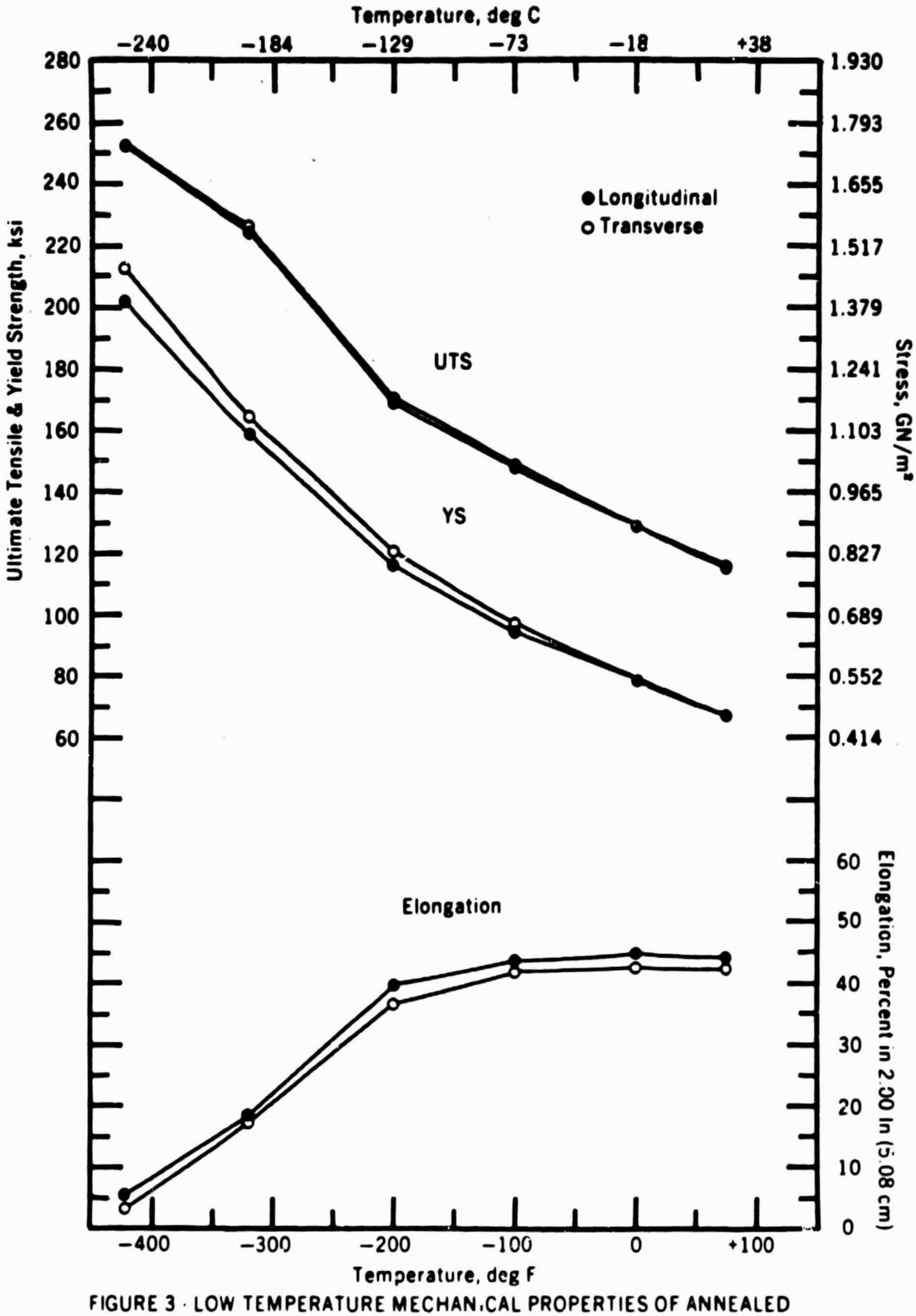


FIGURE 3 · LOW TEMPERATURE MECHANICAL PROPERTIES OF ANNEALED 18–3 MN STAINLESS STEEL IN THE AS WELDED CONDITION

