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FERROUS ALLOYS

	Fe
18	Cr
9	Ni
+	S
or	Se

TYPES 303, 303 Se

1. GENERAL

These varieties of the 18-8 austenitic stainless steel family contain additions of sulfur or selenium for the purpose of improving machining characteristics, and are limited to service temperatures below 700 F. Because of the presence of these elements they are inferior to the basic Type 302 in formability and corrosion resistance. Type 303Se is superior to Type 303 in these respects, and its formability can be further improved by keeping the nickel content between 10 and 12 percent and reducing the selenium content to 0.07 percent minimum (also called Type 303A). Low carbon, columbium-tantalum stabilized types (AMS 5642C) are made to provide increased service and fabrication temperatures. In addition, types containing increased manganese (Type 303 Mod, AMS 5640J - Type 3) and lead additions (AMS 5635) are produced. Cast forms of these alloys containing suitable combinations of selenium, phosphorous and molybdenum and of sulfur and molybdenum are also known under the designations CF-16Fa and CF-16F respectively. Most properties of these alloys are nearly identical with those of the basic Types 302 and 304, and references should be made to these basic alloys.

1.01 Commercial Designation

Wrought: Type 303, Type 303Se, and Type 303Pb.
Cast: CF-16F and CF-16Fa.

1.02 Alternate Designations

AISI Type 303 and Type 303Se austenitic stainless steels, free machining 18-8 stainless steels, 18-8FM, SAE 30303, SAE 30303Se, SAE 30303 Mod, SAE 30303F, SAE 30303F + Cb.

1.03 Specifications

Table 1.03

1.04 Composition

1.041 AMS specified composition.
1.0411 AMS specified composition for Type 303 alloys, Table 1.0411.
1.0412 AMS specified composition for Type 303Se alloys, Table 1.0412.
1.042 ASTM specified composition.
1.0421 ASTM specified composition for Type 303 alloys, Table 1.0421.
1.0422 ASTM specified composition for Type 303Se alloys, Table 1.0422.

1.05 Heat Treatment

1.051 Annealing or solution treatment. 1900 to 2050 F, air cool or quench, depending on section thickness; cooling to 800 F maximum should be within 3 minutes.
1.0511 Bar and forgings. 1900 to 1950 F, 1/2 hr per in thickness water quench.
1.0512 Sheet and tubing. 1900 to 1950 F, 10 min, air cool up to 0.064 in thickness, water quench 0.065 in and thicker.
1.0513 Castings. 1900 to 2100 F, 30 min minimum, water quench or rapid cool by other means.
1.052 Heat treatment for maximum dimensional stability. 1950 F, 1/2 hr, water quench + 600 F, 1 hr, air cool + 200 F, 20 hr, air cool (13).

1.06 Hardness

These alloys can be hardened only by cold work, which increases both strength and hardness. The extent of possible cold working is less than for the other 18-8 grades because of embrittlement by the sulfur or selenium content (14, p. 116).

1.07 Forms and Conditions Available

The steel is available in the full commercial range of sizes for bar, wire, forgings, sheet and tubing(14, p. 8). All wrought products are available in the annealed condition. Sheet, bar and wire are also available in cold worked condition to various reductions. Castings are available in the annealed condition.

1.08 Melting and Casting Practice

Electric-arc, electric-induction, or other suitable commercial processes.

1.09 Special Considerations

When chromium-nickel steels containing more than about 0.04C are subject to annealing at temperatures of 1850 to 2050 F and are then reheated to or held at temperatures of approximately 800 to 1600 F, chromium carbides will precipitate at the austenite grain boundaries (15, p. 24). This intergranular precipitation or sensitization promotes intergranular corrosion cracking and reduces corrosion resistance of these steels. Heat treatment and welding conditions should be chosen to avoid carbide formation. Additions of columbium and titanium are used to stabilize these alloys and reduce intergranular corrosion sensitivity.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.011 Melting range. 2550 to 2590 F (14, p. 43) (15, p. 38-39), (16, p. 22).
2.012 Phase changes. Severe cold working will transform a small amount of austenite to ferrite (martensite).
2.0121 Time-temperature-transformation diagrams.
2.013 Thermal conductivity, Figure 2.013.
2.014 Thermal expansion, Figure 2.014.
2.015 Specific heat. 0.12 Btu/F/lb from 32-212 F (14, p. 40) (15, p. 38)(16, p. 22).
2.016 Thermal diffusivity.

