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Austenitic Steels: Mechanical Properties at Cryogenic Temperatures

We discussed the maximum service temperatures of common austenitic steels in Engineering Bulletin #106 and we'll now look at how mechanical properties of austenitic steels are influenced by very low (cryogenic) temperatures and what types of stainless steel alloys are best suited for low temperature applications.

Experience with brittle fracture of steel ships during the World War II demonstrated that while many metals have good room-temperature characteristics they do not perform adequately at low temperatures.

For example, Ferritic (405, 409, 430), Martensitic (403, 410, 414, 416) and Duplex stainless steels (329, 2205) tend to become brittle as the temperature is reduced and fracture can occur—sometimes with catastrophic results—without any warning by stretching or bulging as in some plastic failures. Therefore, alloys for low-temperature service must retain suitable properties such as yield and tensile strength and, of course, ductility.

The austenitic stainless steels such as 304 and 316 retain these engineering properties at cryogenic temperatures and can be classified as 'cryogenic steels.' They are commonly used in arctic locations and in the handling and storage of liquid gases such as liquid nitrogen and liquid helium. Liquid helium is the coldest material known with a boiling point of -452°F (-269 °C).

The table below shows some mechanical properties of stainless steels at low temperatures. Note, these alloys show not only good ductility (by means of elongation) at temperatures up to -423°F (-253°C), but they also show an increase in tensile and yield strengths.

MECHANICAL PROPERTIES OF 304, 321 AND 316 STAINLESS STEELS AT CRYOGENIC TEMPERATURES

Alloy	Temperature		Yield Strength		Tensile Strength		Elongation in 2"
	°F	°C	ksi	MPa	ksi	MPa	%
304	-40	-40	34	234	155	1069	47
	-80	-62	34	234	170	1172	39
	-320	-196	39	269	221	1524	40

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	-423	-252	50	344	243	1675	40
316	-40	-40	41	283	104	717	59
	-80	-62	44	303	118	814	57
Alloy	**Temperature**		**Yield Strength**		**Tensile Strength**		**Elonga-tion in 2″**
316	-320	-196	75	517	185	1276	59
	-423	-252	84	579	210	1448	52
321	-40	-40	45	310	120	828	55
	-80	-62	50	345	138	952	52
	-320	-196	60	414	211	1455	23
	-423	-252	68	469	248	1710	34

Note: In designing a metal hose assembly for cryogenic service, care must be taken to ensure that the fittings and any accessory (guard/liner) materials are suitable for the intended operating temperatures as well.

If you have any questions or comments, please contact us.

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