The 300 Series Austenitic Stainless Steels

Differences Between Steels:

The 300 series austenitic stainless steels are a set of iron-based chromium-nickel alloys designed to resist corrosion. This in combination with excellent formability, resistance to wear, and strength at temperature make them common materials of construction within piping systems.

Differences between the alloys are slight but deliberate. While they can be used interchangeably in many applications, sometimes there is an ideal solution. Substitutions in such situations could mean compromised service life.

Corrosion Resistance:

As corrosion resistance is one of the primary reasons end users opt for metal hose, application media typically guides alloy selection. 304 is often used as it is the most cost-effective option, though 321, and 316 especially, offer better corrosion resistance. For this reason, CryoWorks utilizes a 321 or 316L hose unless specified by customer or job specifications.

Braid is usually 304L as it will not be in contact with flow media, though 316L is an option if the application is in a corrosive environment—like in, on or near the ocean—or if the outside of the hose will be subject to corrosive media via drips, spray, run-off, etc.

For especially corrosive applications, superior corrosion resistant properties can be found among higher-nickel alloys like Monel® 400 and Hastelloy® C276.

Chemical Composition:

The chart below shows the chemical composition of the most common 300 series stainless steels used in the metal hose industry. When one figure is listed, it is the maximum percentage allowable under ASTM 240 requirements.

	304	304L	316	316L	321
Chromium	18% - 20%	18% - 20%	16% - 18%	16% - 18%	17% - 19%
Nickel	8% - 10.5%	8% - 12%	10% - 14%	10% - 14%	9% - 12%
Molybdenum			2% - 3%	2% - 3%	
Carbon	0.08%	0.03%	0.08%	0.03%	0.08%
Manganese	2%	2%	2%	2%	2%
Phosphorus	0.045%	0.045%	0.045%	0.045%	0.045%
Sulfur	0.03%	0.03%	0.03%	0.03%	0.03%
Silicon	.75%	.75%	.75%	.75%	.75%
Titanium					5 x (C+N)min - .70%
Nitrogen	0.1%	0.1%	0.1%	0.1%	0.1%
Iron	Balance	Balance	Balance	Balance	Balance

Chemical Composition (Cont'd):

304 is considered the baseline when it comes to corrosion resistance. Various alloying components have been added to the 321 and 316 grades to increase corrosion resistance.

In the case of 304L and 316L, carbon has been taken out. The "L" stands for "low carbon."
Lower carbon alloys are less susceptible to carbide precipitation in the Heat Affected Zone (HAZ) than their standard type counterparts.

Chromium and carbon can mix under the heat of welding to create chromium carbides at the grain boundaries. This reaction depletes the chromium layer that gives stainless steel its corrosion resistant properties, ultimately making the HAZ a target for chemical attack. One way to combat carbide precipitation is to reduce the amount of carbon in the parent material.

Another more effective way is to add titanium to the metal, as is the case with 321. With Type 321, rather than being attracted to the chromium, carbon is attracted to the titanium. This ensures the passive chromium layer remains intact.

Resistance to Pitting Corrosion:

Molybdenum is added to the 316 grades to increase resistance to pitting corrosion, especially in the presence of chlorides.
To help in the selection of an appropriate alloy, an equation based on chemical composition was developed. PREN, or the pitting resistance equivalent number, is a theoretical way of comparing pitting corrosion resistance among various alloys.

Alloy	PREN
304, 304L, 309, 310, 321	18.0 - 20.0
316, 316L	22.6 - 27.9
317, 317L	27.9 - 33.2
AL-6XN	39.8 - 45.1
Inconel® 625	46.4 - 56.0
Hastelloy® C-276	64.0 - 73.8

Taking precautions to ensure the HAZ more closely resembles parent materials in terms of corrosion resistance and planning for pitting corrosion is important if corrosion resistance is a priority. In applications where corrosion is not an issue, any of the 300 series alloys will likely deliver similar results.

Rates of Corrosion:

Another way to demonstrate differing levels of corrosion resistance among these alloys is to consider expected rates of corrosion. Rates vary from chemical to chemical and are illustrated in Penflex's corrosion resistance chart. In thinking about how much metal will be worn away each year, the difference between corrosion resistance capabilities can be seen more easily.