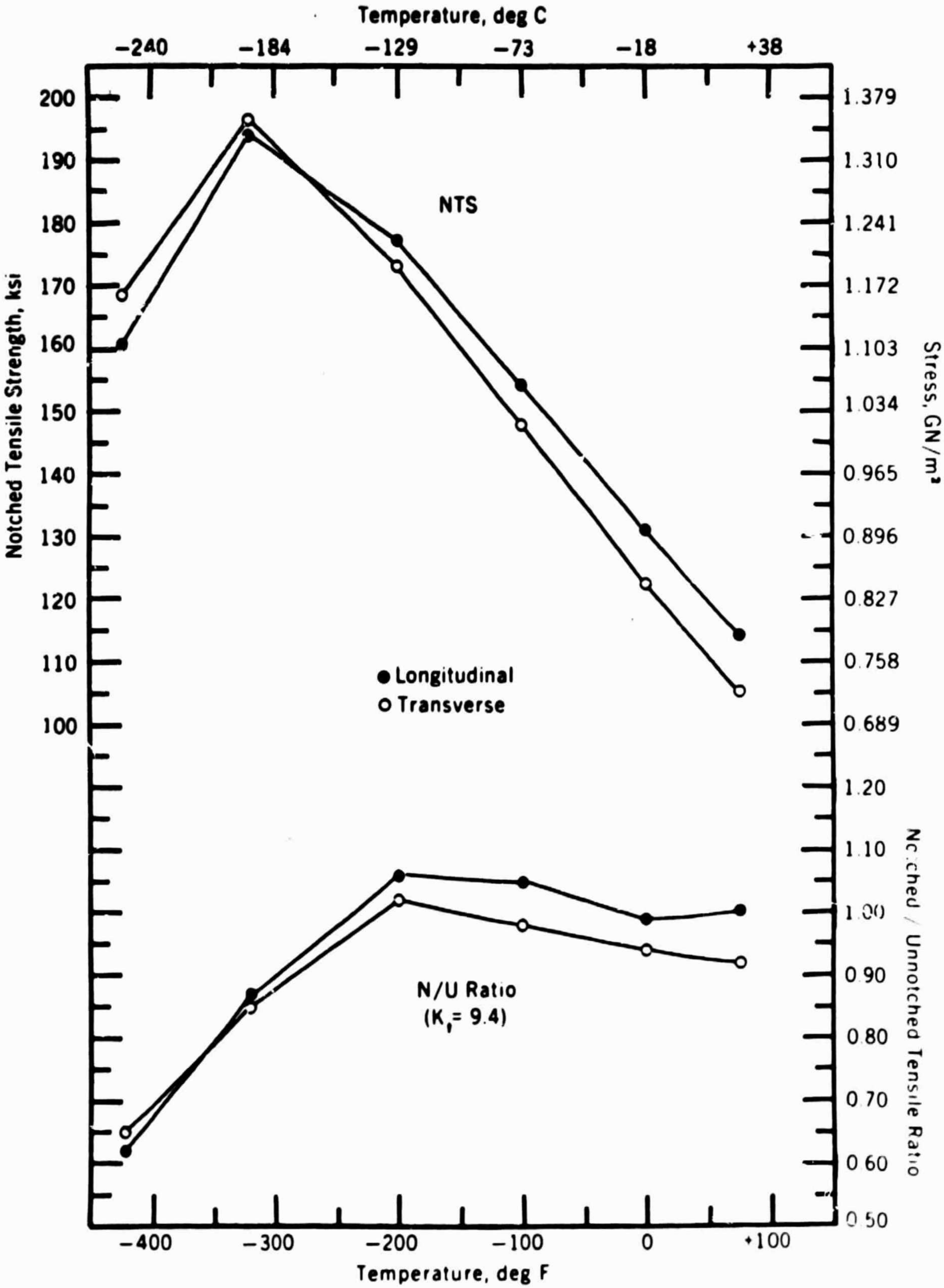
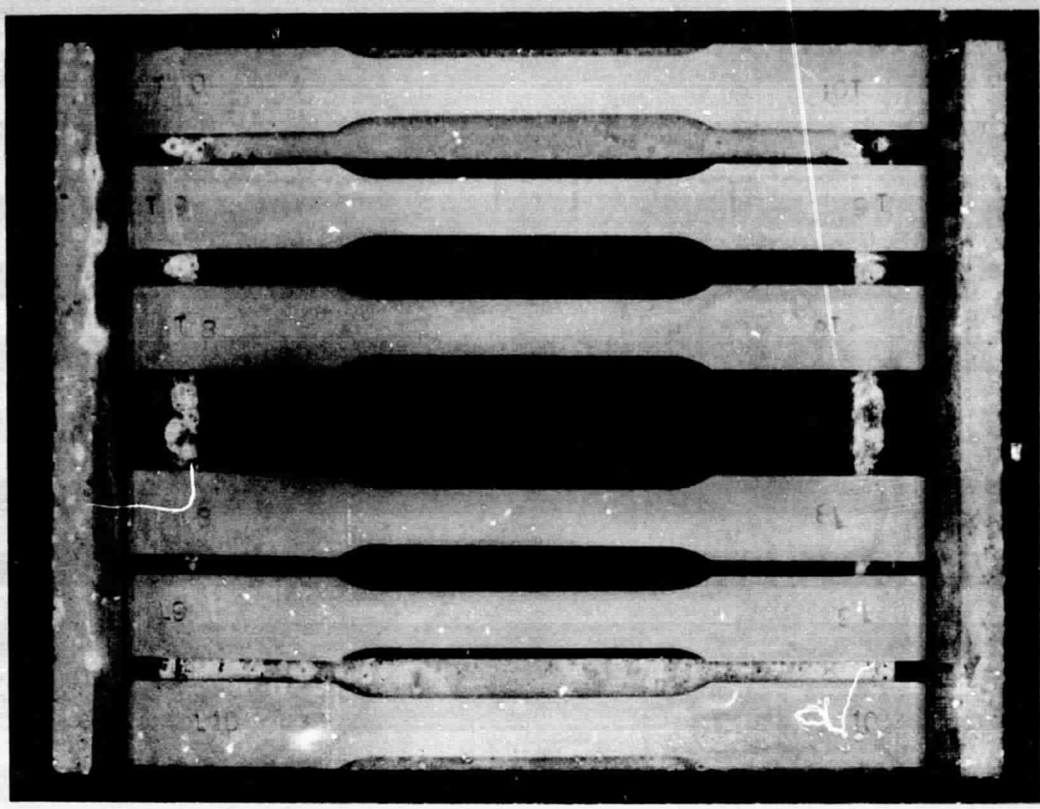
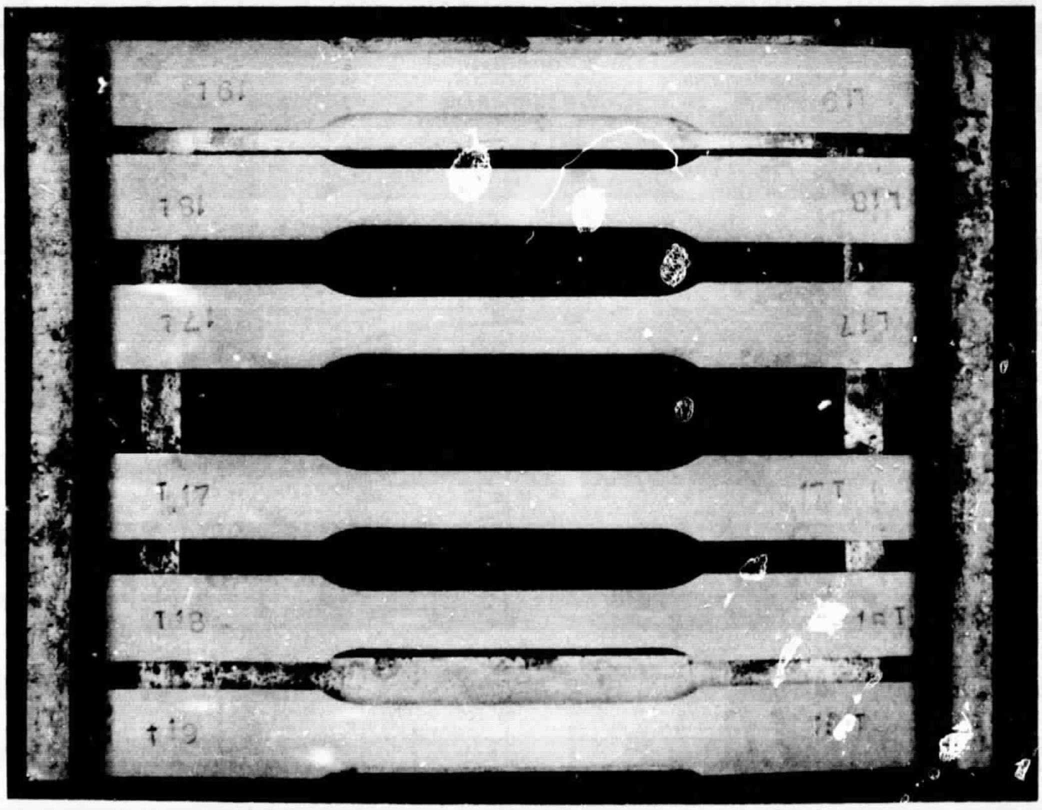