2.02 Other Physical Properties

2.021 Density. 0.286 lb per cu in, 7.93 gm per cu cm.
2.022 Electrical properties.
2.0221 Electrical resistivity, Figure 2.0221.
2.023 Magnetic properties. This steel is nonmagnetic in the annealed condition (15)(16). Permeability of annealed material is less than 1.01. It becomes slightly magnetic when severely cold worked as a result of transformation of a small amount of austenite to ferrite (martensite).
2.024 Emittance.
2.0241 Total hemispherical emittance, Figure 2.0241.
2.025 Damping capacity.

2.03 Chemical Properties

2.031 Corrosion resistance. General corrosion resistance in mildly corrosive atmospheres is slightly inferior and under severe corrosive conditions greatly inferior to that of Type 302. This steel resists nitric acid well, halogen acids poorly and sulfuric acid moderately (14, p. 116).
2.032 Type 303 is susceptible to stress corrosion cracking if cold worked. Type 303Se, therefore, is preferred for applications involving cold forming.
2.033 Oxidization resistance is similar to that of Type 302, but nonuniform scaling may be encountered in strongly oxidizing atmospheres above 1400 F.

2.04 Nuclear Properties

Similar to Type 304.

3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties

3.011 AMS specified mechanical properties.
3.0111 AMS specified mechanical properties for bar, Type and 303Se, Table 3.0111.
3.0112 AMS specified mechanical properties for bar, Types 303(Cb + Ta), 303Se (Cb + Ta) and 303Pb, Table 3.0112.
3.0113 AMS specified mechanical properties for forgings, Table 3.0113.
3.0114 AMS specified mechanical properties for wire, Table 3.0114.
3.012 ASTM specified mechanical properties.
3.0121 ASTM specified mechanical properties for bar and bolting, Table 3.0121.

	Fe
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TYPES 303, 303Se

3.0122 ASTM specified mechanical properties for forgings, Table 3.0122.
3.0123 ASTM specified mechanical properties for wire, Table 3.0123.
3.0124 ASTM specified mechanical properties for castings, Table 3.0124.

3.02 Mechanical Properties at Room Temperature
3.021 Tension.
3.0211 Stress-strain diagrams (see 3.0311).
3.0212 Typical room temperature mechanical properties, Table 3.0212.
3.0213 Effect of cold work on tensile properties.
3.02131 Effect of cold drawing on tensile properties of wire, Figure 3.02131.
3.022 Compression (see 3.032).
3.0221 Stress-strain diagrams.
3.023 Impact (see Table 3.0212).
3.024 Bending.
3.025 Torsion and shear.
3.026 Bearing.
3.027 Stress concentration.
3.0271 Notch properties.
3.0272 Fracture toughness.
3.028 Combined properties.

3.03 Mechanical Properties at Various Temperatures
3.031 Tension.
3.0311 Stress-strain diagrams.
3.03111 Stress-strain diagrams at room and cryogenic temperatures, Figure 3.03111.
3.0312 Tensile properties of Type 303 +S annealed bar at room and cryogenic temperatures, Figure 3.0312.
3.0313 Tensile properties of annealed bar at room and elevated temperatures, Figure 3.0313.
3.0314 Tensile properties of annealed Type 303+Se bar at room and cryogenic temperatures, Figure 3.0314.
3.032 Compression.
3.0321 Stress-strain diagrams.
3.0322 Compressive yield strength and elastic limit at room and cryogenic temperatures, Figure 3.0322.
3.033 Impact.
3.0331 Range and average values of impact energy for annealed bar of Type 303+Se, Figure 3.0331.
3.0332 Range and average values of impact energy for annealed bar of Type 303+S, Figure 3.0332.
3.034 Bending.
3.035 Torsion and shear.
3.036 Bearing.
3.037 Stress concentration.
3.0371 Notch properties.
3.0372 Fracture toughness.
3.038 Combined properties.

3.04 Creep and Creep Rupture Properties
3.041 Creep strength for 1 percent elongation at 10,000 hours, Figure 3.041.

3.05 Fatigue Properties
3.051 Endurance limit of 1/4 hard 303 is about 48 ksi (27).

3.06 Elastic Properties
3.061 Poisson's ratio.
3.062 Modulus of elasticity. 28.0×10^3 ksi (14, p. 40)(15, p. 38)(16, p. 22).
3.063 Modulus of rigidity.

