TYPES 304 AND 304L STAINLESS STEELS FOR LOW TEMPERATURE SERVICE

A PRACTICAL GUIDE TO THE USE OF NICKEL-CONTAINING ALLOYS
Nº 328

Produced by INCO

Distributed by NICKEL INSTITUTE

Nickel INSTITUTE
knowledge for a brighter future

TYPES 304 AND 304L STAINLESS STEELS FOR LOW TEMPERATURE SERVICE

A PRACTICAL GUIDE TO THE USE
OF NICKEL-CONTAINING ALLOYS
Nº 328

Originally, this handbook was published in 1964 by INCO, The International Nickel Company Inc. Today this company is part of Vale S.A.
The Nickel Institute republished the handbook in 2021. Despite the age of this publication the information herein is considered to be generally valid.

Nickel Institute

communications@nickelinstitute.org
www.nickelinstitute.org

Low Temperature Data Sheet

TYPES 304 AND 304L STAINLESS STEELS

Types 304 and 304L stainless steels offer excellent combinations of mechanical and corrosion resisting properties for equipment to operate at subzero temperatures. As temperature is lowered, their strengths increase rapidly; they retain good ductility and do not become brittle. They are particularly well suited for equipment handling liquid gases, as well as other liquids, at low temperatures when corrosion resistance is required or product contamination must be held to a minimum.

Specifications

ASTM Specification A 240 is widely used for plate, sheet and strip for cryogenic service. The compositional requirements of this specification are:

Carbon	.08% max for Type 304 and .03% max for Type 304L
Manganese	2.00 max
Phosphorus	.045 max
Sulfur	.030 max
Silicon	1.00 max
Nickel	8.00-12.00
Chromium	18.00-20.00

To meet other requirements of the specification, including the intergranular corrosion test, this material is ordinarily furnished in the quench-annealed condition (cooled rapidly from a temperature range of 1850-2050 F).

The room temperature mechanical property requirements of this specification for Types 304 and 304L are as follows:

	Type 304	Type 304L
Tensile Strength, psi, min	75,000	70,000
Yield Strength (0.2% offset), psi, min	30,000	25,000
Elongation (in 2 in.), %, min	40	40
Brinell Hardness, max	202	202
Rockwell Hardness, max	B-88	B-88

According to paragraph UHA-51 of the 1959 Edition of ASME Boiler and Pressure Vessel Code, Section VIII, Unfired Pressure Vessels no impact tests are required on these grades for use down to −325 F. Below this temperature a minimum Charpy keyhole value of 15 ft-lb is required at the temperature of use.

ASTM specifications for Type 304 in other shapes employed in construction of cryogenic equipment and which have chemical and mechanical requirements similar to A 240 are as follows:

Seamless tubing	A 213
Welded tubing	A 249
Forgings	A 182
Bolting	A 193

Tensile Properties

The tensile properties of annealed and full-hard material are shown in Figure 1. Yield and tensile strengths increase for both materials with decreasing temperature. However, there is no serious loss of ductility in annealed material at low temperatures, and the full-hard material actually increases in ductility.

Table I gives the properties of a weldment made by welding a Type 302 (.09 C, 19.0 Cr, 8.2 Ni) base material with a Type 304 (.07 C, 18.7 Cr, 9.0 Ni) electrode. Since the rupture occurred in the Type 304 weld metal, these data should be applicable to Type 304 weldments as well.

Impact Properties

The range of impact properties for annealed Types 304 and 304L is shown in Figure 2. As depicted in Table II, cold-worked materials retain these impact properties at very low temperatures. Weldments, while having lower impact values than the base metal, are not embrittled by low temperatures. (See Tables III, IV and V)

Fatigue

The effect of subzero temperatures on the fatigue strength of full-hard (210,000 psi tensile strength at room temperature) Type 304 is shown in Figure 3. The fatigue strengths of annealed Types 304 and 304L also increase at subzero temperatures.