FIGURE 4 · LOW TEMPERATURE NOTCHED TENSILE PROPERTIES OF ANNEALED 18-3 MN STAINLESS STEEL PARENT METAL SHEET SPECIMENS

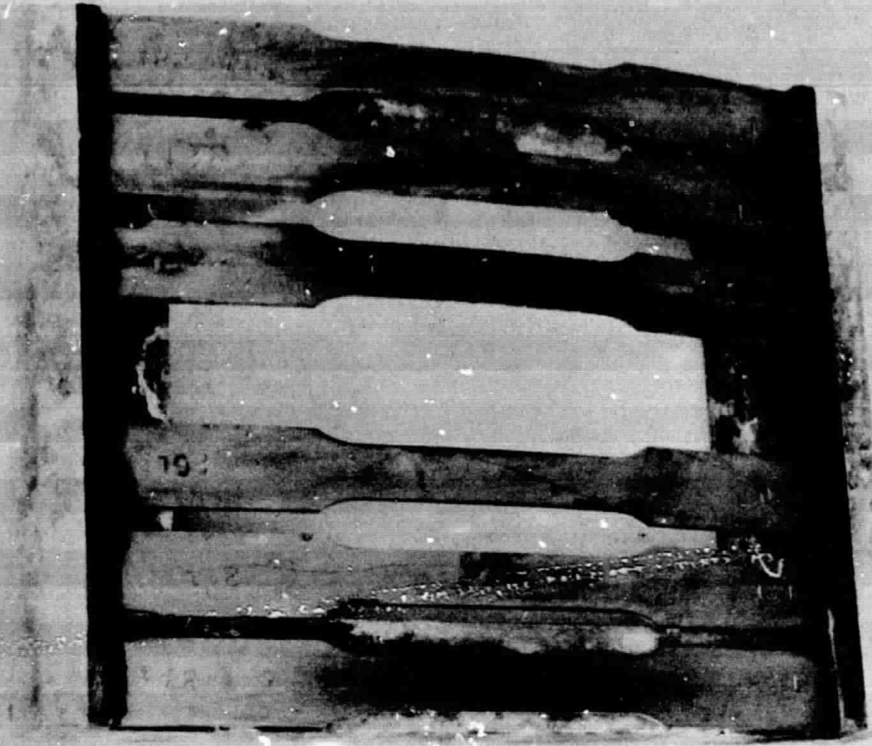


A. ALTERNATE IMMERSION

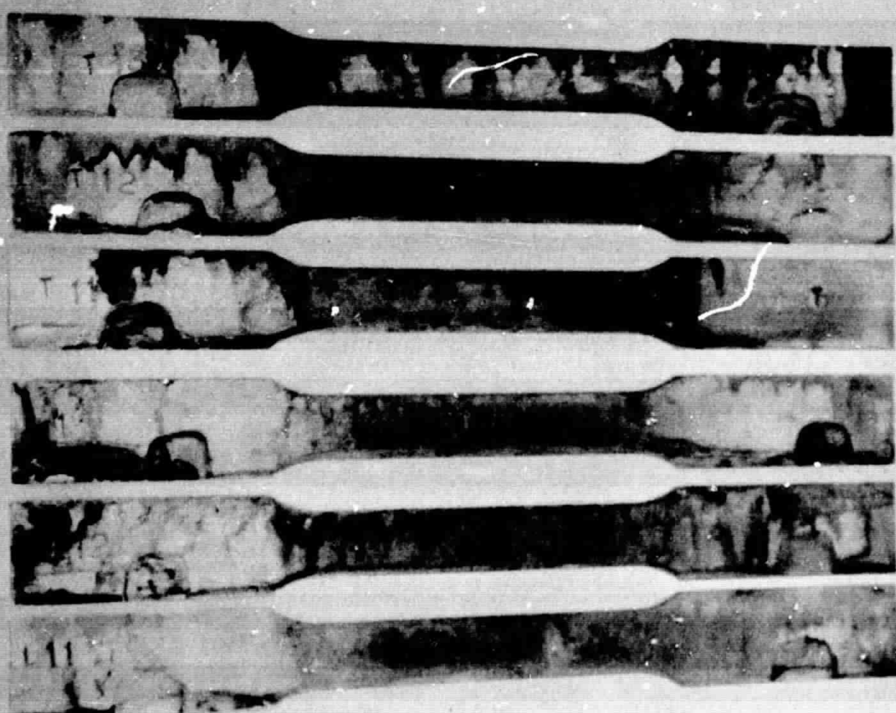


B. HUMIDITY CABINET

FIGURE 5 - ARMCO 18-3MN (NITRONIC 33) STAINLESS STEEL PARENT METAL SPECIMENS, STRESSED TO 75% OF THE YIELD STRENGTH AND EXPOSED FOR 1[illegible]0 DAYS.

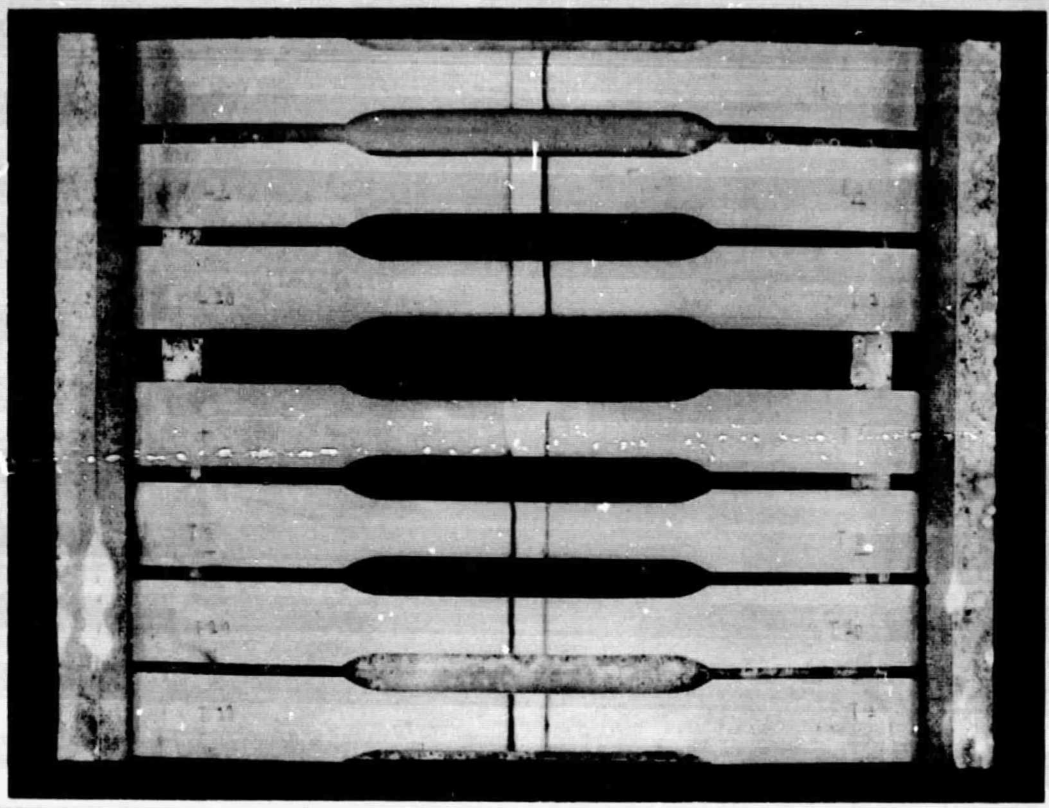


A. STRESSED TO 0% OF YIELD STRENGTH

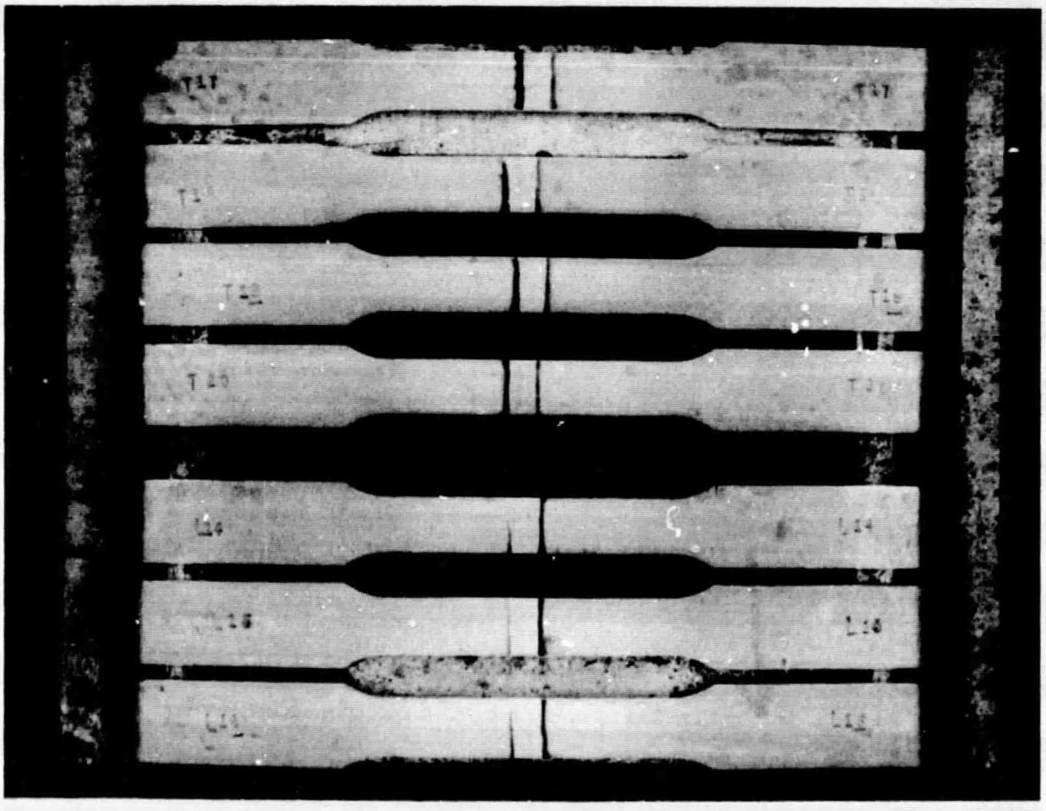


B. STRESSED TO 75% OF YIELD STRENGTH

FIGURE 6 - ARMCO 18-3MN (NITRONIC 33) STAINLESS STEEL PARENT METAL SPECIMENS, AFTER 180 DAYS OF SALT SPRAY EXPOSURE.

