27p

NASA TM X-50,057

N63 82628

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

May 10, 1961 **MTP-M-S&M-M-61-12**

LOW TEMPERATURE MECHANICAL PROPERTIES 202 STAINLESS STEEL PARENT METAL AND WELDMENTS

NOTICE

This document was prepared for NASA internal use, and the information contained herein is subject to change.

MSFC - Form 523 (Rev. November 1960)

CASE FILE COPY

GEORGE C. MARSHALL SPACE FLIGHT CENTER

MTP-M-S&M-M-61-12

By

O. Y. Reece

ABSTRACT

Low temperature mechanical properties were determined on annealed 202 stainless sheet (0.066" thickness). Tests were made on both parent metal and weldments in the temperature range of +80°F to -450°F. The alloy has an ultimate tensile strength of 220,000 psi at the temperature of liquid nitrogen (-320°F), and 190,000 psi at the temperature of liquid helium (-450°F). This high strength, combined with a minimum elongation of 20%, indicates that this alloy is suitable for low temperature structural applications.

Weldments with 308 stainless steel filler metal attained strength values equivalent to or greater than those of the parent metal.

Test on 0.134" thickness sheet, 50% cold worked, gave strength values 30 to 55% higher than those obtained on the annealed sheet. Weldments in the cold worked material with 308 filler metal attained an ultimate tensile strength of 70 to 100% of that of the cold worked sheet, depending upon the test temperature.

May 10, 1961

MTP-M-S&M-M-61-12

LOW TEMPERATURE MECHANICAL PROPERTIES 202 STAINLESS STEEL PARENT METAL AND WELDMENTS

By

O. Y. Reece

ENGINEERING MATERIALS BRANCH
STRUCTURES AND MECHANICS DIVISION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

CONTENTS

TABLES

FIGURES

LOW TEMPERATURE MECHANICAL PROPERTIES
202 STAINLESS STEEL PARENT METAL AND WELDMENTS

SUMMARY

Low temperature mechanical properties were determined on annealed 202 stainless sheet (0.066" thickness). Tests were made on both parent metal and weldments in the temperature range of +80°F to -450°F. The alloy has an ultimate tensile strength of 220,000 psi at the temperature of liquid nitrogen (-320°F), and 190,000 psi at the temperature of liquid helium (-450°F). This high strength, combined with a minimum elongation of 20%, indicates that this alloy is suitable for low temperature structural applications.

Weldments with 308 stainless steel filler metal attained strength values equivalent to or greater than those of the parent metal.

Test on 0.134" thickness sheet, 50% cold worked, gave strength values 30 to 50% higher than those obtained on the annealed sheet. Weldments in the cold worked material with 308 filler metal attained an ultimate tensile strength of 70 to 100% of that of the cold worked sheet, depending upon the test temperature.

INTRODUCTION

An extensive evaluation of the low temperature mechanical properties of engineering alloys which show promise for space vehicle applications is currently in progress in the Engineering Materials Branch, Structures and Mechanics Division. This report covers the investigation of one of the materials selected for evaluation, type 202 stainless steel. Both parent metal and weldments were tested in the temperature range of +80°F to -450°F. A previous report[1] presented data on room temperature and elevated temperature mechanical properties of this alloy. Although the composition of 202 stainless steel suggests applications at moderately elevated temperature, use of the alloy at very high temperatures is limited due to a tendency toward oxidation and carbide precipitation. A study of the mechanical properties in the temperature ranges previously tested suggested that, although manganese was detrimental at higher temperature, an increase in toughness and ductility should be experienced at low temperature.

GENERAL CHARACTERISTICS

Type 202 is an austenitic chromium-nickel-manganese stainless steel, not hardenable by heat treatment and possessing similar mechanical properties and corrosion resistance to type 302 stainless steel. The development of the alloy resulted from national efforts to conserve nickel; therefore, manganese has been substituted for a major portion of the nickel (Table I). Manganese imparts excellent toughness at ambient and low temperatures; however, the manganese reduces resistance to oxidation at elevated temperatures. A sufficient amount of nickel is retained in the alloy to maintain good impact strength and structural stability[2]. Because of a tendency toward oxidation at high temperatures, 202 is not recommended for applications above 1500°F.

Carbide precipitation, with possible associated intergranular corrosion, is experienced within the temperature range of 800-1650°F. These carbides can be dissolved by an annealing treatment at 1900°F, and the resulting homogeneous material will not be subject to intergranular corrosion. Compared to the 300 series austenitic stainless steels, room temperature mechanical properties of 202 are considerably higher; thus, it was anticipated that this factor, coupled with favorable low temperature properties, may offer a solution to certain design requirements.

No low temperature applications have been reported for 202 stainless steel in the literature, nor have data been published concerning low temperature mechanical properties.

EQUIPMENT AND TEST PROCEDURE

Tensile tests were conducted in a low temperature tensile cryostat designed at this Center for evaluation of metals at temperatures down to -450°F. The tensile cryostat is essentially a four-walled cylindrical container having two vacuum jackets separated by liquid nitrogen. Overflow nitrogen is passed through the lid of the cryostat before venting to the atmosphere. The test setup and equipment are shown in figures 1, 2, and 3.

Temperature was sensed by copper-constantan thermocouples and controlled by a controller-recorder, which actuates a solenoid valve located between the dewar, containing the cryogenic liquid, and the tensile cryostat. At intermediate temperatures, in the range of +80 to -320°F, a double walled cylindrical canister with spray holes around the inner periphery was inserted into the cryostat, and cryogenic liquid sprayed onto the test specimen. At -320°F, the specimens were pulled while submerged in liquid nitrogen. Below -320°F, the specimens were tested in a mixture of gaseous and liquid helium.

A minimum of three tensile specimens were tested at each temperature; however, during several tests, unreliable stress-strain curves resulted. In these instances, the reported average was taken from two specimens.

RESULTS AND DISCUSSION

Tensile properties of annealed 202 stainless steel (Table II and figure 4) increased as temperature decreased from room temperature to -450°F. Ultimate tensile strength reached a maximum at -320°F and dropped significantly at -450°F, although the ultimate tensile strength at -450°F was still 90% higher than at room temperature. The moderately high ultimate tensile strength, combined with an elongation of 20% (2.0" gage length) at liquid helium temperature, indicates that this alloy merits consideration for low temperature applications.

Test panels, fusion welded with 308 stainless steel filler and having both flush and intact weld beads, were evaluated in the temperature range of +80 to -450°F. Flush weldments are those having both build-up and penetration machined flush with the original thickness. This is frequently necessary in order to provide proper fit-up of structural components and has considerable effect upon the weld efficiency.