4. FABRICATION

4.01 Formability
4.011 Forging. Starting temperature 2200F maximum, finishing temperature 1700F minimum. These steels will take only light reductions below 1800F.
4.0111 Scaling. Starting temperature 1600F maximum, finishing temperature 1900F maximum for continuous service (14, p. 116).
4.012 Cold forming of these types is possible to a limited extent with Type 303Se being superior to Type 303 in this respect. Type 303 should be annealed after severe forming to prevent stress cracking. A special high nickel, low selenium composition is recommended for more severe cold forming.

4.02 Machining and Grinding
These steels are the most readily machinable of all the austenitic stainless steels. Type 303 permits heavy feeds and deep cuts, while the use of Type 303Se is indicated where a high finish is desired. As with other austenitic steels very sharp tools, low speeds and feeds, and heavy equipment are required. Machining speeds between 60 to 75 percent of those used for mild carbon steels are suitable.

4.03 Welding
Welding of these steels is generally not recommended. Fusion welding with Type 310 electrodes is possible to a very limited extent and post weld annealing is necessary. The columbium bearing types need no post weld annealing.

4.04 Surface Treatment

TABLE 1.03

Form	AMS	ASTM
Bar, forgings, wire (solution treated), forging stock	5640J	A-582, A-473, A-314, A-581
Bar, forgings, (solution treated) (swaging and hot upsetting), forging stock	5641A	
Bar (cold drawn)	5738	
Bolting		A-194, A-320
Casting		A-296
Bar, forgings (solution treated), forging stock (Cb + Ta stabilized)	5642C	
Bar, forgings (solution treated), forging stock (Pb added)	5635	

TABLE 1.0411

Source	AMS (1)				AMS(4)		AMS(5)	
Alloy	Fe-18Cr-9Ni + S							
	Type 303		Type 303 Mod		Type 303 (Cb + Ta)		Type 303Pb	
	Percent		Percent		Percent		Percent	
	min	max	min	max	min	max	min	max
Carbon	-	0.15	-	0.15	-	0.08	-	0.15
Manganese	-	2.00	2.50	4.50	-	2.00	-	2.00
Phosphorus	-	0.15	-	0.20	-	0.040	-	0.040
Sulfur	0.18	0.40	0.15	0.40	0.18	0.35	0.12	0.30
Silicon	-	1.00	-	1.00	-	1.00	-	1.00
Chromium	17.00	19.00	17.00	19.00	17.00	19.00	17.00	19.00
Nickel	8.00	10.00	7.00	10.00	9.00	12.00	8.00	10.00
Molybdenum	-	0.75	-	0.60	-	0.75	-	0.60
Columbium + Tantalum	-	-	-	-	10xC	1.10	-	-
Copper	-	0.50	-	0.50	-	0.50	-	0.50
Lead	-	-	-	-	-	-	0.12	0.30
Iron	Balance		Balance		Balance		Balance	

TABLE 1.0412

Source	AMS (1)		AMS(2)		AMS(3)		AMS(4)	
Alloy	Fe-18Cr-9Ni + Se							
Designation	Type 303Se						Type 303Se (Cb + Ta)	
	Percent		Percent		Percent		Percent	
	min	max	min	max	min	max	min	max
Carbon	-	0.15	-	0.12	-	0.12	-	0.08
Manganese	-	2.00	-	2.00	0.20	2.00	-	2.00
Phosphorus	0.12	0.17	0.11	0.17	-	0.17	0.11	0.17
Sulfur	-	0.04	-	0.040	-	0.10	-	0.030
Silicon	-	1.00	-	0.70	-	1.00	-	1.00
Chromium	17.00	19.00	17.00	20.00	17.00	19.00	17.00	19.00
Nickel	8.00	10.00	8.00	12.00	8.00	10.00	9.00	12.00
Molybdenum	-	0.50	-	0.50	-	0.75	-	0.50
Selenium	0.15	0.40	0.15	0.30	0.15	0.35	0.15	0.35
Columbium + Tantalum	-	-	-	-	-	-	10xC	1.10
Copper	-	0.50	-	-	-	0.50	-	0.50
Iron	Balance		Balance		Balance		Balance	

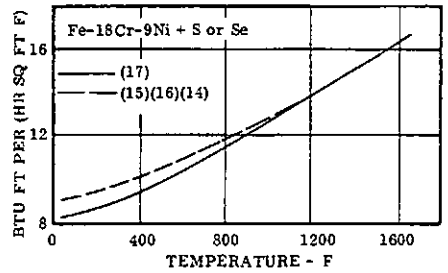

FIG. 2.013 THERMAL CONDUCTIVITY. (17)(15, p.38) (16, p. 22)(14, p. 40)

