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MASTER

ALLOY EVALUATION FOR FOSSIL FUEL PROCESS PLANTS (LIQUEFACTION)

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Alloy Evaluation for Fossil Fuel Process Plants (Liquefaction)

Quarterly Report for

Period

1 April through 30 June 1977

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FOREWARD

This report covers work performed during the period 1 April through 30 June 1977. The work was administered by the Division of Materials and Exploratory Research with Dr. Thomas B. Cox as project manager. The report was prepared by Charles M. Woods and T. E. Scott of the Mechanical Properties Section in the Metallurgy and Ceramics Division at the USERDA - Ames Laboratory, Ames, Iowa.

The work was performed under the direction of Dr. Scott as principal investigator assisted by: C. M. Woods, S. Shei, C. V. Owen and L. K. Reed.

ABSTRACT

ASTM mechanical property specification verification tests have been conducted on the 2 1/4 Cr-1 Mo steel. The base properties have been determined for the steel and calibrations on the thermal expansivity of both the 2 1/4 Cr-1 Mo steel and 316 SS for use as loading rings have been completed.

OBJECTIVE AND SCOPE

The objective of this program is to evaluate the mechanical properties of liquefaction process plant "dissolver" vessel materials in a "dissolver" vessel environment including coal slurry and pressurized hydrogen gas at temperatures up to 900°F.

Specifically, the degradation of notched-bar and smooth bar tensile samples of 2 1/4 Cr - 1 Mo will be monitored as a function of exposure time and stress in the "dissolver" vessel environment.

PROGRESS SUMMARY

A. ASTM Mechanical Property Specification Verification Test

ASTM mechanical property specification verification tests have been carried out and the A387 steel has been found to comply to all the specifications in the as received condition. Composition and mill heat treatment supplied by the vendor is given in Table 1.

Smooth-bar tensile samples (Fig. 1) cut from both the longitudinal (parallel to the rolling direction) and transverse (perpindicular to the rolling direction) sections of the plate have been tested. The longitudinal 0.2% offset yield stress was determined to be 78.3 ksi as compared to 79.2 ksi for the transverse direction. The longitudinal ultimate tensile strength was determined to be 94.2 ksi as compared to 94.5 for the transverse. The major differences between the mechanical properties of the longitudinal and the transverse samples are in the engineering fracture stress (54.0 ksi long., 64.6 ksi trans.), true fracture stress (192.5 ksi long., 162.3 ksi trans.), uniform elongation (U.E.) (9.3% long., 8.8% trans.) and reduction in area (R.A.) (72.5% long., 61% trans.). The ductility in the longitudinal direction was slightly greater than that of the transverse direction as expected.

Notched-bar tensile samples (Fig. 2) cut from both the longitudinal and transverse sections of the plate have been tested. The longitudinal notch tensile strength (N.T.S.) (maximum load divided by original cross sectional area) was found to be 144.6 ksi as compared to 138.8 ksi for the transverse. Data for the smooth-bar tensile samples and for the notched-bar tensile samples are given in Tables 2 and 3 respectively. All tensile samples were pulled at a constant strain rate of $\dot{\varepsilon}=.01\ min.^{-1}$ Average values are given in Table 18.

Charpy V-Notch samples (Fig. 3) were machined from both the longitudinal and transverse sections of the plate with the notch being milled in the plate face side of both types of samples. It was found that the transverse samples had much lower impact toughness than the longitudinal samples. One observation worth noting here is that the notch radius for the transverse samples was sharper (0.16 mm) than that of the longitudinal samples (0.24 mm) which would produce a reduction of the impact energy. However, the impact energy of the transverse samples was much lower than could be attributed to the notch sharpness alone. Impact toughness data for the longitudinal and transverse samples is given in Tables 4 and 5 and in Fig. 4.

Three hardness readings were made on each of the 32 Charpy samples to check the hardness variation locations in the plate. The values were averaged and the hardness was found to be Rockwell "C" 15 ± 2. The data are presented in Tables 6 and 7.

The microstructure of the as received material was elucidated by mechanically polishing and subsequently etching with 2% nital solution (2% HNO_3 in methanol) for ten seconds. The microstructure appears to be mostly upper bainite with a few dispersed ferrite grains. Second phases were detected notably in the center of the thickness dimension of the plate. They appear to be sulfide inclusions in the direction of rolling. Photomicrographs of the longitudinal and transverse faces are shown in Figs. 5 and 6.

B. Baseline Data Test

Base properties tests have been carried out using smooth-bar tensile samples, Fig. 7, and notched-bar tensile samples, Fig. 8. Among the properties investigated were the 0.2% yield stress, ultimate tensile strength, uniform elongation, total elongation, engineering fracture stress, true fracture stress, reduction in area, and notch tensile strength. These tests were carried out on the as received material at room temperature, 500°F and 900°F. Also, the same tests were done after exposing the material to high pressure (2000 psi) inert gas (Argon) for 168 hours at 500°F and 900°F. All samples were tested on a TT-C Instron tensile test machine at a constant strain rate of $\dot{\varepsilon}$=0.05 min.$^{-1}$.

All data was calculated from the stress-strain curves. Fiducial marks were used to measure the total elongation of the samples, however, it was found that the values obtained from the stress-strain curves at point of fracture were within 1 percent of the values obtained by measurement of the fiducial marks before and after testing. Therefore it was decided to use the stress-strain curves for the calculation of the total elongation. Cross sectional areas and reduction in area at the neck were calculated by measuring the diameters at three positions and averaging. All diameter measurements were made on a Gaertner model 2001 Toolmaker's microscope accurate to ± .00004 in. The value reported as Engineering Fracture Stress was calculated by dividing the fracture load by the orginal cross sectional area. The value reported as True Fracture Stress is obtained by dividing the fracture load by the cross sectional area of the neck (i.e. the area at point of fracture). The notch tensile strength is defined as the maximum load divided by the original cross sectional area. The true fracture stress for the notched samples will not be reported here due to the uncertainty in the measurement of the cross sectional area of the notch at fracture. However, it is necessary to note here, that considerable necking did occur in the notch on all the samples tested and is presented as an approximate reduction in area.

A comparison of the results will be presented briefly here, with all the data being presented in Tables 8 thru 17. All values reported here, are statistical averages based on data certified by the 'Q' test at the 90% confidence level. At ambient temperature (i.e. 72°F) the values for the smooth-bar and notched-bar tensile samples were as follows: 0.2% YS = 78.7 ksi, UTS = 95.6 ksi, Total Elongation = 24.7%, Uniform Elongation = 14.2%, RA = 75.5%, RA of Notch = 26%, and Notch Tensile Strength = 148.2 ksi. At 500°F the values were: 0.2% YS = 69.2 ksi, UTS = 84.5 ksi, Total Elongation = 21.1%, Uniform Elongation = 11.7%, RA = 74.3%, RA of Notch = 23%, and Notch Tensile Strength = 129.7 ksi. At 900°F the values were: 0.2% YS = 64.3 ksi, UTS = 78.6 ksi, Total Elongation = 21.1%, Uniform Elongation = 10.9%, RA = 71.5% RA of Notch - 23%, and Notch Tensile Strength = 121.3 ksi. These values agree well with the ASTM specification verification tests and meet the ASTM code specifications as shown in Table 18.