ASME Boiler and Pressure Vessel Code Provisions

Although the strength of Types 304 and 304L (and other austenitic stainless steels) shows marked improvement at subzero temperatures, the allowable design stress permitted by the ASME Boiler and Pressure Vessel Code for pressure vessels operating at subzero temperatures is based on the room temperature properties of the material. For all forms except welded pipe and tubes, the maximum allowable stress for Type 304 at all temperatures below 100 F, according to Table UHA-23, is 18,750 psi. This same table allows a stress of 17,500 psi for Type 304L plate or seamless pipe or tubes. For welded pipe or tubes, the maximum allowable stress is 16,000 psi for Type 304 and 14,900 psi for Type 304L.

Physical Properties

The specific heat and thermal expansion characteristics of Type 304 stainless steel are given in Figures 4 and 5. Emissivity data are shown in Table VI. Electrical resistivity and thermal conductivity are shown in Figures 6 and 7.

Availability

Types 304 and 304L stainless steels have been produced in the form of plates, strip, sheets, bars, tubing, pipe, shapes and forgings, and any such forms are readily available directly from the producers. These materials have an additional advantage that all these forms may also be obtained from local Steel Service Centers.

Similarly, casting grades, Types CF-8 and CF-3, of chemical compositions comparable to Types 304 and 304L, are readily available from various foundries.

Information as to current sources for the various products may be obtained through the offices of The International Nickel Company, Inc., in principal cities.

Table I

Low Temperature Tensile Properties of a Type 304 Weldment

Test Temperature	70 F	–108 F	–320 F
Tensile Strength, psi	92,000	139,000	223,000
Elongation (in 2 in.), %	50	22	21

Table II

Impact Properties of Type 304 Cold Rolled to a Room Temperature Tensile Strength of 210,000 psi

(Average of Three Tests)

	Charpy Impact (Keyhole Notch), ft-lb at:		
Room Temp.	–108 F	–320 F	–423 F
25	35	30	26

Table III

Charpy Keyhole Notch Impact Properties of Welds

(Average of Several Tests)

Type of Plate	Type of Electrode	Heat Treatment	Impact, ft-lb at:		
			Room Temp	–105 F	–320 F
304	304	As Welded	35	26	21
		Annealed	39	33	26
304	308	As Welded	32	23	17
		Annealed	44	40	36

Table IV

Low Temperature Charpy V-Notch Impact Properties of Inert-gas Welds in 3½″ Plate

(Average of Several Tests)

(Values in ft-lb)

Type	Test Temperature F	Weld Metal	Heat Affected Zone Distance from Notch to Fusion Line			Base Metal
			1/16″	⅛″	½″	
304	–320	38.5	51.5	63.	64.5	90.
	–421	22.5	53.	62.	60.	87.
304L	–320	48.5	58.5	56.	65.5	68.5
	–421	45.	53.	45.	64.	67.5

Table V

Impact Properties of Welded Type 304L at –440 F

(Average of Several Tests)

(Values in ft-lb)

	Charpy V-Notch	Charpy Keyhole Notch
Weld Metal	24.5	17.5
Heat Affected Zone	69.	58.5
Base Metal (Longitudinal)	108.	69.
Base Metal (Transverse)	110.	71.

Table VI

Emissivity of Type 304 Stainless Steel

(Average of Several Tests)

Temperature K	Temperature F	Emissivity Value (Black Body = 1)
77	–320	.048
300	80	.08