Generally, welds are left "intact", or with full penetration and slight build-up added purposely for additional strength. Careful attention should be given to both the condition of the parent metal and the characteristics of the filler metal where flush machining is considered. Room temperature tensile properties of flush weldments (Table III and figure 5) were lower than those of the parent metal; however, the tensile properties at -450^{o}F were equal to or greater than those of the parent metal. These tests indicated that the flush bead resulted in a predominance of failures in the weld fusion zone at temperatures down to -320^{o}F.

The ultimate tensile strength and yield strength of intact weldments (Table IV and figure 6) was equal to or greater than that of the parent metal at all temperatures, except at -450^{o}F, in which case failure occurred at the interface of the fusion and heat affected zone. Originally this persistent 100% plus weld efficiency was thought to be partially due to experimental error; however, similar results obtained in a second series of tests indicates that this strength increase may be attributed to thermal effects from welding. It is apparent that some strengthening occurred within the 2 inch gage length of the transverse welded specimens and it was established that 100% weld efficiences are realistic for this alloy at both ambient and low temperatures.

The ultimate tensile strength of the 50% cold-worked 202 stainless steel sheet (Table V and figure 7) was (30 - 55%) above that of the annealed sheet. Elongation of the 50% cold-worked sheet remained at about 20% throughout the range of test temperatures. This was true for both the parent metal and welded test specimens at -320^{o}F. Weldments of the 50% cold worked sheet had an ultimate tensile strength equivalent to 89% of that of the parent metal sheet (Table VI and figure 8). The gain in ultimate tensile strength is offset by the drop in yield strength experienced in the welded sheet; therefore, it is questionable if any advantage could be realized by fabricating with the cold-worked sheet.

CONCLUSIONS

It is concluded that type 202 stainless steel offers excellent possibilities as a low temperature structural alloy. The alloy appears to be a logical contender for current applications using 300 series stainless steels, such as 301, 302 or 304. Carbide precipitation in weldments must be considered on the same basis as for 300 series stainless steels until additional work is completed to establish this relative susceptibility.

Room temperature tensile and yield strengths are approximately doubled at liquid nitrogen temperature with only a slight decrease in strength where the temperature is lowered to that of liquid helium.

TABLE I

NOMINAL COMPOSITION OF 202 STAINLESS STEEL

Carbon	0.15 Max.
Manganese	7.50 - 10.00
Phosphorous	0.060 Max.
Sulphur	0.030 Max.
Silicon	1.00 Max.
Chromium	17.0 - 19.0
Nickel	4.00 - 6.00
Nitrogen	0.025 Max.
Iron	Remainder

TABLE II

MECHANICAL PROPERTIES
202 STAINLESS STEEL SHEET, 0.066" THICKNESS, PARENT METAL

Temperature °F		Ultimate Strength psi	Yield Strength 0.2% Offset psi	Yield Strength 0.1% Offset psi	Proportional Limit psi	Elongation % in 2 in.	Fracture Location
+ 80		100,800	46,500	40,200	35,300	57.0	GL
+ 80		101,500	57,000	40,200	32,400	56.0	GL
+ 80		102,200	47,800	42,400	30,364	57.5	GL
	Ave.	101,500	47,100	40,900	32,700	56.8	
0		127,600	56,400	49,300	----	58.0	GL
0		130,600	56,000	48,500	----	56.0	GL
0		129,500	54,700	47,100	----	58.0	GL
	Ave.	129,200	55,700	48,300		57.3	
- 50		139,500	59,900	53,900	----	50.0	GL
- 50		140,400	60,200	54,700	----	52.0	GL
- 50		139,500	62,900	56,900	----	50.0	GL
	Ave.	139,800	61,000	55,200		50.7	
-100		151,700	65,000	59,300	----	40.0	GL
-100		157,700	72,700	69,300	----	40.0	GL
-100		158,700	72,800	68,900	----	40.7	GL
	Ave.	156,000	70,200	65,800		40.7	
-200		176,400	77,700	72,600	61,000	43.5	GL
-200		175,900	78,800	73,500	62,200	44.0	GL
-200		175,600	68,300	72,600	57,900	43.5	GL
	Ave.	176,000	78,300	72,900	60,400	43.7	
-320		230,700	83,000	72,900	68,100	51.0	GL
-320		228,300	94,100	83,000	62,800	52.0	GL
-320		234,700	87,800	79,600	62,800	52.0	GL
	Ave.	231,200	88,300	78,500	64,600	51.7	
-450		191,100	108,900	100,800	78,600	22.0	OGL
-450		220,700	109,300	100,800	79,300	27.5	GL
-450		207,300	114,600	106,100	81,300	25.0	OGL
	Ave.	206,400	111,000	102,600	79,700	25.0	

GL = Gage length

OGL = Outside the gage length

TABLE III

MECHANICAL PROPERTIES
202 STAINLESS STEEL SHEET, 0.066" THICKNESS, TRANSVERSE
WELDS, FLUSH BEAD, 308 STAINLESS STEEL FILLER

Temperature °F		Ultimate Strength psi	Yield Strength 0.2% Offset psi	Yield Strength 0.1% Offset psi	Proportional Limit psi	El. In 2 In.	Fracture Location
+ 80		98,600	47,600	37,300	11,900	30	Fusion
+ 80		96,300	53,500	43,300	16,000	28	Fusion
+ 80		97,200	43,600	34,800	11,400	32	Fusion
	Ave.	97,400	48,200	38,500	13,100	30	
0		119,100	----	----	----	38.0	Fusion
0		112,300	49,000	37,900	12,900	34.5	Fusion
0		121,100	55,300	47,800	23,100	37.0	Fusion
	Ave.	120,800	52,150	42,800	18,000	36.5	
- 50		138,000	----	----	----	41.0	Fusion
- 50		139,100	61,000	52,700	20,800	37.0	Fusion
- 50		139,600	59,000	51,700	27,300	40.0	Fusion
	Ave.	138,900	60,000	52,200	24,100	39.3	
-100		163,100	62,200	54,000	26,200	42.0	Fusion
-100		159,700	69,800	60,200	29,300	42.0	Fusion
-100		159,100	63,000	56,100	30,300	45.5	Fusion
	Ave.	160,600	65,000	55,700	28,600	41.5	
-200		182,200	70,000	60,000	28,900	42.0	Parent Metal
-200		183,800	75,800	66,900	30,400	41.5	Parent Metal
-200		183,000	71,500	66,900	38,000	42.0	Parent Metal
	Ave.	183,000	72,400	64,600	32,400	41.8	
-320		229,200	81,600	70,100	35,000	40.0	Fusion
-320		227,500	78,800	68,800	33,600	46.5	Parent Metal
-320		228,500	77,600	63,800	33,600	48.0	Parent Metal
	Ave.	228,400	79,300	67,600	34,100	44.8	
-450		217,900	103,400	96,000	74,000	23.0	Parent Metal
-450		212,600	99,100	90,500	69,000	25.5	OGL/PIN
-450		195,200	104,500	97,000	80,000	25.0	FUZ/HAZ
	Ave.	208,600	102,300	94,500	74,300	25.0	

OGL = Outside the gage length
FUZ/HAZ = Interface of the fusion and the heat affected zone.