The next set of tests was made to determine the effect of prolonged exposure to high temperature and pressure. The actual tensile testing was carried out at ambient temperature. The resulting average values, given in Table 18, were as follows:

i) Material exposed to 500°F and 2000 Psi Argon for 168 hours: 0.2% YS = 79.6 ksi, UTS = 96.4 ksi, Total Elongation = 24.5%, Uniform Elongation = 14.3%, RA = 75.8%, RA of Notch = 26% and Notch Tensile Strength = 148.6 ksi.

ii) Material exposed to 900°F and 2000 Psi Argon for 168 hours: 0.2% YS = 78.2 ksi, UTS - 95.7 ksi, Total Elongation = 24.3% Uniform Elongation = 14%, RA = 75.0%, RA of Notch = 27% and Notch Tensile Strength = 147.9 ksi.

It can be seen from the data, that all of the mechanical properties decrease with increasing temperature. It is also apparent, Table 18, that the prolonged exposure to high temperature and pressure had no effect on the ambient mechanical properties of the material. Graphs of the effect of temperature on the mechanical properties are given in Figs. 9 and 10.

C. Thermal Expansion and Thermal Stability Tests

The thermal expansion coefficient for the A387 steel was determined for the temperature range 72°F - 500°F and was found to be 7.4 μin/in/°F. The sample was held at 500°F for 168 hours and no appreciable change in length was noted with time, indicating good structural stability at 500°F. Presently, studies are being made to determine the thermal expansion coefficient for the steel over the 72°F = 900°F temperature range. Likewise, a 168 hour test will be made in order to determine the structural stability at 900°F. The A387 will then be loaded in tension to 48.2 ksi in a 316 stainless steel ring and the composite will be monitored at 500°F and 900°F in order to note any system relaxation. The indicated stress is 75 percent of the 0.2% offset Yield Stress of the material at 900°F.

The values determined for the thermal expansion coefficients of both A387 and 316 stainless (i.e. α_{A387} = 7.4 μin/in/°F, α_{316} = 9.09 μin/in/°F) are in good agreement with those values published in the literature. Thermal expansion and relaxation data will be analyzed, graphed and presented in the annual report for FY 1977.

WORK FORECAST

The delays in procurring the pressure vessels required to conduct the coal slurry exposure tests have necessitated a revision of the milestone chart. The static 168 hour exposures to 4000 Psi Argon at 500°F and 900°F, orginally scheduled for fiscal year 1978, will be completed during the next quarter along with tests of samples stressed during prolonged exposures in Argon as outlined on the milestone charts for FY 1977 and FY 1978. This schedule change is done with the concurrence of Project Manager Dr. T. B. Cox.

TABLE #1

A387-74A GRADE 22 CLASS 2

ELEMENTAL COMPOSITION AND HEAT TREATMENT

ELEMENT	wt. %
Cr	2.41
Mo	0.93
C	0.115
S	0.029
Mn	0.42
Si	0.17

HEAT TREATMENT:

NORMALIZED, 1650°-1700°F, HELD 1 HOUR PER INCH MINIMUM AND AIR COOLED, THEN TEMPERED 1350°F, HELD 3/4 HOUR PER INCH MINIMUM AND AIR COOLED.

TABLE #2

ASTM SMOOTH BAR TENSILE SAMPLE DATA

STRAIN RATE = $\dot{\varepsilon}$ = .01 in/in/min

Sample #	0.2% YS (ksi)	UTS (ksi)	Engineering Fracture Stress (ksi)	True Fract. Stress (ksi)	Uniform Elongation (%)	RA (%)
1L*	79.1	94.3	55.0	192.5	9.75%	72
2L	78.3	94.4	53.0	193.4	9.75	73
3L	78.0	93.9	54.0	200.8	9.0	73.5
4L	78.1	93.9	53.7	183.0	9.5	72
5L	78.2	94.4	54.5	192.5	8.5	72
6T**	78.1	94.1	64.5	162.0	9.5	61
7T	82.9	94.3	65.2	166.0	7.5	61.5
8T	78.3	95.2	64.8	165.0	9.0	61.5
9T	77.6	94.4	63.7	156.0	9.0	60

* L-refers to Longitudinal Sample

** T-refers to Transverse Samples

TABLE #3

ASTM NOTCHED BAR TENSILE SAMPLE DATA

$\dot{\varepsilon}$ = .01 in/in/min

Sample #	Notch Area (in^2)	Notch Radius (in)	Notch Angle (°)	Notch Tensile Strength (ksi)
1T	.2032	<.001	63.5°	137.8
2T	.2042	.001	65	139.1
3T	.2013	.001	67	139.6
4T	.2017	<.001	66	138.8
5L**	.1982	.001	66	145.3
6L	.1986	.00125	66	144.7
7L	.1996	.001	66	143.8
8L	.2007	.001	66	144.3
9L	.2001	.0015	67	144.9

* T-refers to Transverse samples
** L-refers to Longitudinal samples

TABLE #4

CHARPY V-NOTCH LONGITUDINAL SAMPLES

Sample #	Test Temperature (°C)	Impact Energy (ft-lbs)	Area at Base of Notch (in^2)	Notch Radius (mm)	Notch Angle (°)
CL1	25°	≥120	-	0.24	45
CL2	-78.5	5.5	.122	0.24	45
CL3	-195.8	-	.121	0.24	45
CL4	0	≥120	.122	0.24	45
CL5	0	≥120	.124	0.24	45
CL6	-25	78.5	.123	0.24	45
CL7	-25	70	.125	0.24	45
CL8	-50	21	.124	0.24	45
CL9	-50	17	.122	0.24	45
CL10	-75	18	.122	0.24	45
CL11	-60	27	.122	0.24	45
CL12	-195.8	2	.125	0.24	45

TABLE #5

CHARPY V-NOTCH TRANSVERSE SAMPLES

Sample #	Test Temp. (°C)	Impact Energy (ft-lbs)	Area at Base Notch (in^2)	Notch Radius (mm)	Notch Angle (°)
CT1	23°C	58.5	.125	.16 (mm)	45°
CT2	23	42	.123	.16	45
CT3	0	26.5	.124	.16	45
CT4	0	37	.123	.16	45
CT5	-25	22.5	.121	.16	45
CT6	-25	14	.124	.16	45
CT7	-25	18.5	.125	.16	45
CT8	-40	14	.122	.16	45
CT9	-40	18.5	.122	.16	45
CT10	-50	11.5	.124	.16	45
CT11	-50	20	.123	.16	45
CT12	-70	3	.125	.16	45
CT13	-70	6	.123	.16	45
CT14	-195.8	1.5	.125	.16	45
CT15	-195.8	2	.124	.16	45