And when it comes to corrosion resistance, it's not just the alloy that must be considered, but the wall thickness of the alloy as well. Penflex has another bulletin to specifically address this topic.

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Derating Factors by Temperature:

No other materials can maintain their properties through such a wide temperature differential as metal. Anything below 0°F will likely require metal so cryogenic applications are a common use case for metal hose. Some of the austenitic stainless steel mechanical properties actually increase at low temperatures! Anything above about 400°F will also require metal so applications with super saturated steam or those within steel mills or furnaces are also likely scenarios for metal hose.

It's important to remember that with increased temperatures comes a reduction in pressure ratings, and there are some differences in those factors among the common 300 series stainless steels. Derating factors are based on braid alloy.

Temp°F	304/304L	316/316L	321
-452	1	1	N/A
-425	1	1	N/A
-325	1	1	1
70	1	1	1
150	0.95	0.93	0.97
200	0.91	0.89	0.94
250	0.88	0.86	0.92
300	0.85	0.83	0.88
350	0.81	0.81	0.86
400	0.78	0.78	0.83
450	0.77	0.78	0.81
500	0.77	0.77	0.78
600	0.76	0.76	0.77
700	0.74	0.76	0.76
800	0.73	0.75	0.68
900	0.68	0.74	0.62
1000	0.60	0.73	0.60
1100	0.58	0.67	0.58
1200	0.53	0.61	0.53
1300	0.44	0.55	0.46
1400	0.35	0.48	0.42
1500	0.26	0.39	0.37

***Chart on Derating Factors**

The temperature reduction factors for 321 and 304 are higher than 316 until about 700°F and then the reverse is true with 316 having the higher reduction factors than 321 and 304. The higher the derating factor, the higher the pressure ratings will remain.

*There are also factors to consider in the lower cryogenic temperatures. In accordance with ASME B31.3 type 321 stainless steel (ASTM A240 plate) has a minimum design temperature of -325°F which limits the use of 321 to around Liquid Nitrogen temperatures. 304L and 316L have minimum design temperatures of -425°F which limits the use of these materials to around Liquid Hydrogen temperatures. It is worth noting that to use these materials in accordance with ASME code, the fabricator must weld the assemblies with a weld procedure that has been qualified to the service temperature through additional impact testing, which is captured in the qualification records. CryoWorks' standard weld procedures meet these requirements for both 304/L and 316/L materials. To go below -425°F and get down to Liquid Helium Temperatures of -452°F, in addition to a qualified weld procedure being used, all base and filler material heat numbers must be impact tested in accordance with ASME B31.3 code prior to use.

For example, to calculate the maximum working pressure for a P4 Series ¾" 321 stainless steel corrugated hose with one layer of 304L braid that will be operating at 800°F, multiply working pressure (940 PSIG) by appropriate derating factor (.73).

The working pressure for the hose at 800°F is 686 PSIG.

CryoWorks, Inc.® | 951.360.0920 | www.CryoWorks.net | 3309 Grapevine Street, Jurupa Valley, CA 91752

Derating Factors by Temperatures (Cont'd):

Penflex developed its derating factors after gathering raw data on tensile strength at elevated temperatures from major material suppliers and taking the lowest values in each category for the various alloys. For this reason, they may be more conservative than derating factors published by NAHAD or ISO 10380.

It's important to remember the maximum working temperature of the end fittings and their method of attachment also needs to be considered when working with increased operating temperatures.

For application temperatures above 1000 °F, we often suggest Inconel® 625.

Considering The Entire Application:

As mentioned above, in many applications substitutions in hose alloy will have little impact on hose performance. It's when temperatures rise, pressures increase, or hoses cycle frequently that we must pay closer attention.

The impacts of temperature, pressure and movement can be compounded, leading to corrosion sooner than anticipated had application media been the only factor in our corrosion calculations. While the differences between the 300 series stainless steels may seem small, we can begin to see how quickly they could become magnified.

Please contact Penflex or CryoWorks with any questions.

Notes:

Penflex granted permission to CryoWorks to utilize information from their original engineering bulletin Differences Between the 300 Series Stainless Steels, to be repurposed into a CryoWorks brochure for educational purposes.

*CryoWorks has compiled and provided this supplemental information from the original engineering bulletin that Penflex developed. For any technical questions on the chart and Derating Factors Temperature factors, please contact CryoWorks .