TABLE IV

MECHANICAL PROPERTIES
202 STAINLESS STEEL SHEET, 0.066" THICKNESS, TRANSVERSE WELDS,
INTACT BEAD, 308 STAINLESS STEEL FILLER

Temperature °F		Ultimate Strength psi	Yield Strength 0.2% Offset psi	Elongation % In 2 In.	Fracture Location
+ 80		111,400	57,900	46.0	Parent Metal
+ 80		106,100	54,700	49.5	Parent Metal
+ 80		104,900	54,300	49.5	Parent Metal
	Ave.	107,500	55,600	48.3	
0		131,200	54,500	53.0	Parent Metal
0		130,700	57,700	55.0	Parent Metal
0		126,100	57,700	50.0	Parent Metal
	Ave.	129,300	56,600	52.6	
- 50		145,000	63,400	53.0	Parent Metal
- 50		142,900	66,000	48.0	Parent Metal
- 50		141,900	61,700	48.5	Parent Metal
	Ave.	143,300	63,700	49.8	
-100		160,100	74,900	44.5	Parent Metal
-100		158,100	73,700	[illegible]	Parent Metal
-100		157,200	71,800	[illegible]	Parent Metal
	Ave.	158,500	73,500	[illegible]	
-200		177,200	80,100	42.0	Parent Metal
-200		178,500	79,500	43.0	Parent Metal
-200		175,400	77,100	44.0	Parent Metal
	Ave.	177,000	78,900	43.0	
-320		229,800	80,500	45.0	Parent Metal
-320		230,600	80,300	43.0	Parent Metal
-320		230,000	89,400	47.0	Parent Metal
	Ave.	230,100	83,400	45.0	
-450		174,300	114,000	19.5	FUZ/HAZ
-450		199,400	108,000	23.0	OGL/PIN
-450		193,000	95,000	22.0	FUZ/HAZ
	Ave.	188,900	105,700	21.5	

FUZ = Fusion zone
HAZ = Heat affected zone
FUZ/HAZ = Interface of the fusion and heat affected zone
OGL = Outside the gage length

TABLE V

PARENT METAL
MECHANICAL PROPERTIES
202 STAINLESS STEEL SHEET, 0.134" THICKNESS, 50% COLD WORKED

Temperature °F		Ultimate Strength psi	Yield Strength 0.2% Offset psi	Yield Strength 0.1% Offset psi	Elongation In 2 In.	Fracture Location
+ 80		155,100	139,100	125,500	22.0	GL
+ 80		157,400	140,100	127,100	21.0	GL
+ 80		156,100	140,500	125,800	20.0	GL
	Ave.	156,200	139,900	126,100	21.0	
-200		214,500	146,800	134,400	26.0	GL
-200		208,500	145,100	130,500	24.0	GL
-200		221,000	150,800	141,100	26.0	GL
	Ave.	214,700	147,600	135,300	25.2	
-320		287,000	158,200	144,800	28.5	GL
-320		287,100	161,000	148,800	28.5	GL
-320		284,600	145,700	131,700	28.5	GL
	Ave.	286,200	154,600	141,800	28.5	
-450		282,700	183,000	170,200	19.5	GL
-450		284,000	177,700	162,700	21.0	GL
	Ave.	283,350	180,350	166,450	20.3	

GL = Gage length

TABLE VI

MECHANICAL PROPERTIES
202 STAINLESS STEEL SHEET, 0.134" THICKNESS, TRANSVERSE WELDS, INTACT BEAD, 308 STAINLESS STEEL FILLER, 50% COLD WORKED

Temperature °F		Ultimate Strength psi	Yield Strength 0.2% Offset psi	Yield Strength 0.1% Offset psi	Proportional Limit psi	El. In 2 In.	Fracture Location
+ 80		114,300	51,600	23,600	25,400	17.0	HAZ
+ 80		113,300	55,400	49,900	26,900	20.0	FUZ/HAZ
+ 80		109,900	53,800	47,400	25,600	22.0	FUZ
	Ave.	112,500	53,600	40,300	26,000	19.6	
- 50		175,800	63,100	56,700	----	25.0	HAZ
- 50		176,100	75,200	65,900	43,300	24.0	HAZ
- 50		176,900	71,900	68,700	49,400	26.0	HAZ
	Ave.	176,300	70,100	63,800	46,400	25.0	
-100		187,800	67,800	59,700	34,300	24.0	HAZ
-100		182,800	59,400	51,600	29,000	24.5	HAZ
-100		193,400	77,000	68,700	38,800	24.0	HAZ
	Ave.	188,000	68,100	60,000	34,000	24.2	
-200		226,000	71,900	----	26,900	21.5	HAZ
-200		206,600	75,500	62,700	30,000	16.0	FUZ
-200		227,100	87,300	66,300	33,100	18.0	FUZ
	Ave.	219,900	78,200	64,500	30,000	18.5	
-320		267,300	87,900	78,300	37,700	18.5	FUZ
-320		240,000	76,500	----	35,700	15.0	FUZ
-320		218,000	----	----	----	13.0	FUZ
-320		278,000	92,600	83,900	49,100	24.0	HAZ
-320		269,000	73,400	62,900	35,900	23.0	HAZ
	Ave.	255,400	82,600	75,000	39,600	18.7	

FUZ = Fusion zone
HAZ = Heat affected zone
FUZ/HAZ = Interface of the fusion and heat affected zone