TABLE #6

ROCKWELL 'C' HARDNESS

Sample #	1st	2nd	3rd	4th	Avg.
CL1	13	14	14	14	14
CL2	11	14	15	14.5	14
CL3	14	14	14.5		14
CL4	12	14.5	15.5		14
CL5	13.5	14.5	14.5		14
CL6	13	14.5	14.5		14
CL7	14	14	15		14.5
CL8	11	15	15		14
CL9	14.5	15	14.0		14.5
CL10	14.5	15	14.5		15
CL11	14	15.5	15		15
CL12	14.5	15.5	15	15	15

Overall Average = 14.5

TABLE #7

ROCKWELL 'C' HARDNESS

Sample #	1st	2nd	3rd	Avg.
CT1	12.5	16	16.5	15
CT2	15	17	17	16.5
CT3	13	16	16	15
CT4	15.5	17	17	16.5
CT5	14	16.5	16	15.5
CT6	14	17		15.5
CT7	14	16		15
CT8	13.5	15		14.5
CT9	11	15	15.5	14
CT10	15.5	16		16
CT11	15	16		15.5
CT12	16	17		16.5
CT13	15	16.5		16
CT14	14	17		15.5
CT15	12	16	15.5	14.5
CT16	13.5	16		15
CT17	14	15.5		15
CT18	14	15		14.5
CT19	16	16		16
CT20	13.5	16	16.5	15.5

Overall Average = 15.5

TABLE #8

Test 1 T=72°F P=1ATM AIR $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL IN AS RECEIVED CONDITION

SMOOTH BAR TENSILE SAMPLES

Sample #	Gage Area (in^2)	0.2% YS (ksi)	UTS (ksi)	Total Elongation (%)	Uniform Elong. (%)	Engr. Fracture Stress (ksi)	Reduction Area (%)	True Fracture Stress (ksi)
TS11	.0356	80.1	96.9	24.9	14.2	54.8	75.2	221.0
TS12	.0355	80.3	97.2	23.7	13.1	54.9	75.1	221.0
TS13	.0346	79.3	96.0	25.1	14.1	53.5	75.9	222.0
TS14	.0361	78.3	95.3	24.7	14.3	52.6	75.5	215.3
TS15	.0352	78.1	94.3	25.7	14.9	52.6	75.9	217.8
TS16	.0351	78.6	95.4	24.5	14	52.7	75.8	217.8
TS17	.0361	78.3	95.0	25.7	15.1	52.6	76	219.4
TS18	.0352	78.1	95.2	24	14.4	52.6	75.4	213.7
TS19	.0349	78.8	96.0	23.8	13.9	55.2	74.7	218.1
TS20	.0359	77.3	94.7	24.9	14.2	52.2	75.4	212.5

TABLE #9

Test 2 T=72°F P=1ATM AIR $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL IN AS RECEIVED CONDITION

NOTCHED BAR TENSILE SAMPLES

Sample #	Notch Area (in^2)	Notch Radius (in)	Notch Angle (°)	Notch Tensile Stress (ksi)	∼ Area At Fracture (in^2)	∼ Reduction in Area (%)
NS11	.0350	.00125	67	147.1	.0256	27
NS12	.0353	.00125	67.5	146.7	.0265	25
NS13	.0346	.00125	67	149.7	.0259	25
NS14	.0346	.001	67.5	148.0		
NS15	.0350	.00125	68	148.6		
NS16	.0343	.001	68.5	149.9		
NS17	.0346	.001	68.5	148.6		
NS18	.0350	.001	67.5	146.9		
NS19	.0346	.00125	67.5	148.6		
NS20	.0350	.001	68	148.3		

TABLE #10

Test 3 T=500°F P=1ATM AIR $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL IN AS RECEIVED CONDITION

SMOOTH BAR TENSILE SAMPLES

Sample #	Gage Area (in^2)	0.2% YS (ksi)	UTS (ksi)	Total Elongation (%)	Uniform Elong. (%)	Engr. Fracture Stress (ksi)	Reduction Area (%)	True Fracture Stress (ksi)
TS31	.0349	68.1	84.0	20.9	12	51.6	73.8	196.5
TS32	.0348	69.0	83.9	21	11.7	50.3	74.2	194.6
TS33	.0354	69.9	85.0	20.6	11.3	50.8	74.6	200.2
TS34	.0353	70.1	85.0	20.5	11.3	52.4	73.1	194.7
TS35	.0355	69.7	85.2	21.4	12	51.3	74.2	198.7
TS36	.0339	68.6	84.1	21.2	11.8	50.1	74.5	196.3
TS37	.0353	68.6	83.9	22	12.2	48.9	74.0	188.3
TS38	.0351	69.5	84.8	20.9	11.4	50.7	74.4	198.0
TS39	.0356	68.8	84.3	21.7	11.7	51.1	74.3	198.7
TS40	.0345	69.6	84.9	20.5	11.3	50.7	74.4	198.3

TABLE #11

Test 4 T=500°F P=1ATM AIR $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL IN AS RECEIVED CONDITION

NOTCHED BAR TENSILE SAMPLES

Sample #	Notch Area (in^2)	Notch Radius (in)	Notch Angle (°)	Notch Tensile Stress (ksi)	~ Area At Fracture (in^2)	~ Reduction in Area (%)
NS31	.0350	.00125	68	129.3	.0264	24
NS32	.0353	.00125	67	129.6	.0276	22
NS33	.0346	.00125	67.5	130.1	.0268	23
NS34	.0350	.001	68	130.0		
NS35	.0350	.001	68	129.3		
NS36	.0350	.00125	67.5	130.3		
NS37	.0343	.001	68	129.7		
NS38	.0350	.001	67.5	128.0		
NS39	.0350	.00125	68	129.7		
NS40	.0248	.001	68	129.6		

TABLE #12

Test 5 T=900°F P=1ATM Argon $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL IN AS RECEIVED CONDITION

SMOOTH BAR TENSILE SAMPLES

Sample #	Gage Area (in^2)	0.2% YS (ksi)	UTS (ksi)	Total Elongation (%)	Uniform Elong. (%)	Engr. Fracture Stress (ksi)	Reduction Area (%)	True Fracture Stress (ksi)
TS41	.0354	65.0	80.2	21.5	11.3	45.2	72.2	162.4
TS42	.0361	63.0	75.5	21.3	10.5	40.9	71.2	142.0
TS43	.0354	65.0	78.4	20.2	10.5	45.2	70.7	154.0
TS44	.0351	64.1	79.2	20.8	11.1	50.6	67.8	156.9
TS45	.0360	64.6	79.2	20.9	11.2	49.3	70.6	168.0
TS46	.0355	64.8	78.9	21.6	11.2	44.2	72.7	162.2
TS47	.0363	65.0	78.3	21.8	11	44.1	71.4	154.0
TS48	.0354	63.8	77.7	20.6	10.3	43.8	71.7	154.6
TS49	.035	63.6	77.9	21.5	10.8	42.9	72.4	155.0
TS50	.0354	64.1	78.5	21	11	44.5	70.7	151.6