Fe
18 Cr
9 Ni
+ S
or Se

TYPES 303, 303Se

TABLE 1.0421

Source	ASTM(6)(8)		ASTM(7)(9)		ASTM(10)(11)		ASTM(12)	
Alloy	Fe-18Cr-9Ni + S							
Designation	Type 303						Type 303 (CF-16Fa)	
	Percent		Percent		Percent		Percent	
	min	max	min	max	min	max	min	max
Carbon	-	0.15	-	0.15	-	0.15	-	0.16
Manganese	-	2.00	-	2.00	-	2.00	-	1.50
Phosphorus	-	0.20	-	0.20	-	0.20	-	0.04
Sulfur	0.15	-	0.15	-	0.15	0.35	0.20	0.40
Silicon	-	1.00	-	1.00	-	1.00	-	2.00
Chromium	17.00	19.00	17.00	19.00	17.00	19.00	18.00	21.0
Nickel	8.00	10.00	8.00	10.00	8.00	10.00	9.0	12.0
Molybdenum	-	0.60(b)	-	0.60	-	0.60(b)	0.40	0.80
Zirconium	-	-	-	-	-	0.60(a)	-	-
Iron	Balance		Balance		Balance		Balance	

(a) Optional additions
(b) Optional addition for A320-68 (11)

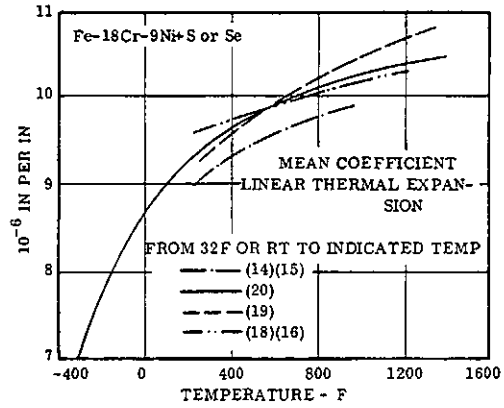

FIG. 2.014 THERMAL EXPANSION. (14, p. 40)(15, p.38) (16, p. 22)(18)(19)(20)

TABLE 1.0422

Source	ASTM(6)(7)(8)(10)		ASTM (11)		ASTM (12)	
Alloy	Fe-18Cr-9Ni + Se					
Designation	Type 303Se				Type 303Se (CF-16F)	
	Percent		Percent		Percent	
	min	max	min	max	min	max
Carbon	-	0.15	-	0.15	-	0.16
Manganese	-	2.00	-	2.00	-	1.50
Phosphorus	-	0.20	-	0.20	-	0.17
Sulfur	-	0.06	-	0.06	-	0.04
Silicon	-	1.00	-	1.00	-	2.00
Chromium	17.00	19.00	17.00	19.00	18.0	21.0
Nickel	8.00	10.00	8.00	10.00	9.0	12.0
Molybdenum	-	-	-	-	-	1.50
Selenium	0.15	-	0.15	0.35	0.20	0.35
Iron	Balance		Balance		Balance	

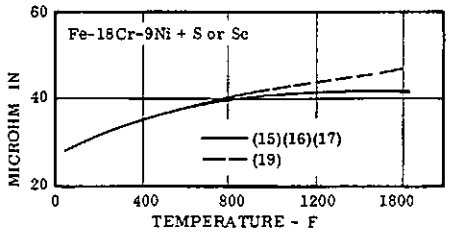

FIG. 2.0221 ELECTRICAL RESISTIVITY. (15, p.38) (16, p. 22)(17)(19)

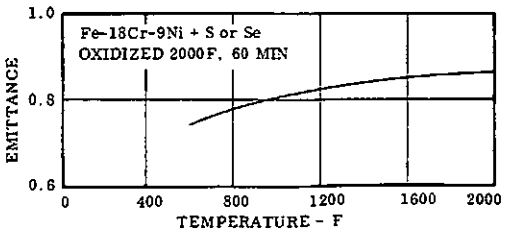

FIG. 2.0241 TOTAL HEMISPHERICAL EMITTANCE. (21)