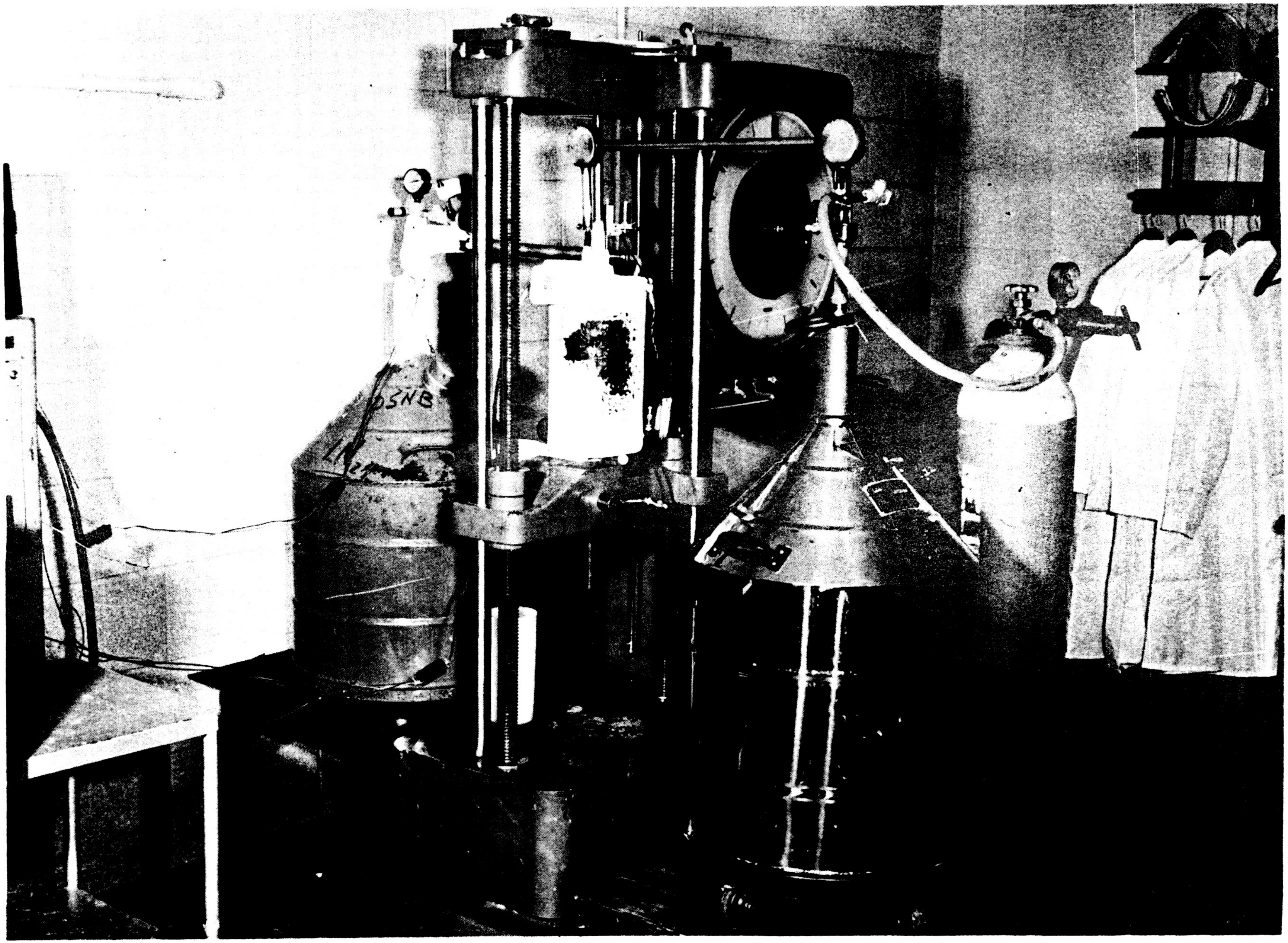

Fig 1 Low Temperature Tensile Cryostat and Accessory Equipment

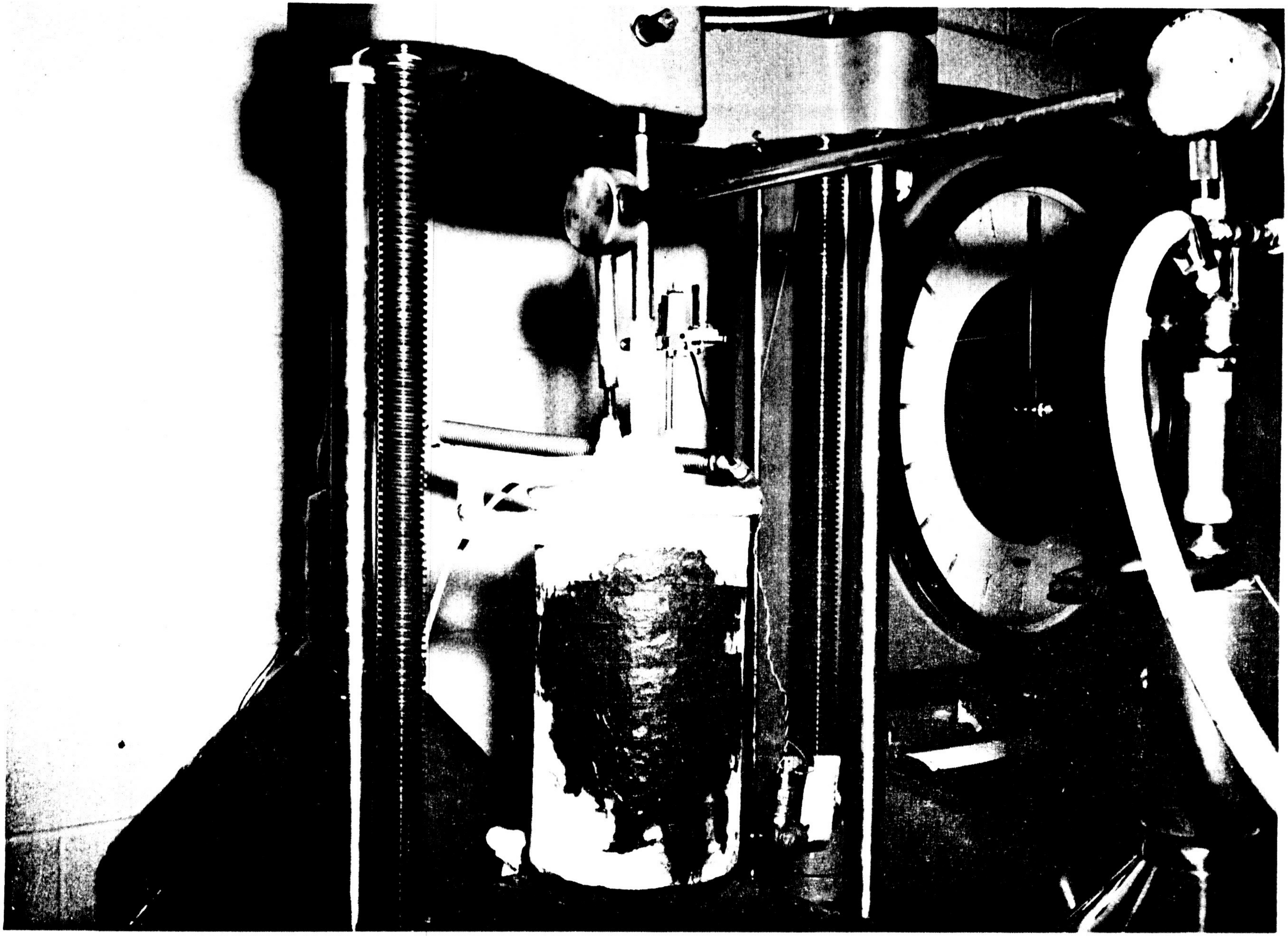

Fig 2 Low Temperature Tensile Cryostat Showing Extensometer Probes and Extensometer