TABLE #13

Test 6 T=900°F P=1ATM Argon $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL IN AS RECEIVED CONDITION

NOTCHED BAR TENSILE SAMPLES

Sample #	Notch Area (in^2)	Notch Radius (in)	Notch Angle (°)	Notch Tensile Stress (ksi)	∿ Area At Fracture (in^2)	∿ Reduction in Area (%)
NS41	.0346	.00125	68	123.1	.0283	18%
NS42	.0346	.001	68	121.4	.0267	23%
NS43	.0348	<.001	67.5	122.1	.025	28%
NS44	.0350	.001	67.5	121.7		
NS45	.0346	.001	66.5	121.4		
NS46	.0348	.00125	66.5	119.8		
NS47	.0346	.001	67	119.9		
NS48	.0353	.00125	67	119.7		
NS49	.0348	.001	69.5	120.7		
NS50	.0351	.00125	67.5	122.8		

TABLE #14

Test 7 T=72°F P=1ATM AIR $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL EXPOSED FOR 168 HOURS AT 500°F AND 2000 psi Argon

SMOOTH BAR TENSILE SAMPLES

Sample #	Gage Area (in^2)	0.2% YS (ksi)	UYS (ksi)	Total Elongation (%)	Uniform Elong. (%)	Engr. Fracture Stress (ksi)	Reduction Area (%)	True Fracture Stress (ksi)
TS1	.0348	80.2	96.8	25	14.5	54.6	75.6	223.7
TS2	.0353	79.3	96.3	25.6	14.7	53.1	76.4	225.0
TS3	.0363	79.2	96.4	23.6	14	55.1	75.7	226.6
TS4	.0354	80.2	96.0	24.3	14	54.4	75.1	218.1
TS5	.0362	79.4	96.0	24.8	14.6	56.6	76.1	236.7
TS6	.0357	79.8	96.4	24.6	14.2	54.6	76.2	229.6
TS7	.0344	79.5	95.2	24.2	14.7	55.2	75.3	223.7
TS8	.0353	80.0	96.0	23.1	13.5	54.5	75.9	226.6
TS9	.0354	79.4	96.3	24.9	14.2	53.7	76.0	223.7
TS10	.0356	80.1	96.1	24.7	14	54.1	76.1	226.6

TABLE #15

Test 8 T=72°F P=1ATM AIR $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL EXPOSED FOR 168 HOURS AT 500°F AND 2000 psi Argon

NOTCHED BAR TENSILE SAMPLES

Sample #	Notch Area (in^2)	Notch Radius (in)	Notch Angle (°)	Notch Tensile Stress (ksi)	~ Area At Fracture (in^2)	~ Reduction in Area (%)
NS1	.0346	.00125	67.5	150.3	.0263	24
NS2	.0346	.00125	67.5	148.8	.0263	24
NS3	.0343	.00125	67.5	151.6	.0253	26
NS4	.0346	.00125	68.5	149.4		
NS5	.0350	.00125	67.5	148.6		
NS6	.0353	.00125	68.5	148.7		
NS7	.0350	.00125	67.5	148.6		
NS8	.0350	.00125	68	145.7		
NS9	.0346	.00125	67	147.4		
NS10	.0353	.00125	68	147.3		

TABLE #16

Test 9 T=72°F P=1ATM AIR $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL EXPOSED FOR 168 HOURS AT 900°F AND 2000 psi Argon

SMOOTH BAR TENSILE SAMPLES

Sample #	Gage Area (in^2)	0.2% YS (ksi)	UTS (ksi)	Total Elongation (%)	Uniform Elong. (%)	Engr. Fracture Stress (ksi)	Reduction Area (%)	True Fracture Stress (ksi)
TS21	.0359	78.7	96.4	24.4	14	54.3	75.8	225.2
TS22	.0352	79.0	96.3	23.9	13.7	55.4	74.0	212.9
TS23	.0352	78.1	95.9	24.5	14.1	54.0	74.9	215.3
TS24	.0350	77.9	95.0	23.8	13.7	54.3	74.7	215.3
TS25	.0353	78.5	95.8	23.5	13.6	56.7	74	218.3
TS26	.0355	78.2	95.8	24.5	14.1	54.6	74.7	215.7
TS27	.0360	77.2	94.7	24.6	14.2	53.9	75.9	224.0
TS28	.0356	77.9	95.5	24.2	14.2	55.3	75.2	223.2
TS29	.0353	78.6	95.8	24.6	14.7	54.4	75	217.6
TS30	.0366	77.9	95.6	24.8	14.1	54.1	75.9	224.4

TABLE #17

Test 10 T=72°F P=1ATM AIR $\dot{\varepsilon}$=.05 in/in/min

HISTORY: MATERIAL EXPOSED FOR 168 HOURS AT 900°F AND 2000 psi Argon

NOTCHED BAR TENSILE SAMPLES

Sample #	Notch Area (in^2)	Notch Radius (in)	Notch Angle (°)	Notch Tensile Stress (ksi)	~ Area At Fracture (in^2)	~ Reduction in Area (%)
NS21	.0350	.00125	67	148.6	.0250	29
NS22	.0346	<.00125	67.5	149.4	.0249	28
NS23	.0350	.00125	67	147.7	.027	23
NS24	.0350	.00125	68	146.3		
NS25	.0350	.00125	68	148.6		
NS26	.0350	.001	68	148.6		
NS27	.0350	.00125	68	146.0		
NS28	.0350	.001	67	147.7		
NS29	.0343	.001	66.5	148.7		
NS30	.0350	.00125	67	147.1		

TABLE =18

Comparison of Room Temperature Tensile Properties of A387-74A-Gr. 22-Cl. 2

	0.2% YS (ksi)	UTS (ksi)	Total Elongation (%)	Uniform Elongation (%)	RA (%)	Notch Tensile (ksi) Strength	Engnr. Fracture (ksi) Stress
ASTM Code Specifications	45.0 min.	75.0 to 100.0	22% min.	-	45 min.	-	-
ASTM Specification Verification Tests (Longitudinal)	78.3 (5)*	94.2 (5)	-	9.3 (5)	72.5 (5)	146.0 (5)	54.0 (5)
ASTM Specification Verification Tests (Transverse)	79.2 (4)	94.5 (4)	-	8.8 (4)	61.0 (4)	138.8 (4)	64.6 (4)
Base Data Tests	78.7 (10)	95.6 (10)	24.7 (10)	14.2 (10)	75.5 (10)	148.2 (10)	53.4 (10)
Exposed Sample Tests (500°F Exposure)	79.6 (10)	96.4 (9)	24.5 (10)	14.3 (10)	75.8 (10)	148.6 (10)	54.6 (10)
Exposed Sample Tests (900°F Exposure)	78.2 (10)	95.7 (10)	24.3 (10)	14.0 (10)	75.0 (10)	147.9 (10)	54.7 (10)

* The number in ( ) following each value indicates the number of samples averaged.