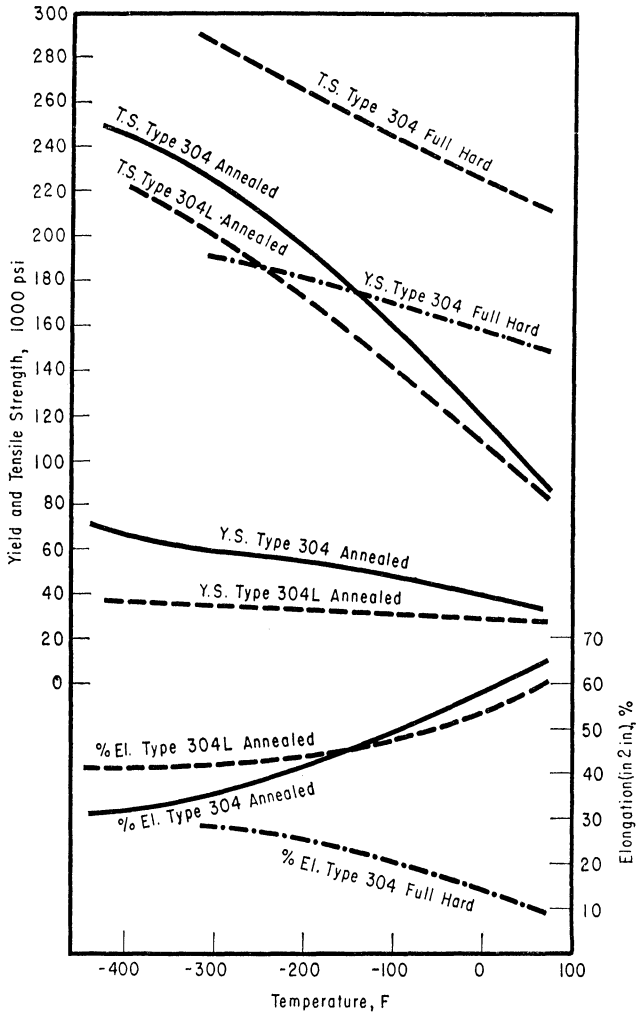

Fig. 1. Relation of tensile properties to temperature for annealed Types 304 and 304L and full-hard Type 304.

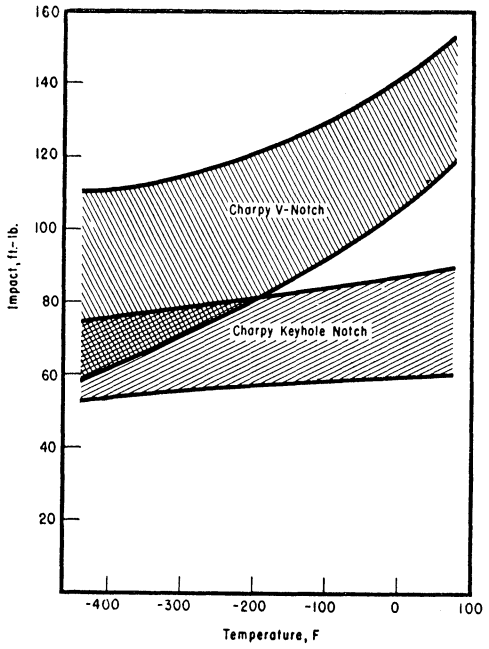

Fig. 2. Probable range of Charpy impact properties of annealed Types 304 and 304L stainless steels.

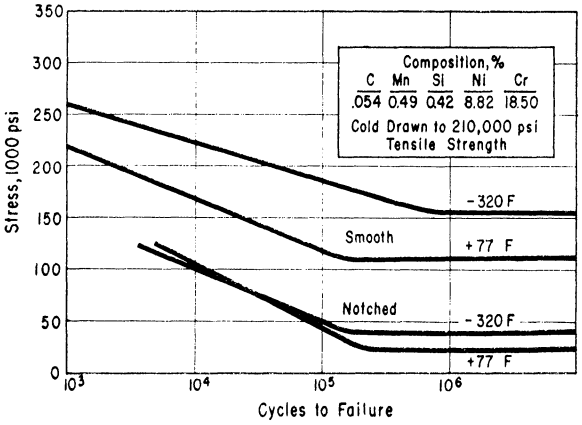

Fig. 3. Results of vibrating beam tests of notched and unnotched stainless steel Type 304.