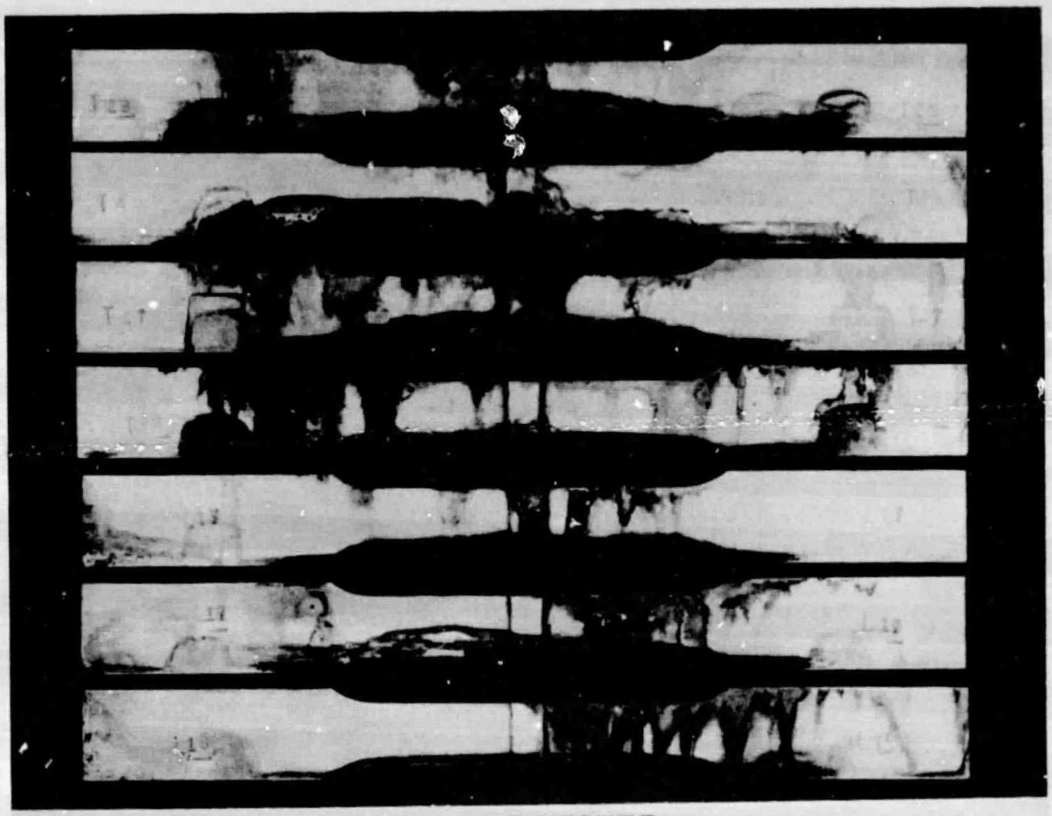


A. ALTERNATE IMMERSION

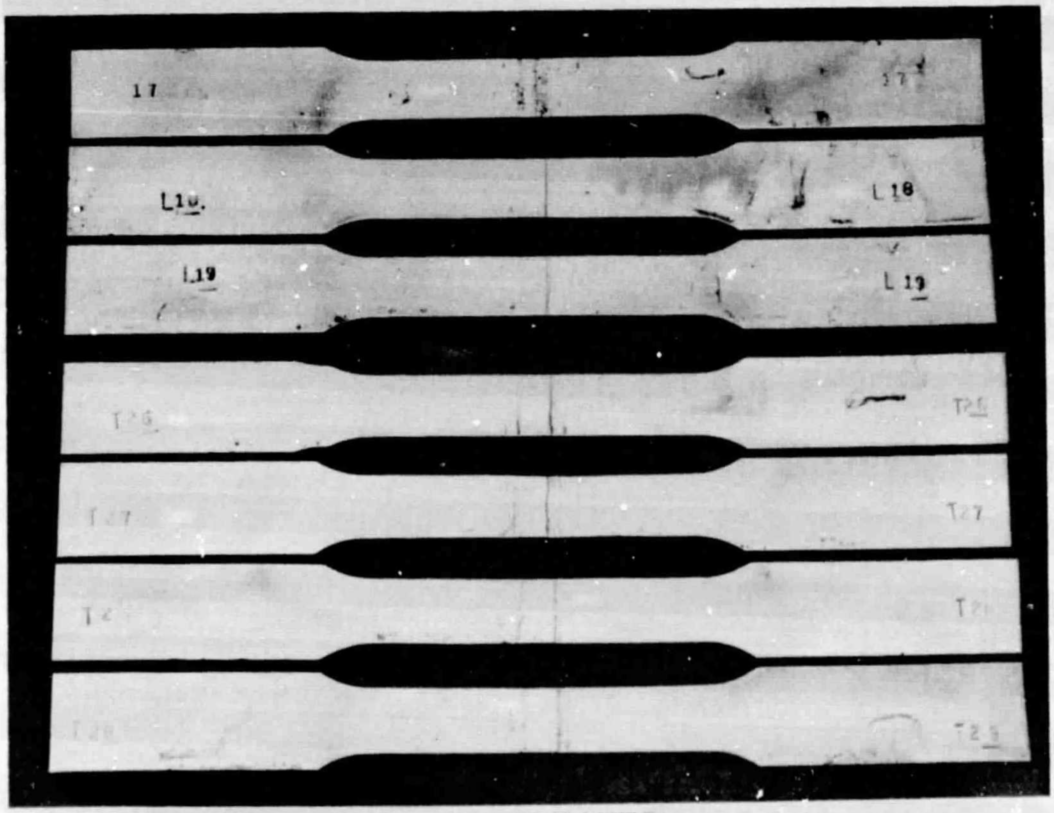


B. HUMIDITY CABINET

FIGURE 7 - ARMCO 18-3MN (NITRONIC 33) STAINLESS STEEL AS WELDED SPECIMENS, STRESSED TO 75% OF THE YIELD STRENGTH AND EXPOSED FOR 180 DAYS.