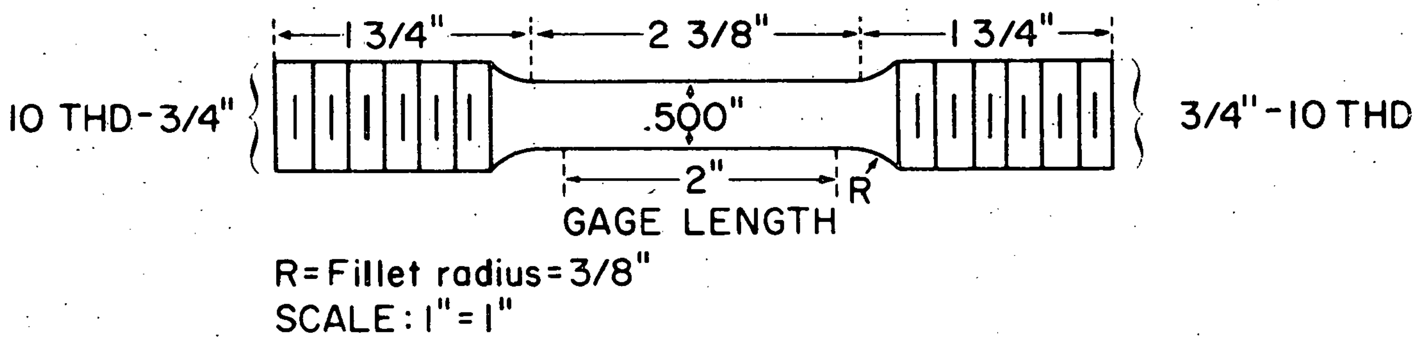


Fig. 1: ASTM Standard Sample for Mechanical Properties Specification Verification Tests.

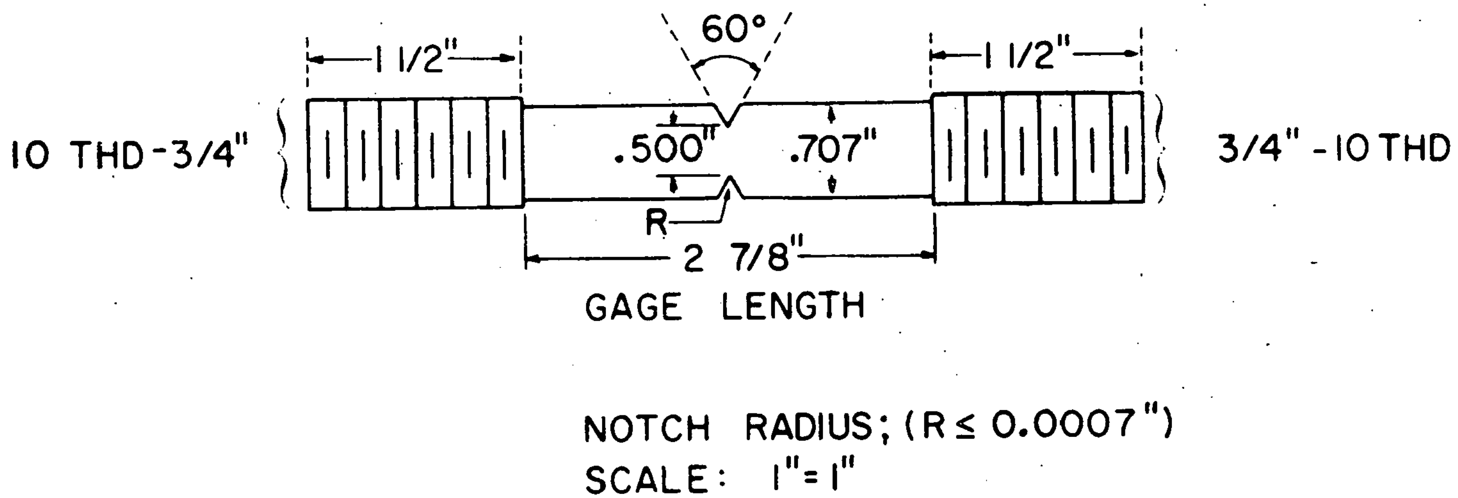


Fig. 2: ASTM Standard Notch Sample for Mechanical Properties Specification Verification Tests.