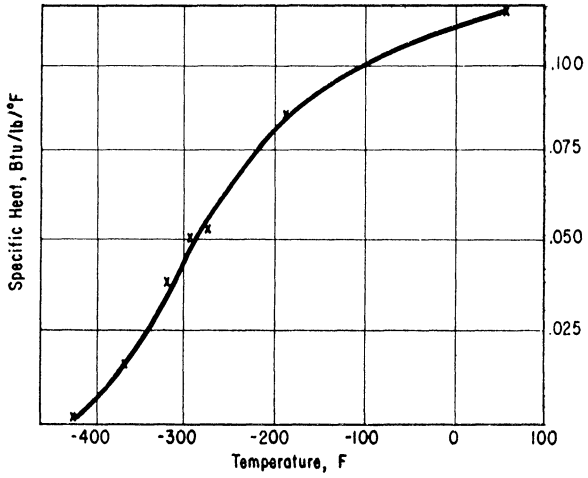

Fig. 4. Specific heat of Type 304 stainless steel at subzero temperatures.

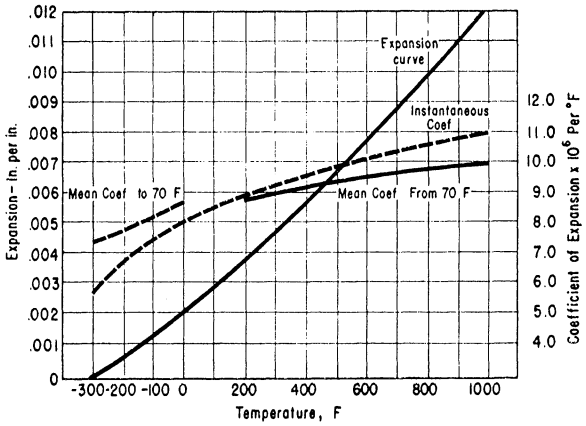

Fig. 5. Thermal expansion of Type 304 stainless steel from –300 F to 1000 F.

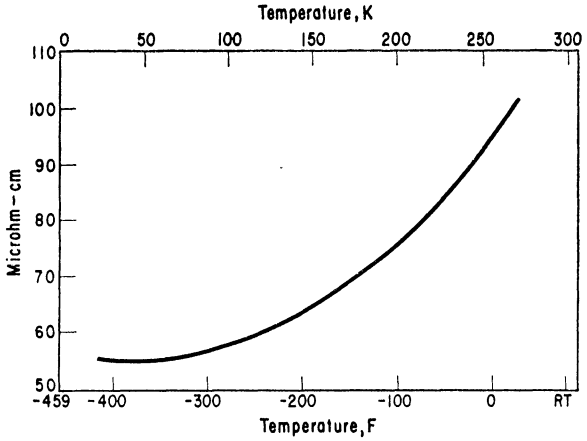

Fig. 6. Electrical resistivity of Type 304 stainless steel.

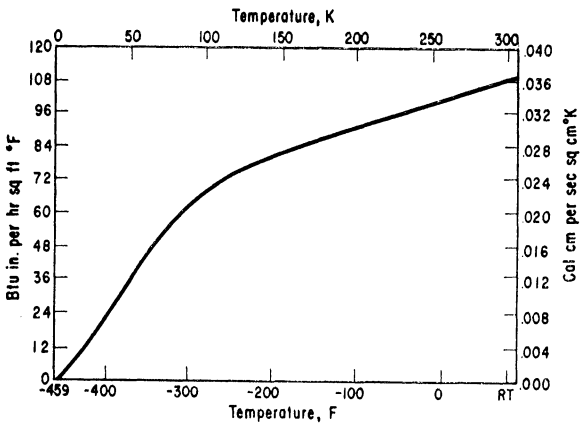

Fig. 7. Thermal conductivity of Type 304 stainless steel.