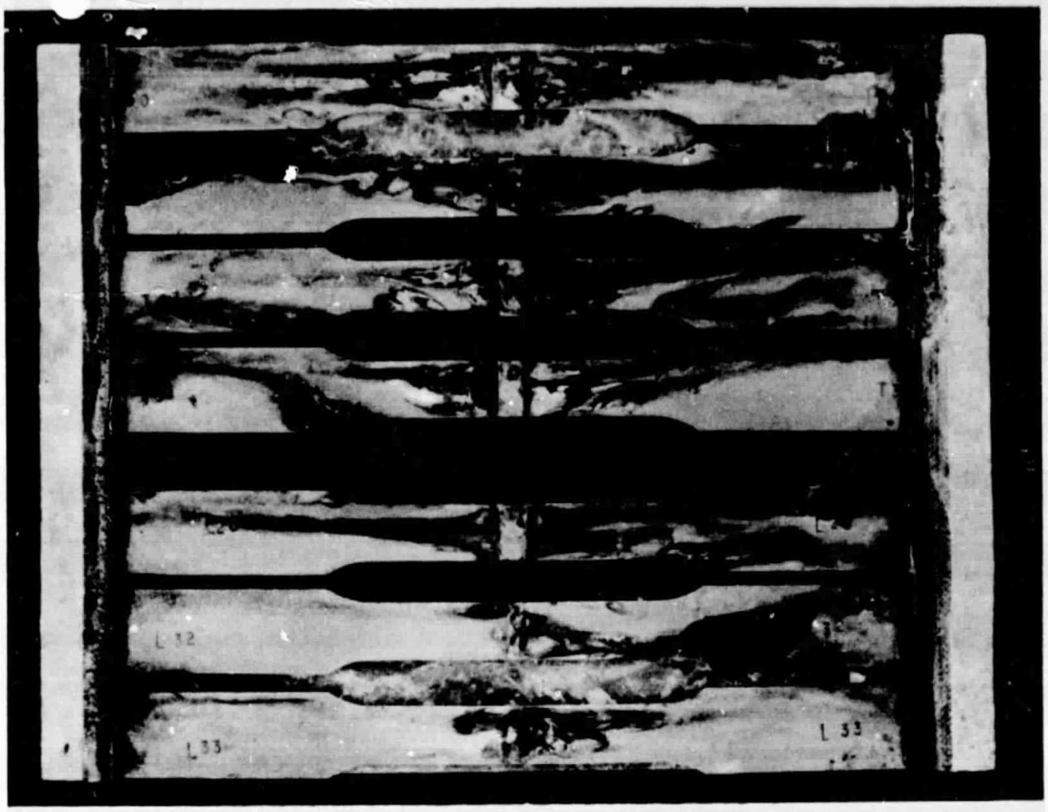


A. AS TESTED

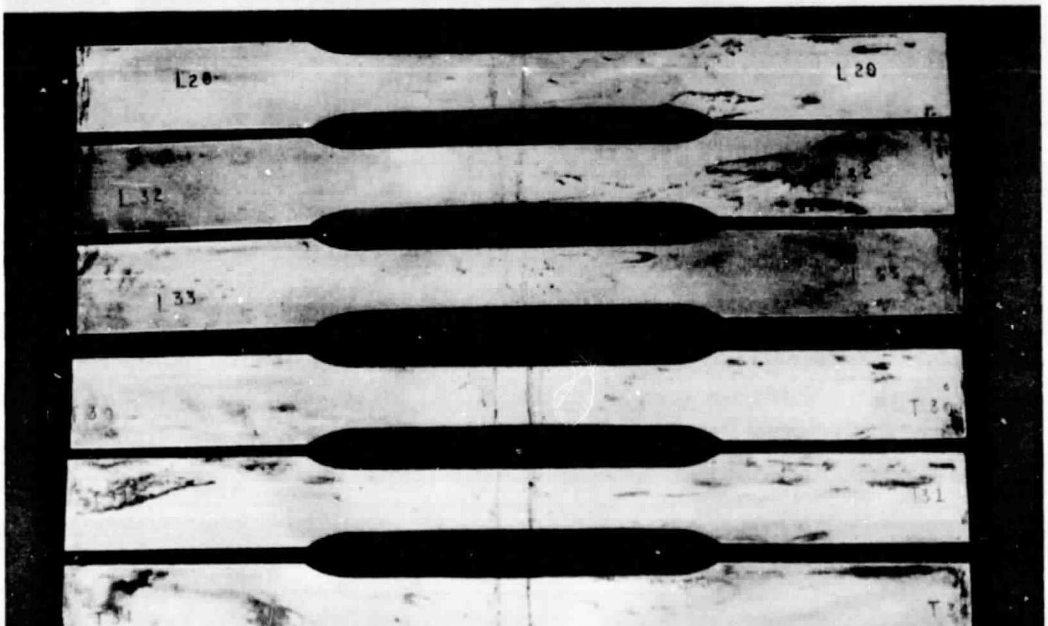


B. CLEANED

FIGURE 8 - ARMCO 18-3MN (NITRONIC 33) STAINLESS STEEL AS WELDED SPECIMENS, UNSTRESSED AND EXPOSED FOR 180 DAYS TO SALT SPRAY.

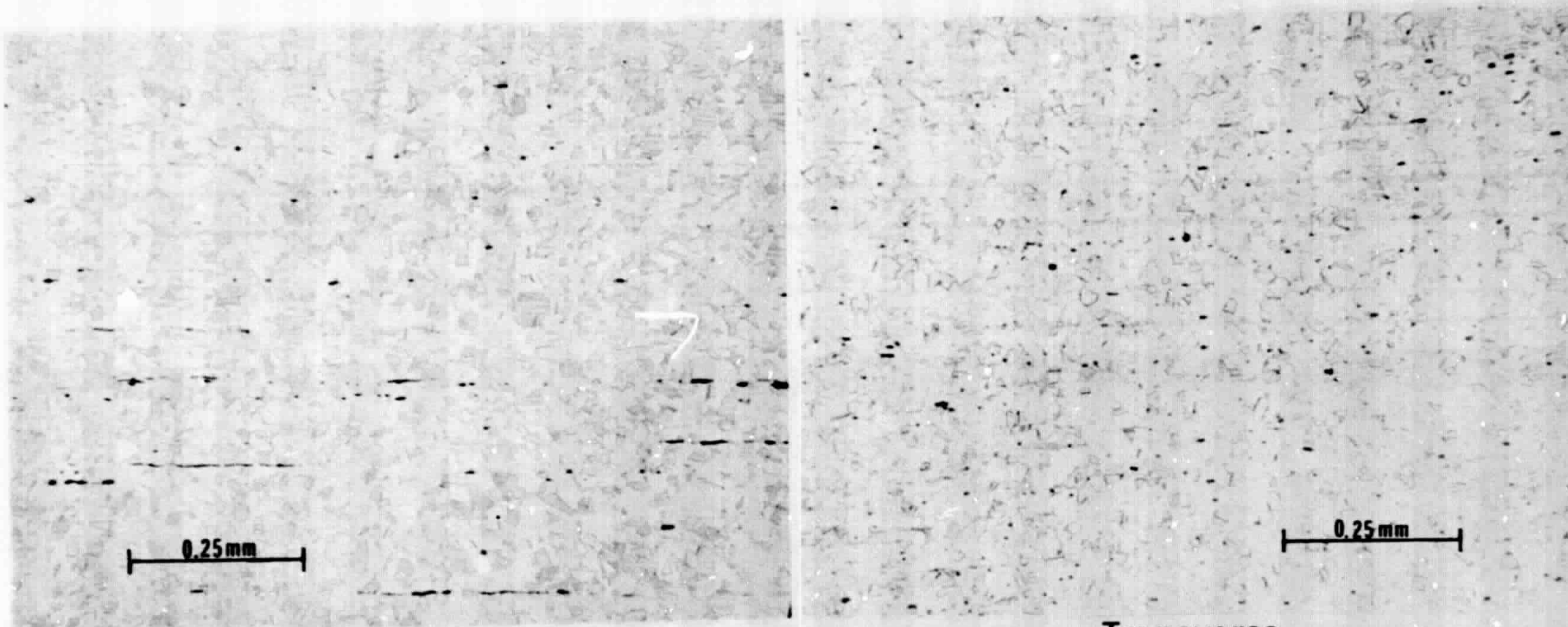


A. 180 DAYS - AS TESTED



B. 180 DAYS - CLEANED

FIGURE 9 - ARMCO 18-3MN (NITRONIC 33) STAINLESS STEEL AS WELDED SPECIMENS, STRESSED TO 75% OF THE YIELD STRENGTH AND EXPOSED TO SALT SPRAY.