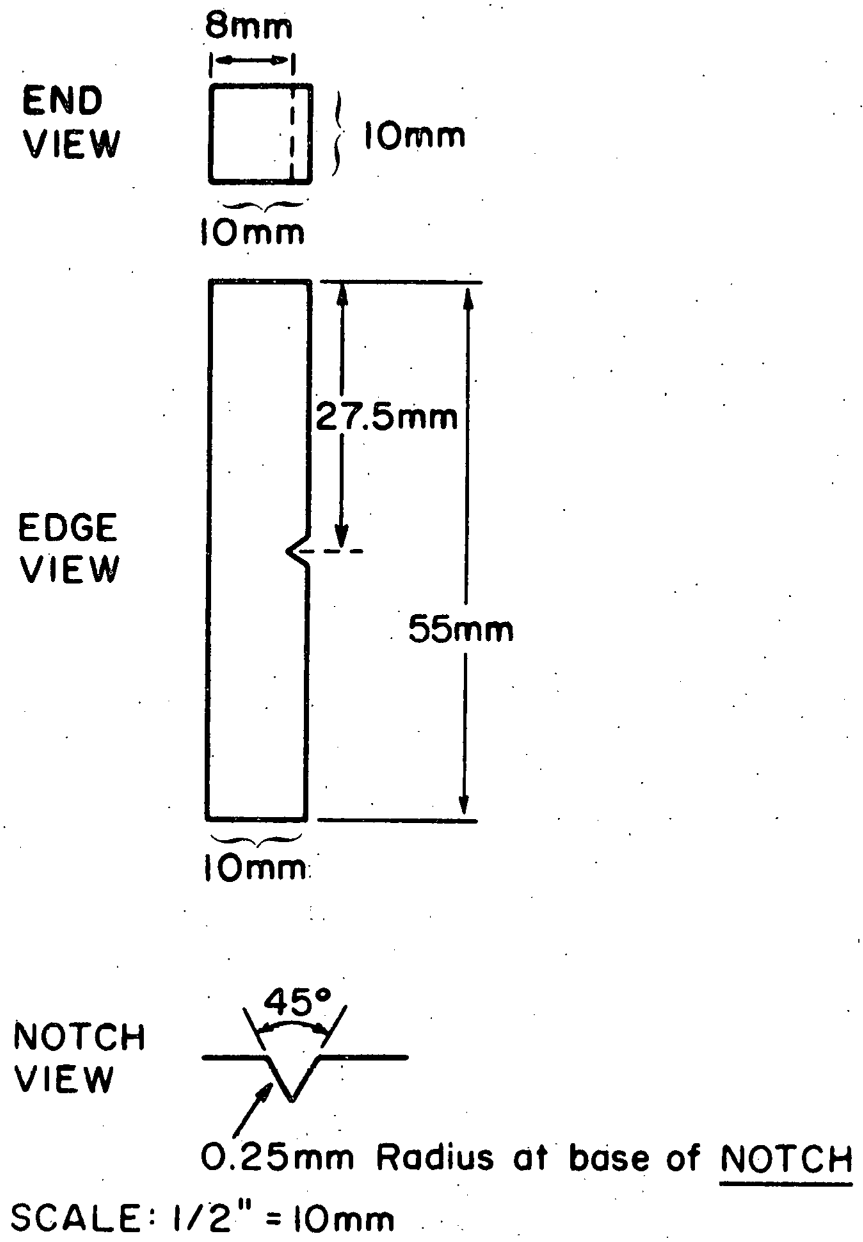


Fig. 3: Charpy V-Notch Sample

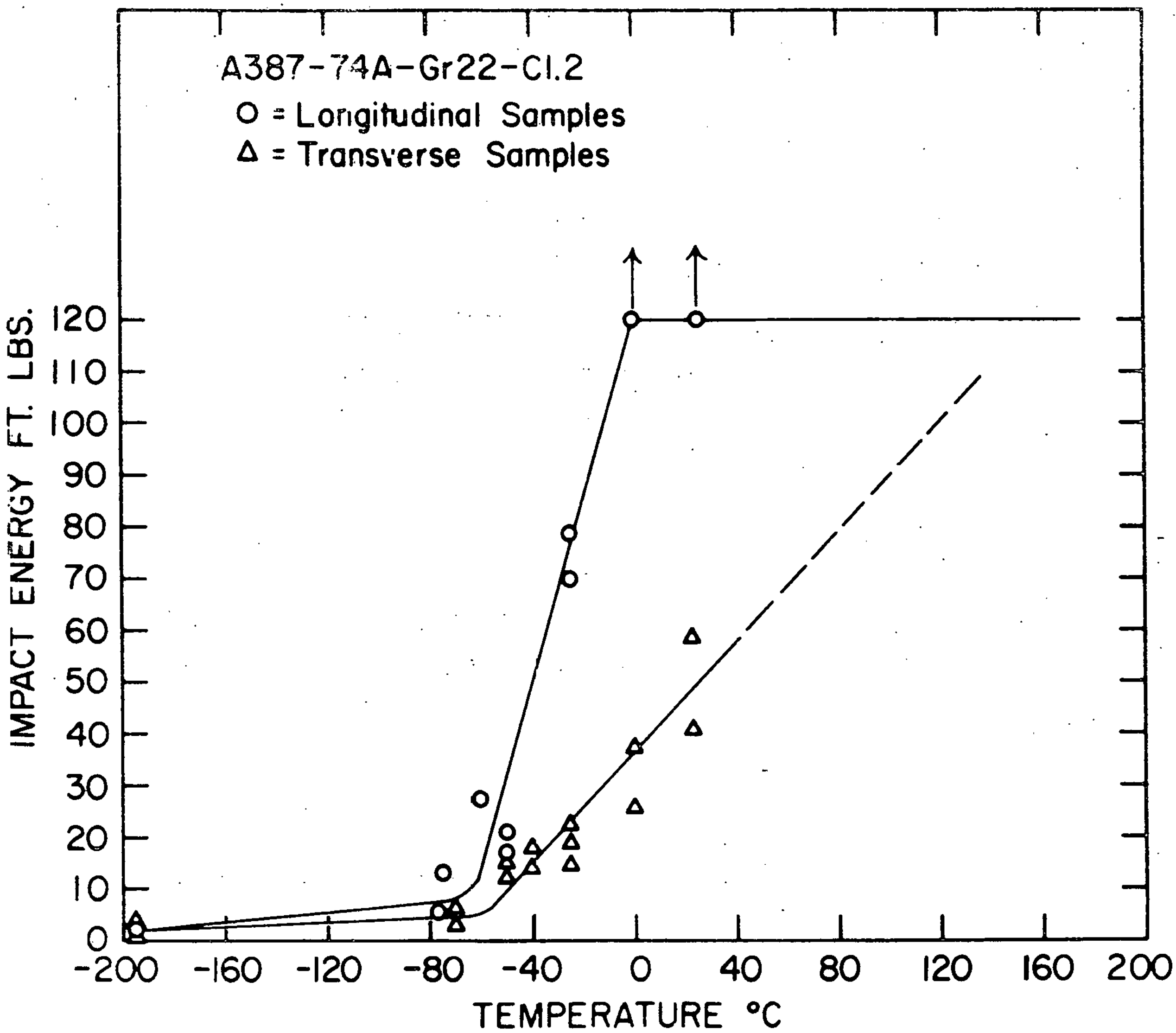
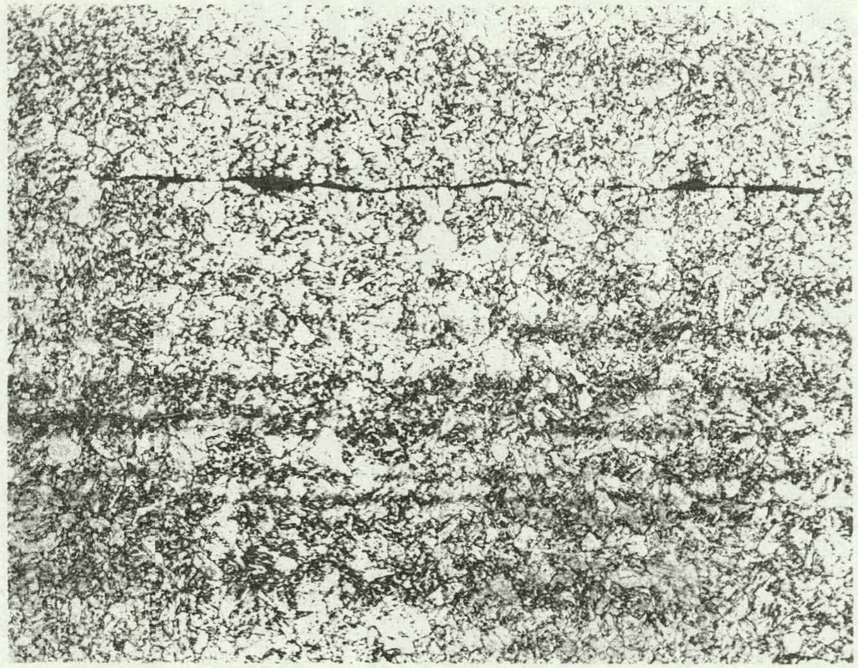
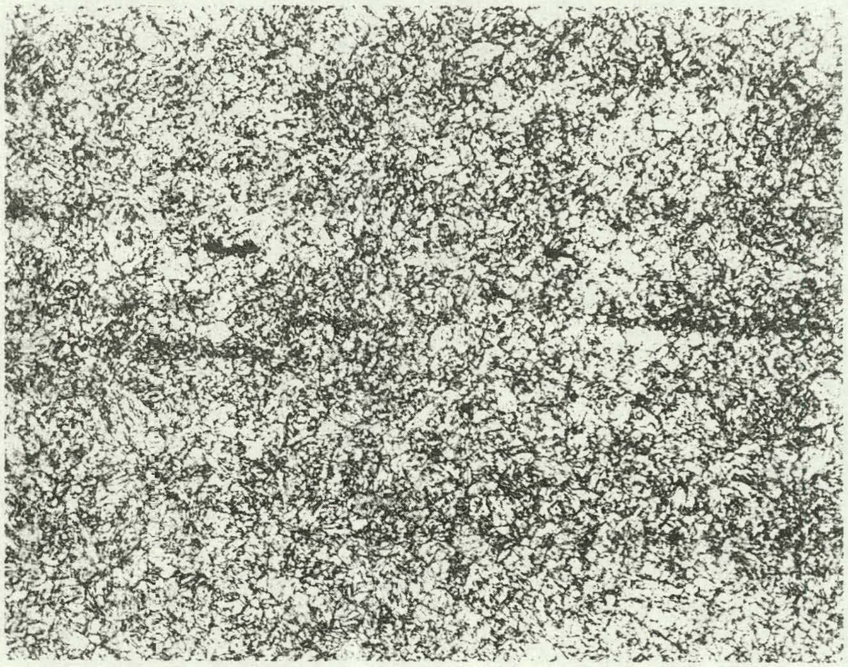