	Fe
18	Cr
9	Ni
+	S
or	Se

TYPES 303, 303Se

TABLE 3.0111

Source	(1)	(2)	(3)			
Alloy	Fe-18Cr-9Ni+S or Se (Types 303 and 303Se)					
Form	Bar					
Condition	ST(a)	ST(a)	ST + Cold Finish			
Diameter or least distance between parallel sides - in	(a)	(a)	≤0.750	0.751 to 1.000	1.001 to 1.250	1.251 to 1.750
F_{tu} - min - ksi	-	75	125	115	105	95
- max - ksi	-	115	-	-	-	-
F_{ty} - min - ksi	-	-	100	80	65	45
e(2 in or 4D) - min - percent	-	35	12	15	20	28
RA - min - percent	-	-	35	35	35	45
Hardness, BHN(b) min	140	-	-	-	-	-
max	255	-	-	-	-	-

(a) Bars ≤2.75 inch shall be cold finished, unless specified otherwise.
(b) Hardness taken approximately midway between surface and center.

TABLE 3.0112

Source	AMS (4)(c)			AMS (5)		
Alloy	Fe-18Cr-9Ni+S or Se (Cb+Ta), Types 303 (Cb+Ta) and 303Se (Cb+Ta)			Fe-18Cr-9Ni + Pb Type 303Pb		
Form	Bar					
Condition	ST(a)			ST Hot finished	ST Cold finished	
Diameter or least distance between parallel sides-in	≤0.75	>0.75 to 1.50	>1.50	-	≤0.500	>0.500
F_{tu} - min - ksi	-	-	-	75	90	75
F_{ty} - min - ksi	-	-	-	30	45	30
e(2 in or 4D) - min - percent	-	-	-	40	35	40
RA - min - percent	-	-	-	50	45	50
Hardness, BHN(b)						
- minimum	175	163	140	170(d)	140(e)	
- maximum	255	255	241	255(d)	241(e)	

(a) Bars ≤2.75 inch shall be cold finished, unless specified otherwise.
(b) Hardness taken approximately midway between surface and center.
(c) Embrittlement: material shall be capable of meeting specified test for embrittlement.
(d) For bars ≤0.75 inch
(e) For bars >0.75 inch

TABLE 3.0113

Source	AMS(1)(5)	AMS(2)
Alloy	Fe-18Cr-9Ni+S or Se (Types 303 and 303Se) and Fe-18Cr-9Ni(+Pb) (Type 303Pb)	
Form	Forgings	
Condition	ST	
Hardness, BHN - min	-	149
- max	187	229

TABLE 3.0114

Source	AMS (1)
Alloy	Fe-18Cr-9Ni+S or Se (Types 303 and 303Se)
Form	Wire
Condition	ST
F_{tu} - minimum - ksi	85
- maximum - ksi	125

TABLE 3.0121

Source	(7)	(10)	(11)				
Alloy	Fe-18Cr-9Ni + S or Se (Types 303 and 303Se)						
Form	Bar	Bolting					
Condition	ST	ST	ST	ST + Cold Work			
Diameter or least distance between parallel sides - inches	-	-	-	≤0.75	>0.75 to 1.00	>1.00 to 1.25	>1.25 to 1.50
F_{tu} - min - ksi	-	-	75	125	115	105	100
F_{ty} - min - ksi	-	-	30	100	80	65	50
e(2 in) - min - percent	-	-	35	12	15	20	28
RA - min - percent	-	-	50	35	35	35	45
Hardness - BHN							
- minimum	-	149	-	-	-	-	-
- maximum	262	-	-	-	-	-	-

TABLE 3.0122

Source	ASTM (8)
Alloy	Fe-18Cr-9Ni + S or Se (Types 303 and 303Se)
Form	Forgings
Condition	ST
F_{tu} - minimum - ksi	75
F_{ty} - minimum - ksi	30
e(2 in) - minimum - percent	40
RA - minimum - percent	50

TABLE 3.0123

Source	ASTM (9)	
Alloy	Fe-18Cr-9Ni + S or Se (Types 303 and 303Se)	
Form	Wire	
Condition	Annealed	Annealed + Cold Drawn
F_{tu} - minimum - ksi	85	115
maximum - ksi	125	145

TABLE 3.0124

Source	ASTM (12)
Alloy	Fe-18Cr-9Ni + S or Se (CF16-F and CF-16Fa)
Form	Castings
Condition	Annealed
F_{tu} - minimum - ksi	70
F_{ty} - minimum - ksi	30
e(2 in) - minimum - percent	25