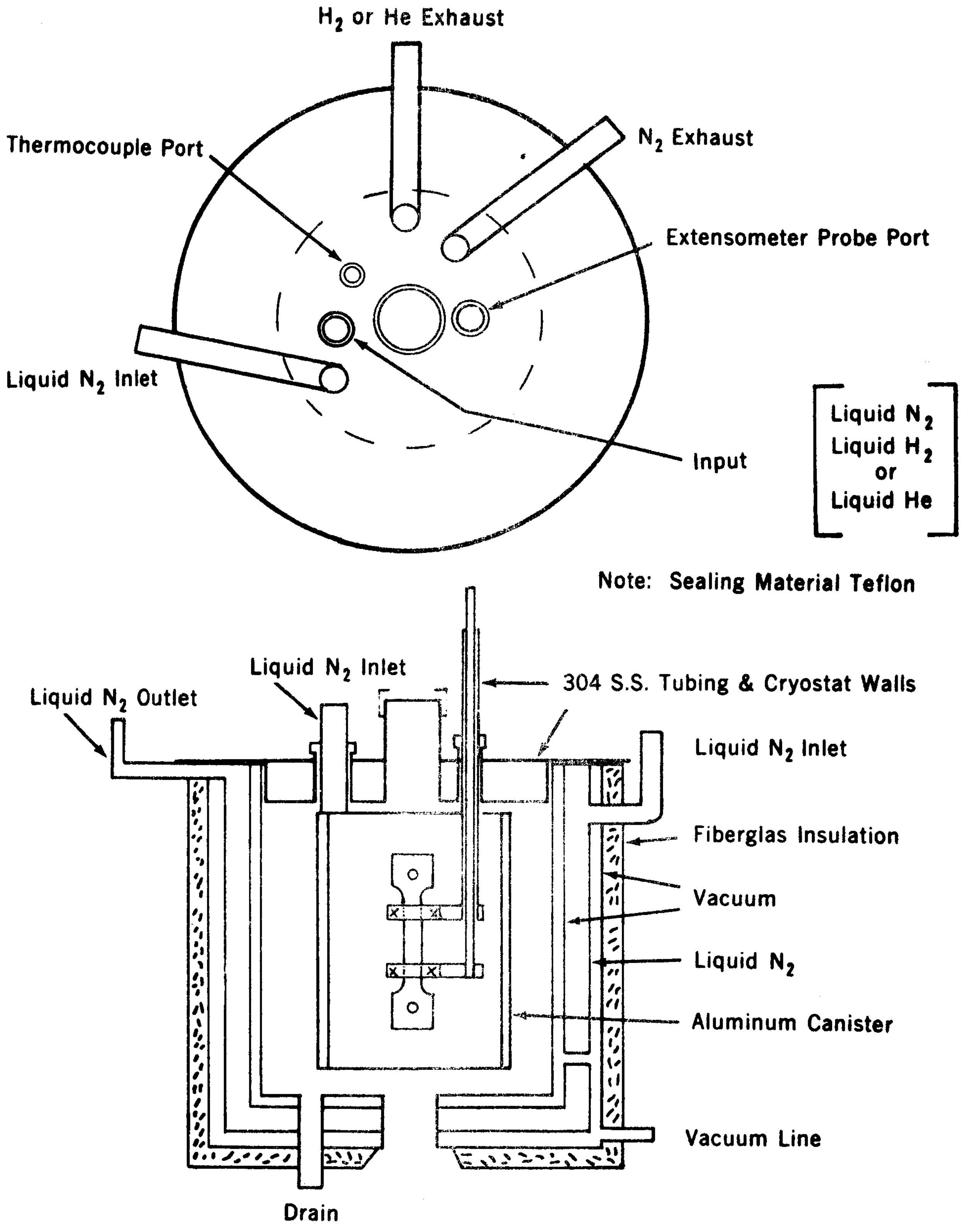

Fig. 3 Diagram of Tensile Cryostat and Extensometer

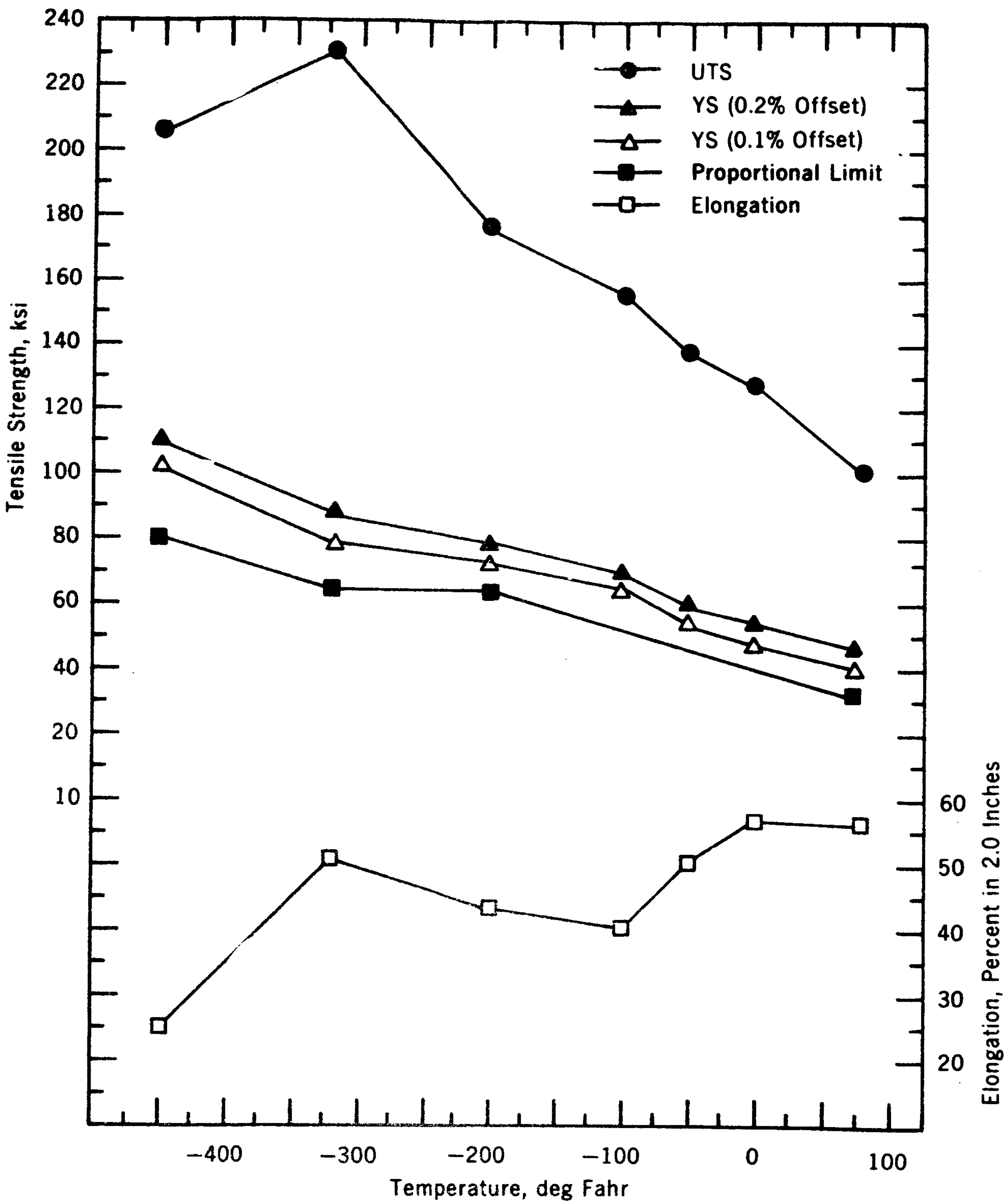

Fig. 4 Mechanical Properties, 202 Stainless Steel Sheet, 0.066 Inch Thickness, Parent Metal