Fig. 4: Charpy Impact Energy vs. Temperature plots for A387-74A-Grade 22-Class 2 steel.



Rolling Direction →

Fig. #5 Microstructure of A387 Edge View
Mag. = 100X



Rolling Direction is into the page

Fig. #6 Microstructure of A387 Edge View
Mag. = 100X

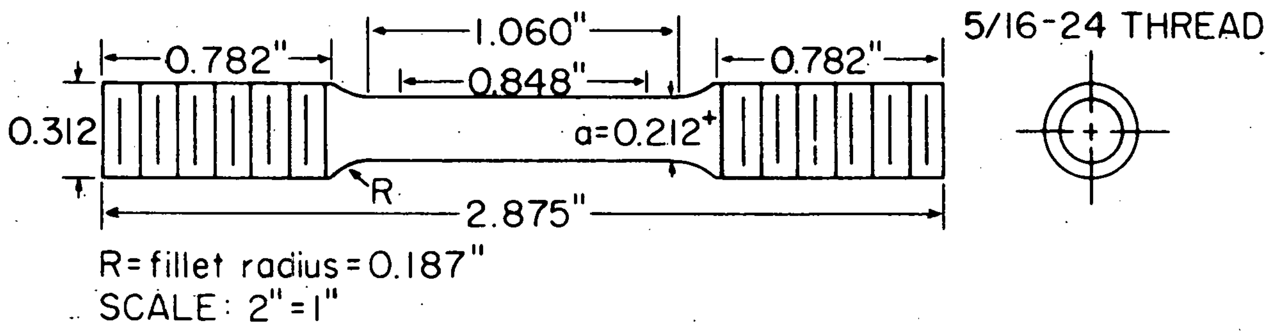


Fig. 7: Base Property Determination Smooth Tensile Sample.

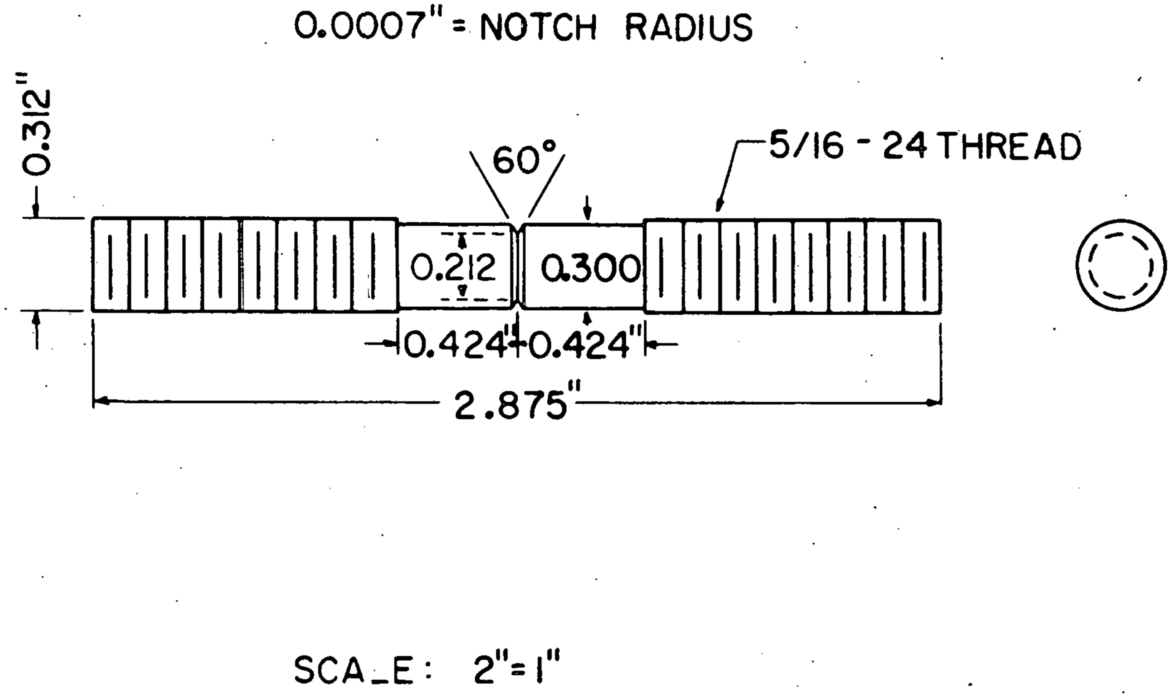


Fig. 8: Base Property Determination Notched Tensile Sample.