TABLE 3.0212

Source	(22)										(18)	(15)	(14)
Alloy	Fe-18Cr-9Ni- + S or Se												
Form	Bar				Wire						Cast test bars	Bar	
Condition	Ann	CD	High tensile		Annealed		Soft temper		Hard temper			Annealed	
Diameter - inches	-	1	7/8	1 1/2	0.062	0.500	0.062	0.500	0.062	0.500	-	-	1
F_{tu} - typical - ksi	90	100	125	110	105	90	125	100	160	140	77	85	90
F_{ty} - typical - ksi	35	60	95	75	35	35	90	60	125	105	40	35	35
e(2 in) - min - percent	50	40	20	30	50	50	30	40	15	20	52	55	50
RA - percent	55	53	50	50	60	60	55	55	45	50	-	60	55
Hardness - BHN	160	228	277	240	-	-	-	-	-	-	152	150	160
Impact Strength													
Izod - ft lb	80	-	35	-	-	-	-	-	-	-	-	85	80
Charpy Keyhole - ft lb	-	-	-	-	-	-	-	-	-	-	75	-	-

	Fe
18	Cr
9	Ni
+	S
or	Se

TYPES 303, 303 Se

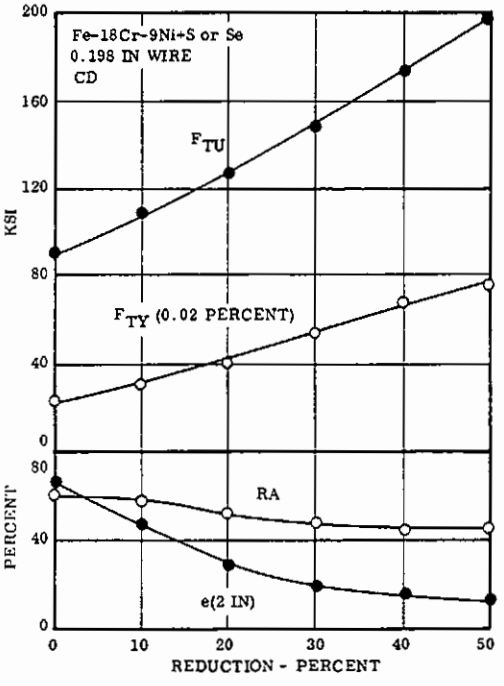

FIG. 3.02131 EFFECT OF COLD DRAWING ON TENSILE PROPERTIES OF WIRE. (19)

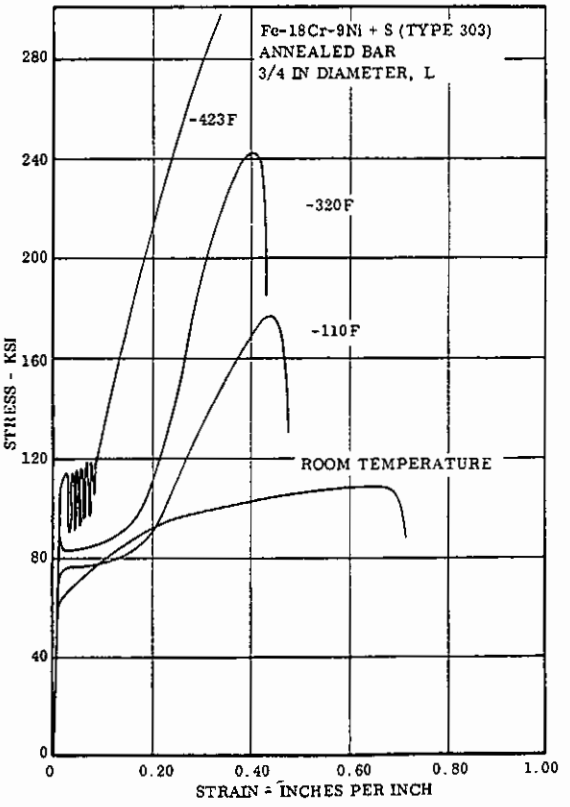

FIG. 3.03111 STRESS-STRAIN DIAGRAMS AT ROOM AND CRYOGENIC TEMPERATURES. (23, p. 40)