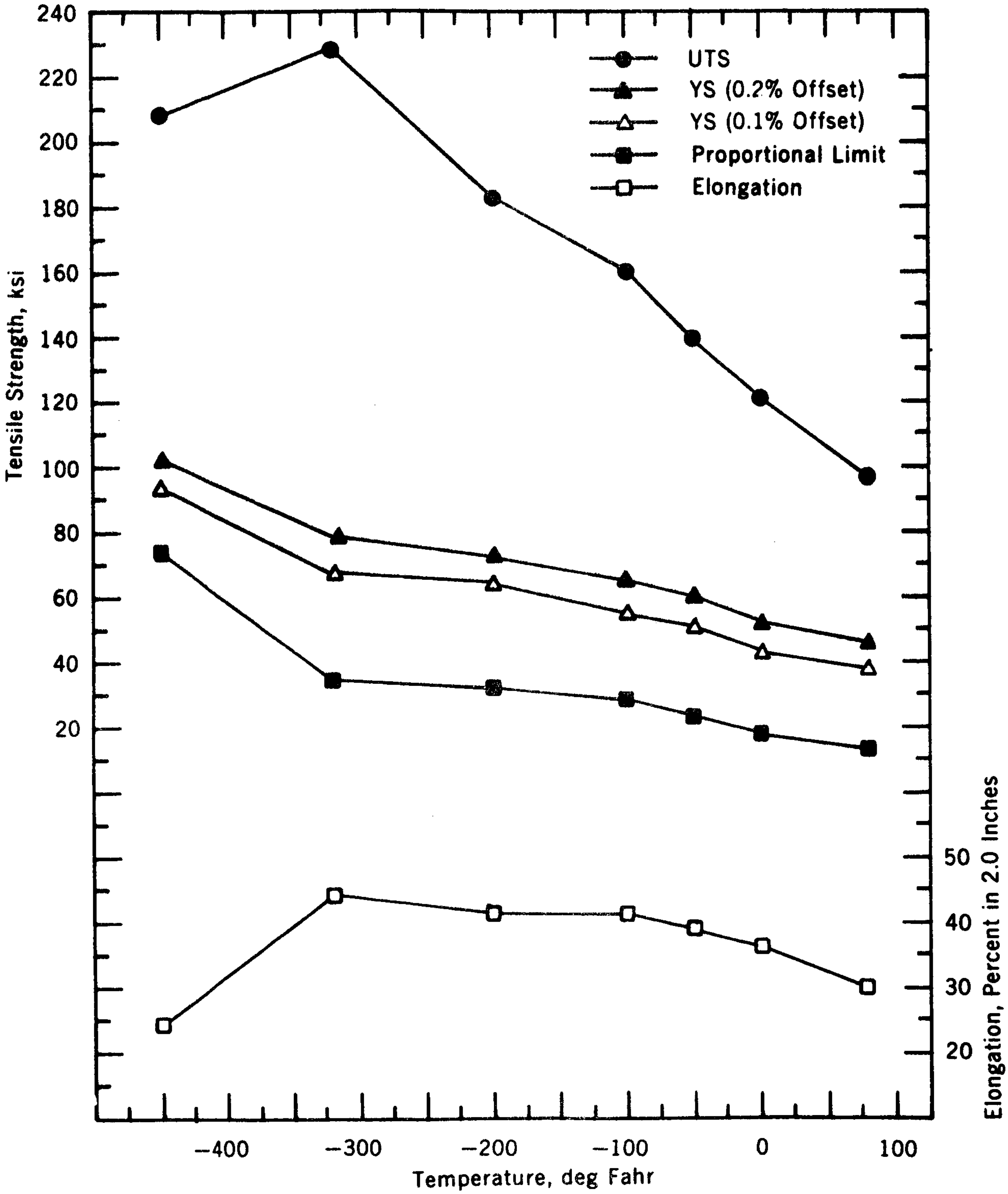

Fig. 5 Mechanical Properties, 202 Stainless Steel Sheet, 0.066 Inch Thickness, Transverse Welds, Flush Bead, 308 Stainless Steel Filler