Longitudinal   Transverse

FIGURE 10 — MICROSTRUCTURE OF 18-3 MN (NITRONIC 33) STAINLESS STEEL ALLOY
10% Oxalic Acid Etch   Mag 100X

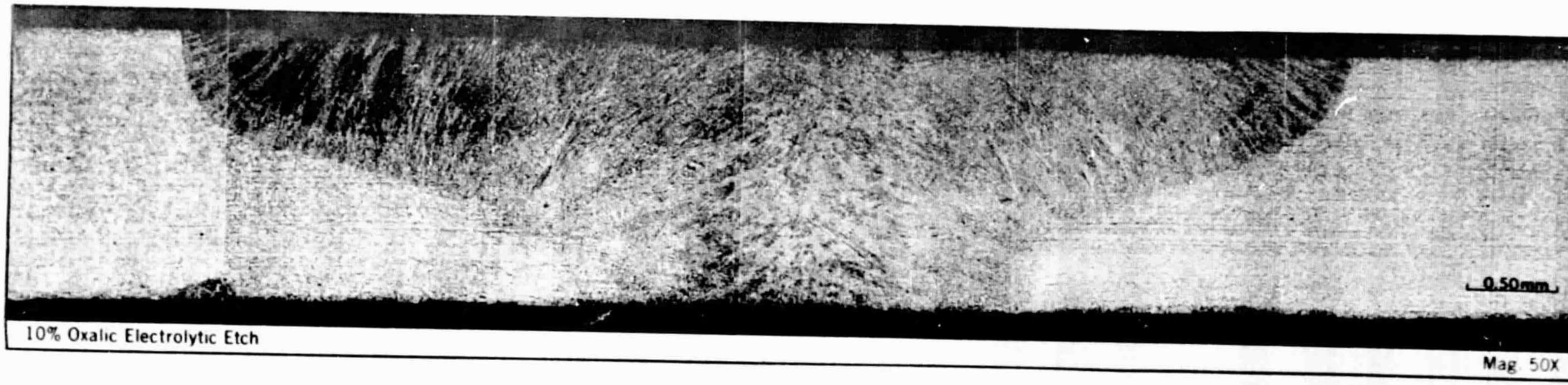
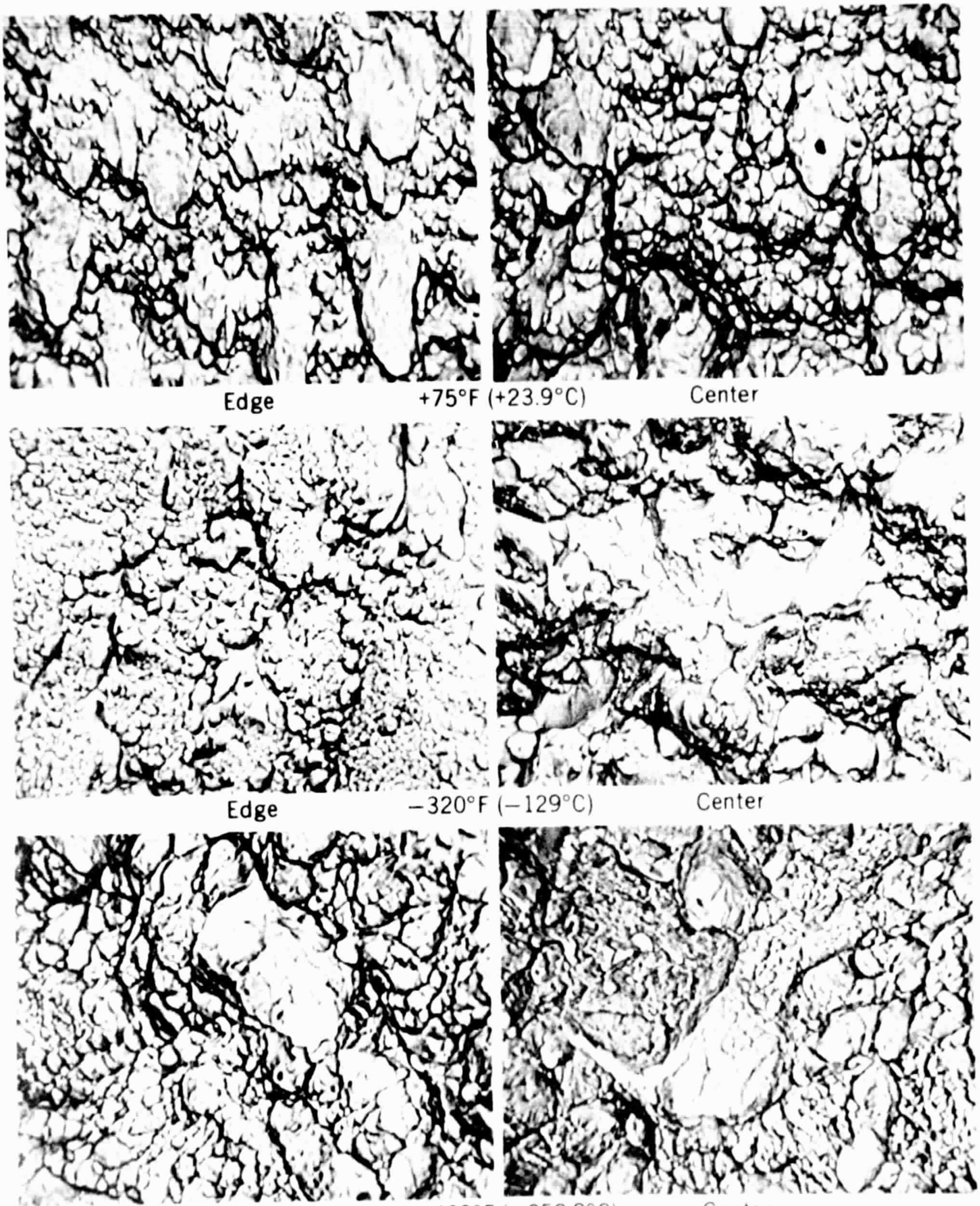


FIGURE 11 - MICROSTRUCTURE OF 18-3 MN (NITRONIC 33) STAINLESS STEEL TIG WELDED WITH NITRONIC 35W FILLER WIRE



Edge +75°F (+23.9°C) Center

Edge −320°F (−129°C) Center

Edge −423°F (−252.8°C) Center

FIGURE 12 — SEM FRACTOGRAPHS OF 18-3 MN (NITRONIC 33) STAINLESS STEEL ALLOY LONGITUDINAL SMOOTH TENSILE FRACTURES Mag 1000X