	Fe
18	Cr
9	Ni
+	S
or	Se

TYPES 303, 303 Se

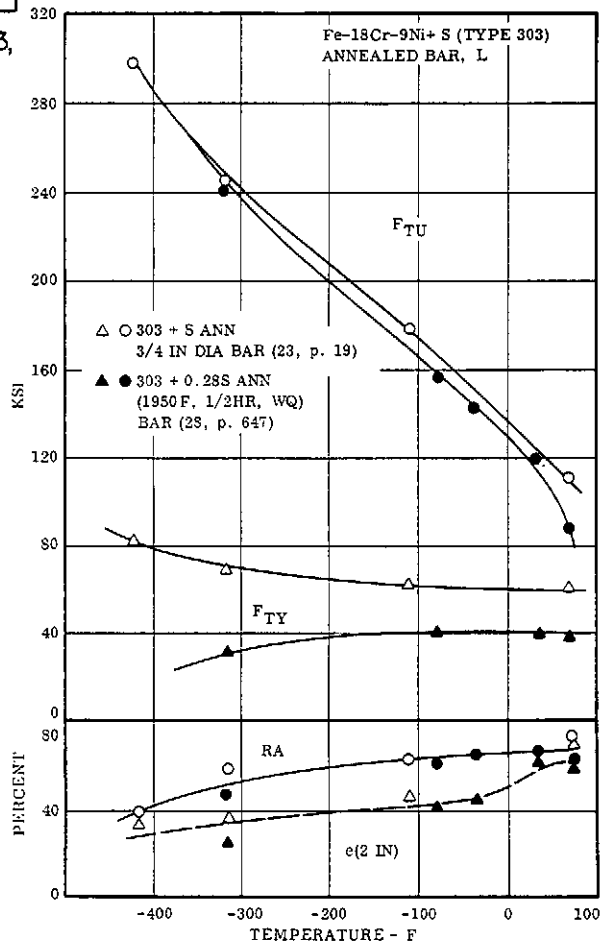

FIG. 3.0312 TENSILE PROPERTIES OF TYPE 303 + S ANNEALED BAR AT ROOM AND CRYOGENIC TEMPERATURES. (23)(28)

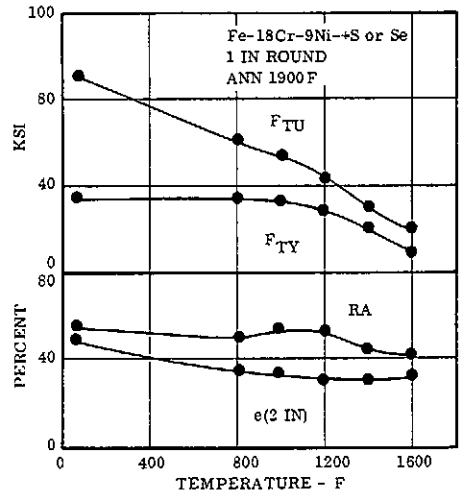

FIG. 3.0313 TENSILE PROPERTIES OF ANNEALED BAR AT ROOM AND ELEVATED TEMPERATURES. (14, p. 117)

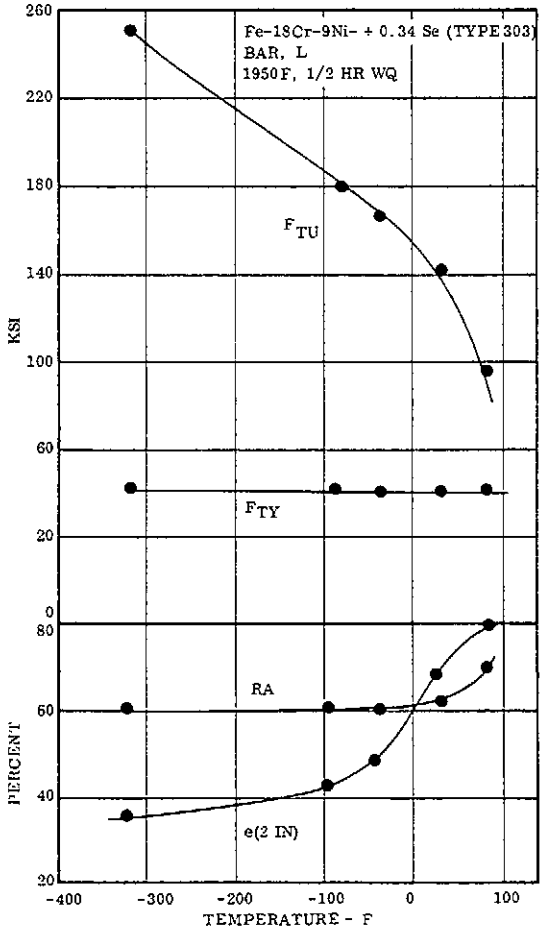

FIG. 3.0314 TENSILE PROPERTIES OF ANNEALED TYPE 303+Se BAR AT ROOM AND CRYOGENIC TEMPERATURES. (28, p. 647)