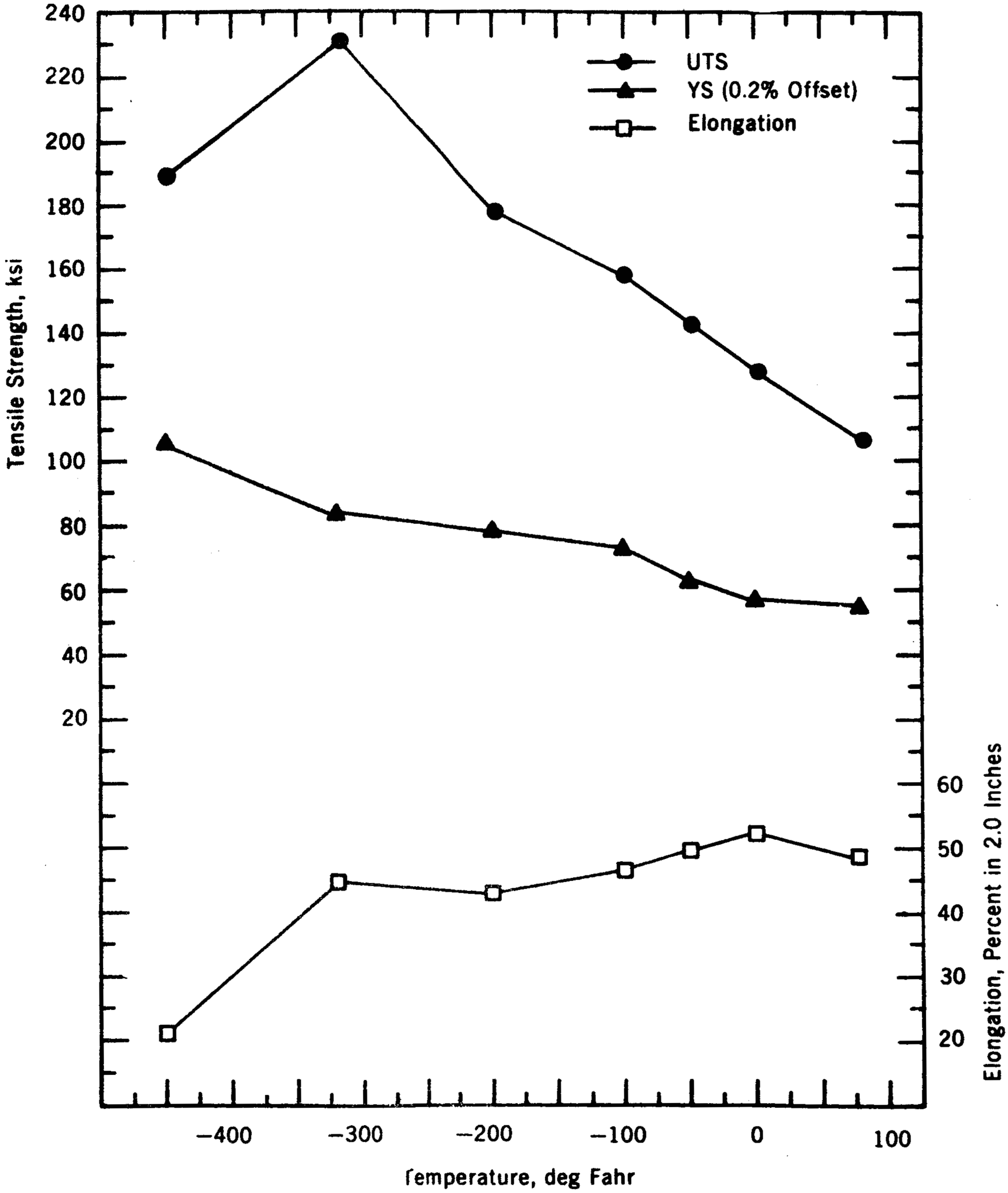

Fig. 6 Mechanical Properties, 202 Stainless Steel Sheet, 0.066 Inch Thickness, Transverse Welds, Intact Bead, 308 Stainless Steel Filler