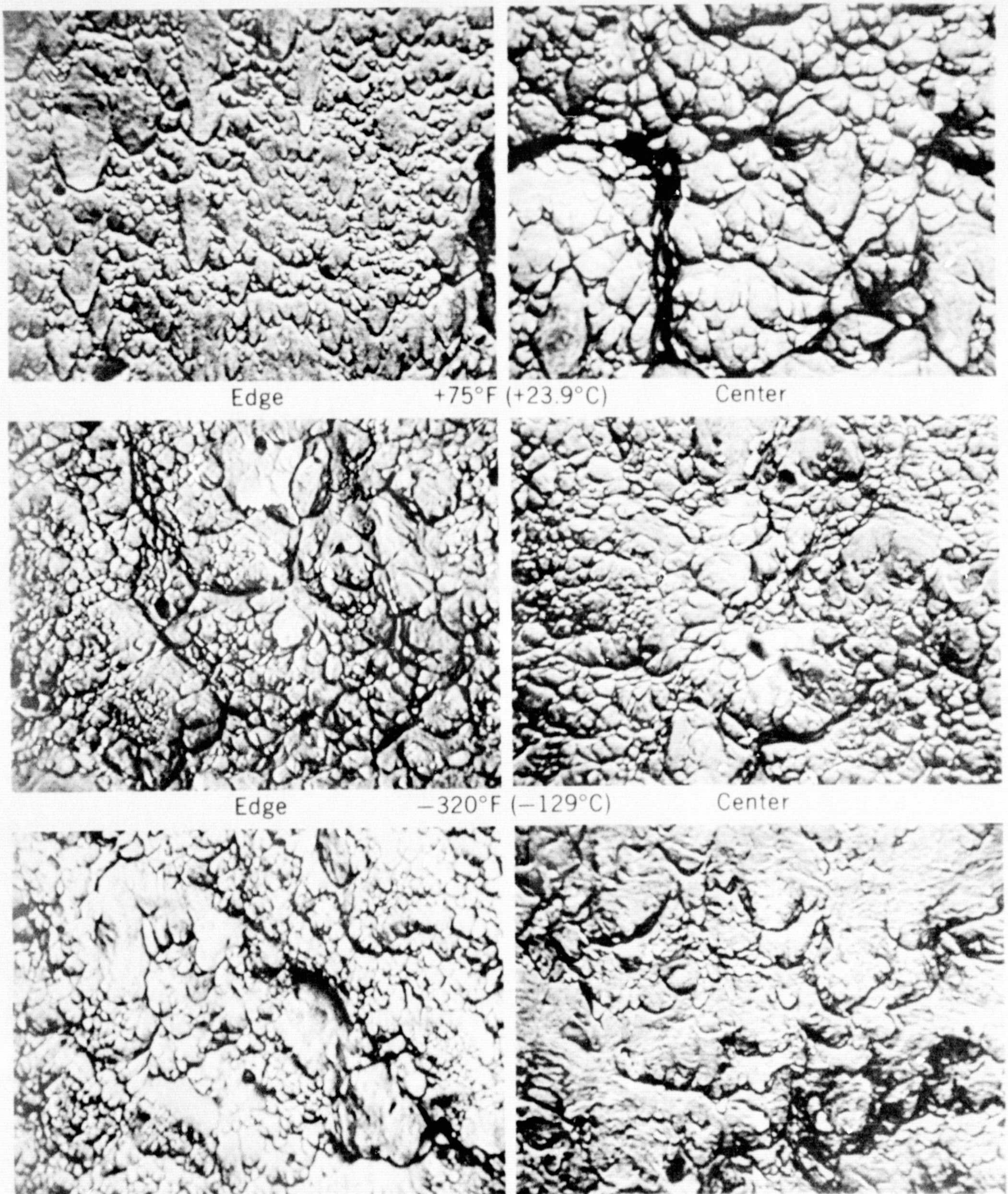
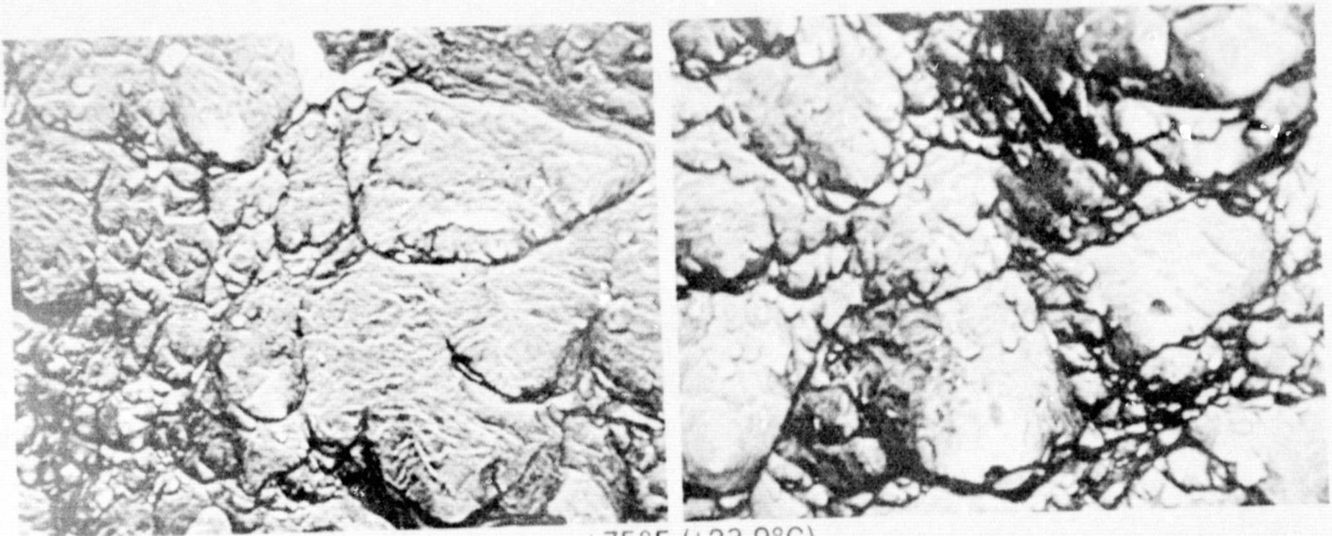
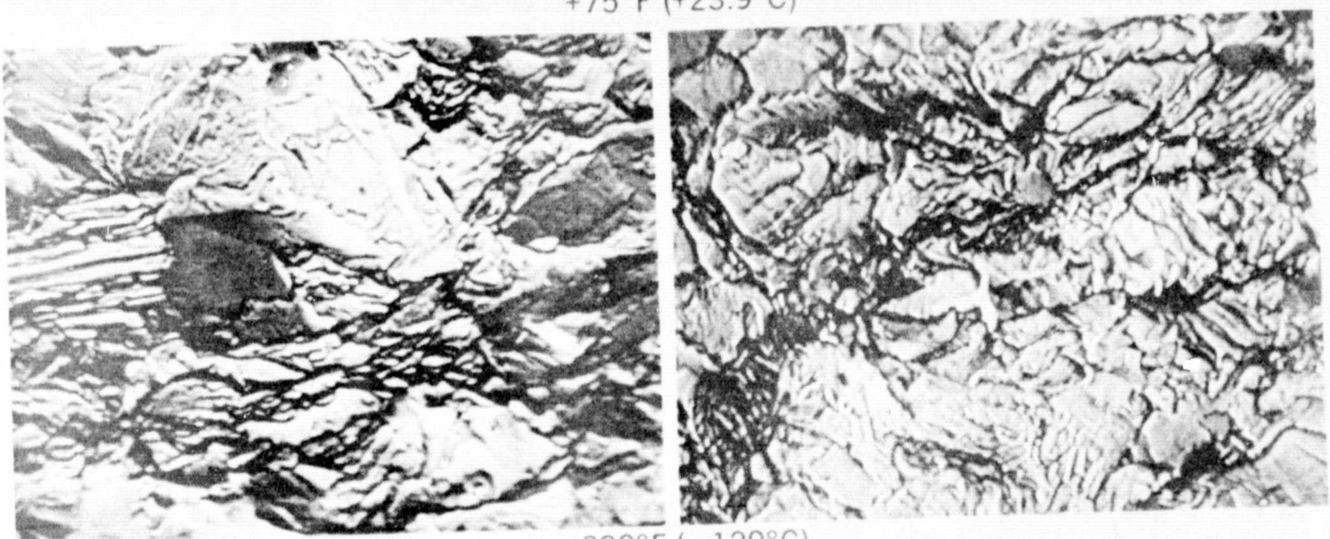