	Fe
18	Cr
9	Ni
+	S
or	Se

TYPES 303, 303 Se

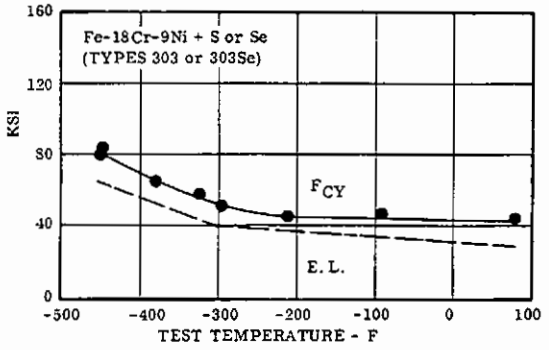

FIG. 3.0322 COMPRESSIVE YIELD STRENGTH AND ELASTIC LIMIT AT ROOM AND CRYOGENIC TEMPERATURES. (24, Fig B5)

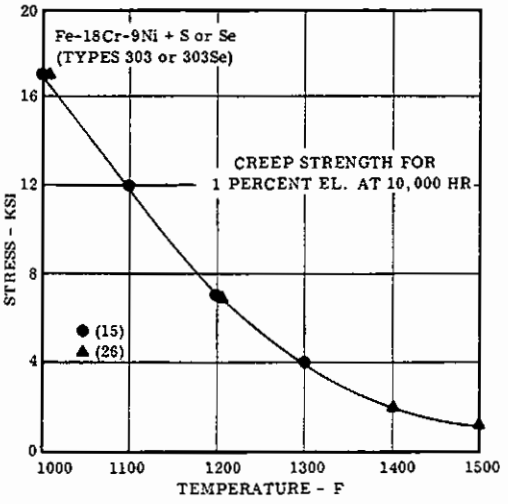

FIG. 3.041 CREEP STRENGTH FOR 1 PERCENT ELONGATION AT 10,000 HOURS. (15, p. 38)(26, p. 112)

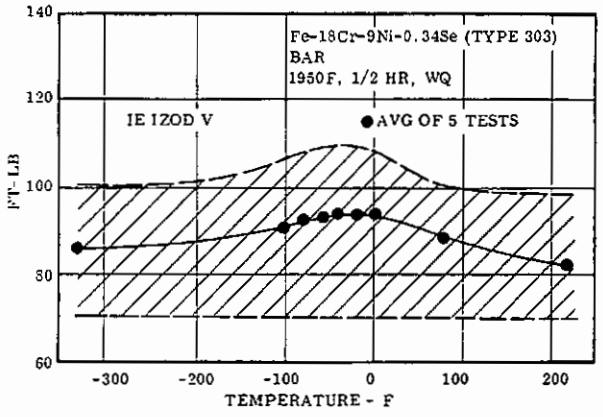

FIG. 3.0331 RANGE AND AVERAGE VALUES OF IMPACT ENERGY FOR ANNEALED BAR OF TYPE 303+Se. (29, p. 647)

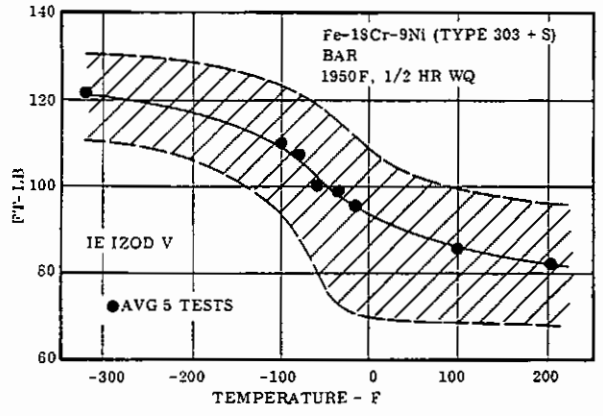

FIG. 3.0332 RANGE AND AVERAGE VALUES OF IMPACT ENERGY FOR ANNEALED BAR OF TYPE 303 + S. (29, p. 647)

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	Fe
18	Cr
9	Ni
+	S
or	Se

TYPES 303, 303 Se

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