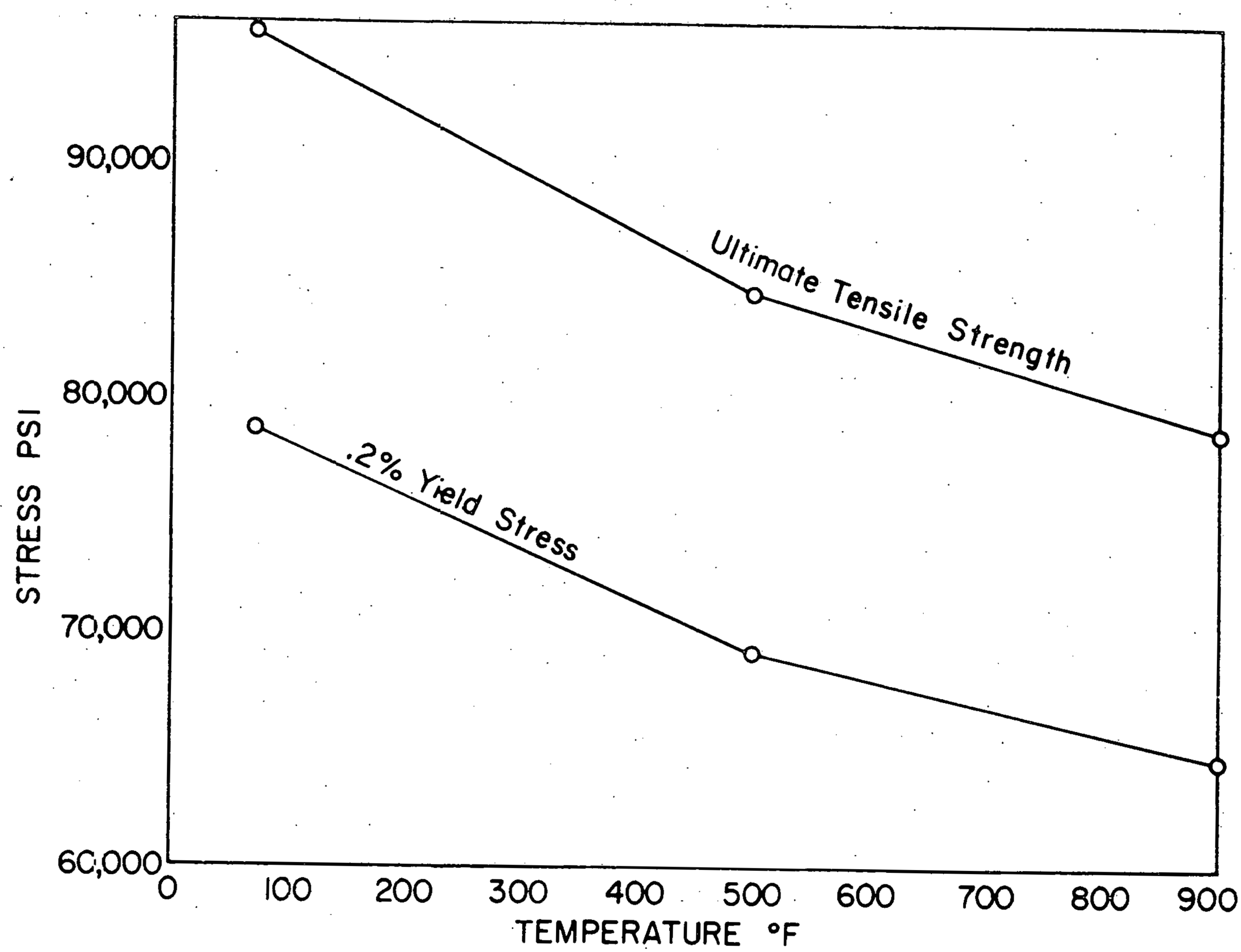


Fig. 9: Temperature dependence of UTS and 0.2% Yield Stress for A387-74A-Gr. 22-Cl. 2.

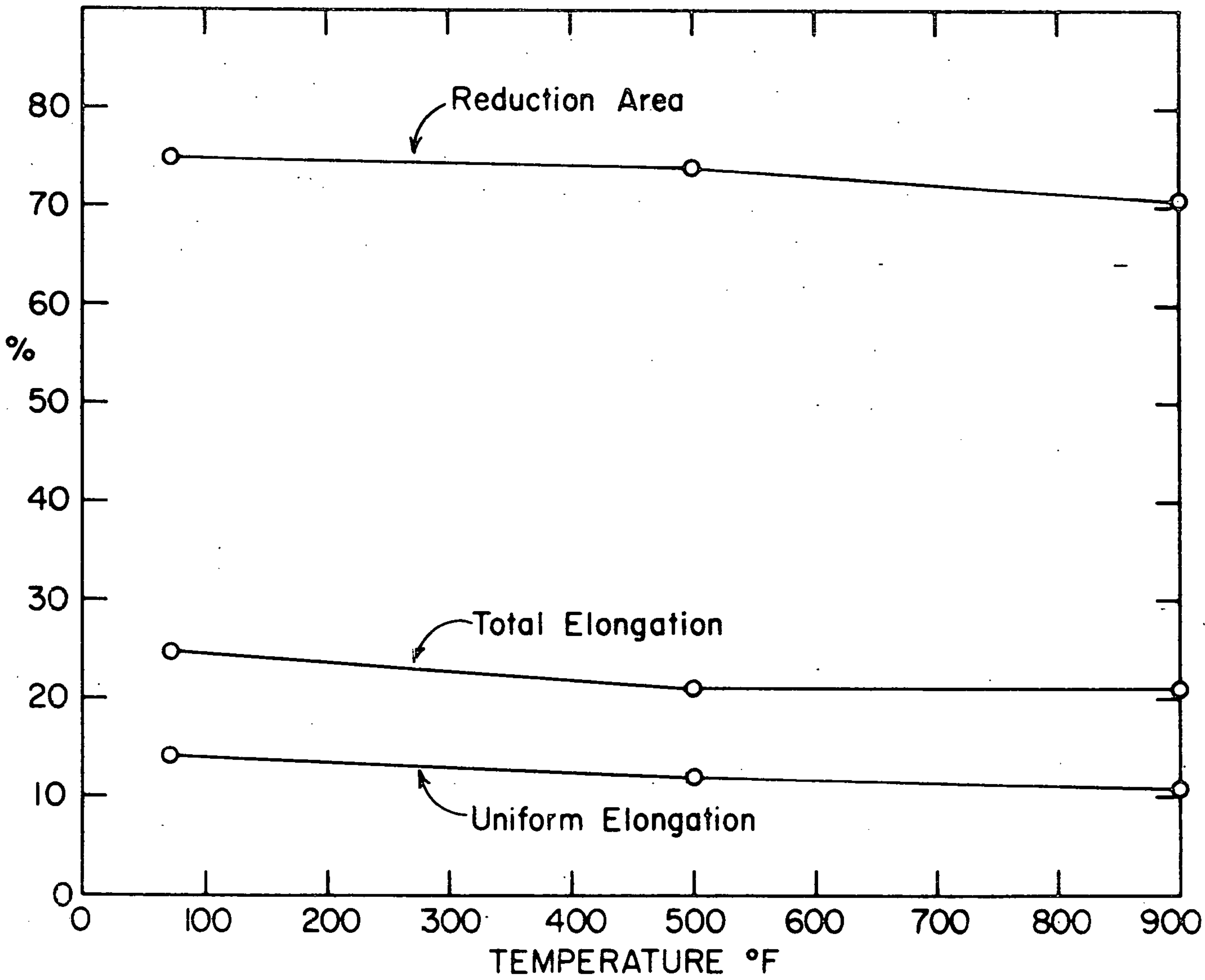


Fig. 10: Temperature dependence of ductility properties for A387-74A-Gr. 22-Cl. 2.

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