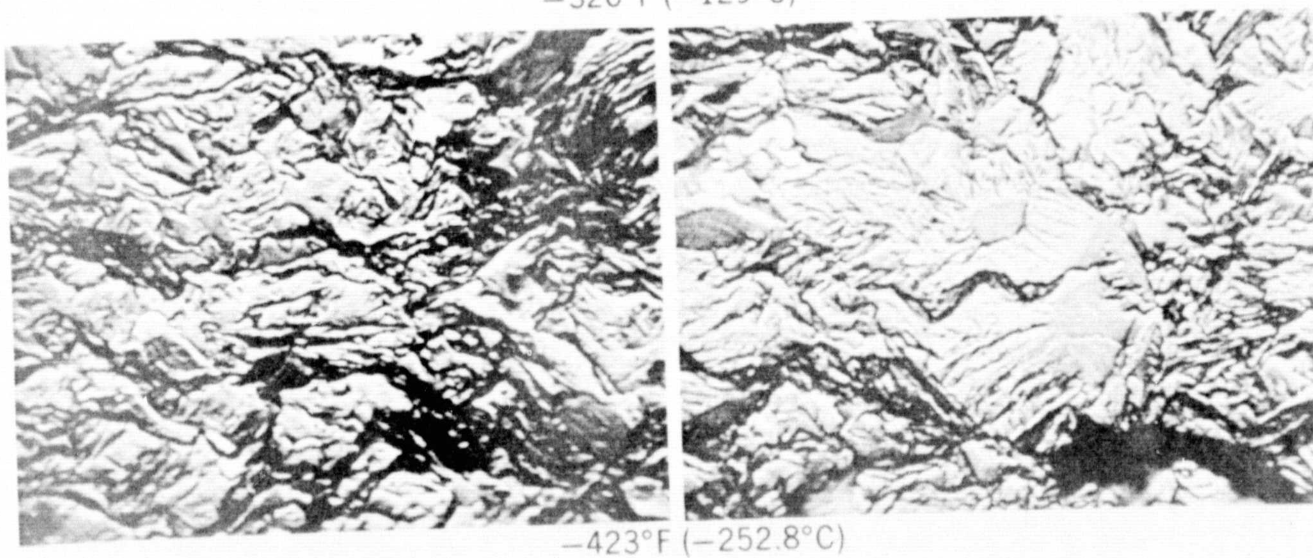
FIGURE 13A — SEM FRACTOGRAPHS OF 18-3 MN (NITRONIC 33) STAINLESS STEEL ALLOY
LONGITUDINAL V-NOTCHED TENSILE FRACTURES Mag 1000X
(DUCTILE FRACTURE AREA)



+75°F (+23.9°C)



−320°F (−129°C)



−423°F (−252.8°C)

FIGURE 13B — SEM FRACTOGRAPHS OF 18-3 MN (NITRONIC 33) STAINLESS STEEL ALLOY
LONGITUDINAL V-NOTCHED TENSILE FRACTURES Mag 1000X
(FRACTURE INITIATION EDGES)

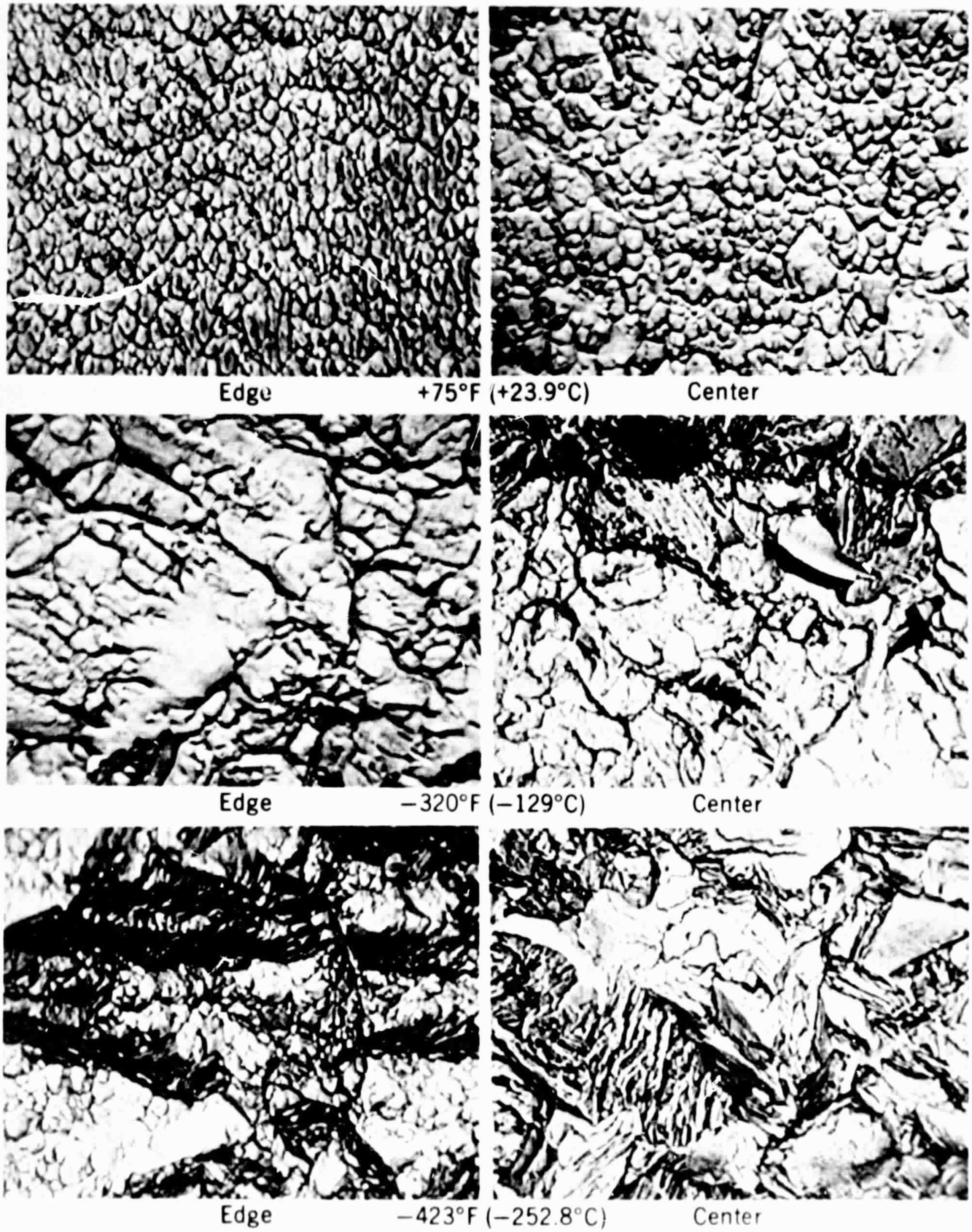


FIGURE 14 – SEM FRACTOGRAPHS OF 18-3 MN (NITRONIC 33) STAINLESS STEEL ALLOY LONGITUDINAL AS WELDED TENSILE FRACTURES Mag 1000X

APPROVAL

THE STRESS CORROSION RESISTANCE AND THE CRYOGENIC TEMPERATURE MECHANICAL BEHAVIOR OF 18-3 MN (NITRONIC 33) STAINLESS STEEL PARENT AND WELDED MATERIAL

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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