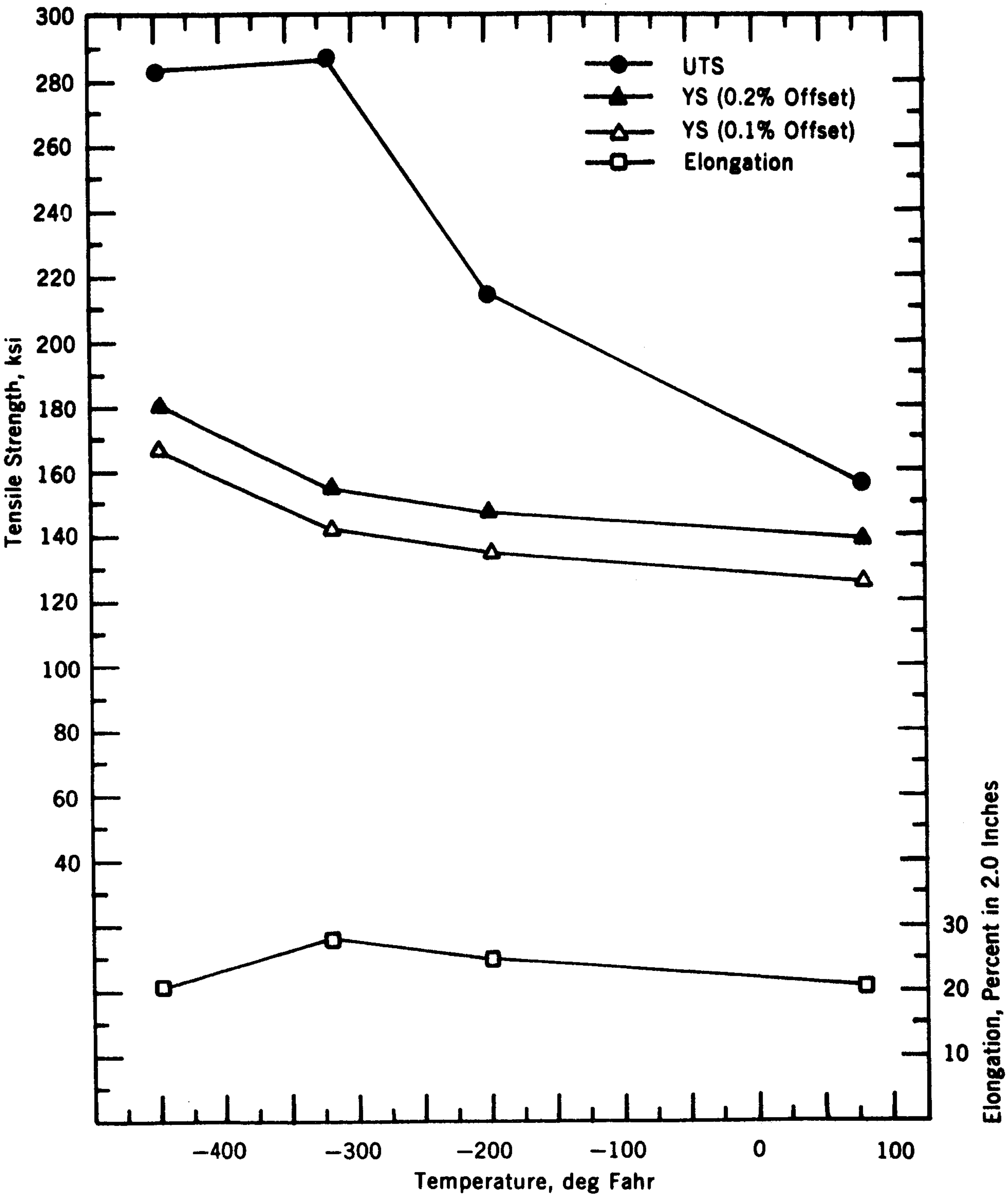

Fig. 7 Mechanical Properties, 202 Stainless Steel Sheet, 0.134 Inch Thickness, 50 Percent Cold Worked

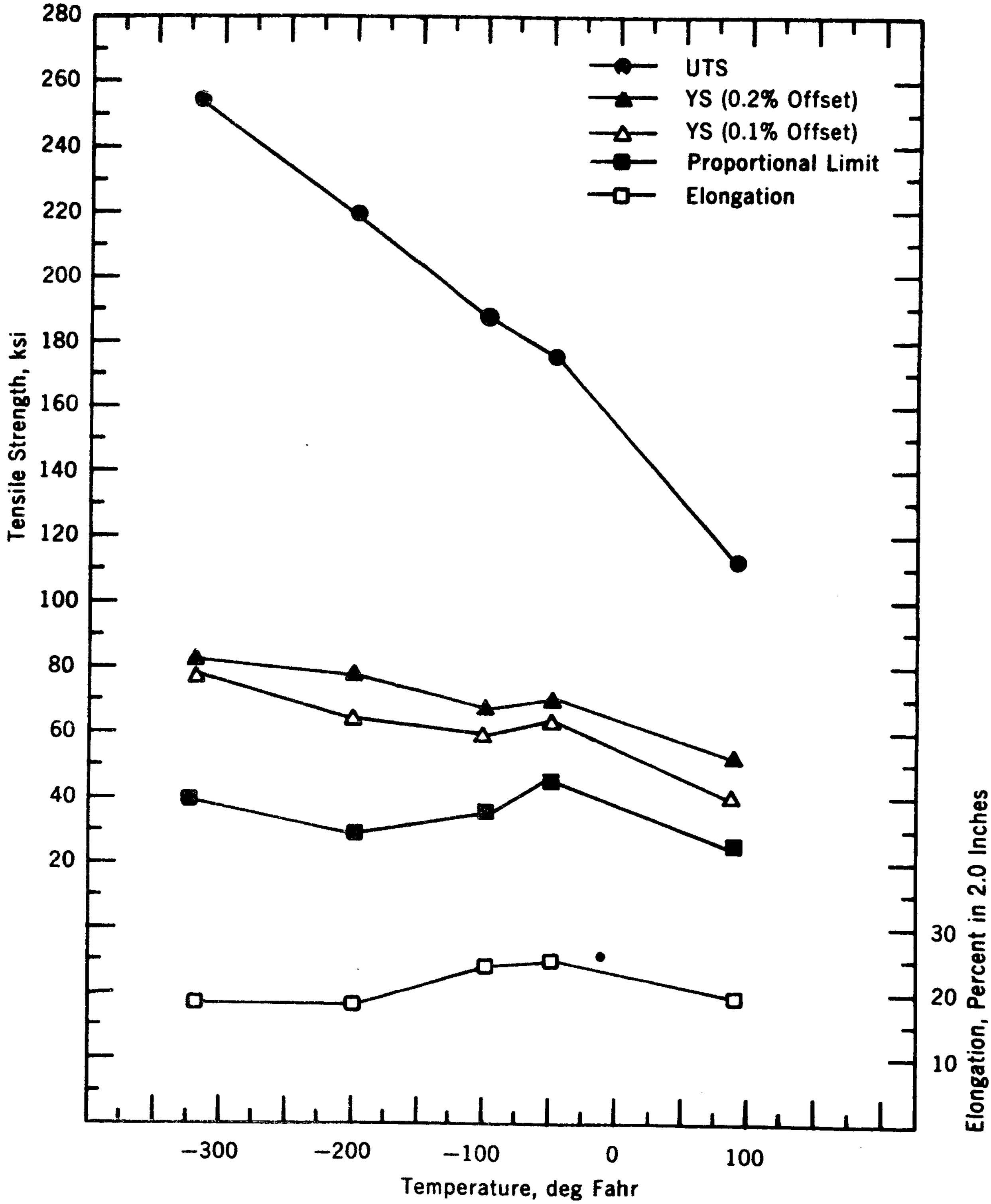

Fig. 8 Mechanical Properties, 202 Stainless Steel Sheet, 0.134 Inch Thickness, Transverse Welds, Intact Bead, 308 Stainless Steel Filler, 50 Percent Cold Worked

REFERENCES

1. ABMA, Structures & Mechanics, Technical Note N-42, "A Metallurgical Evaluation of 201 and 202 Conservation Stainless Steels", by W. G. Mitchell, August 14, 1956.

2. Alloy Digest, Stainless Steel, SS-65, December 1957.

APPROVAL: MTP-M-S&M-M-61-12

C. E. CATALDO
Chief, Metallurgy Section

W. R. LUCAS
Chief, Engineering Materials Branch

W. A. MRAZEK
Director
Structures & Mechanics Division

DISTRIBUTION

M-S&M-DIR
M-S&M-DEP DIR
M-TEST-DIR
M-F&AE-DIR
M-F&AE-MM
M-QUAL-DIR
M-S&M-P
M-S&M-PM
M-S&M-PA
M-S&M-F
M-S&M-FD (2)
M-S&M-S (2)
M-S&M-SA
M-S&M-SB (2)
M-S&M-SS
M-S&M-SE
M-S&M-M (2)
M-S&M-ME
M-S&M-MM (6)
M-MS-IPL (8)
M-PAT
Attn: Mr. Warden
M-MS-H
Attn: Mr. Akins
M-S&M-ADM
Attn: Miss Leonard