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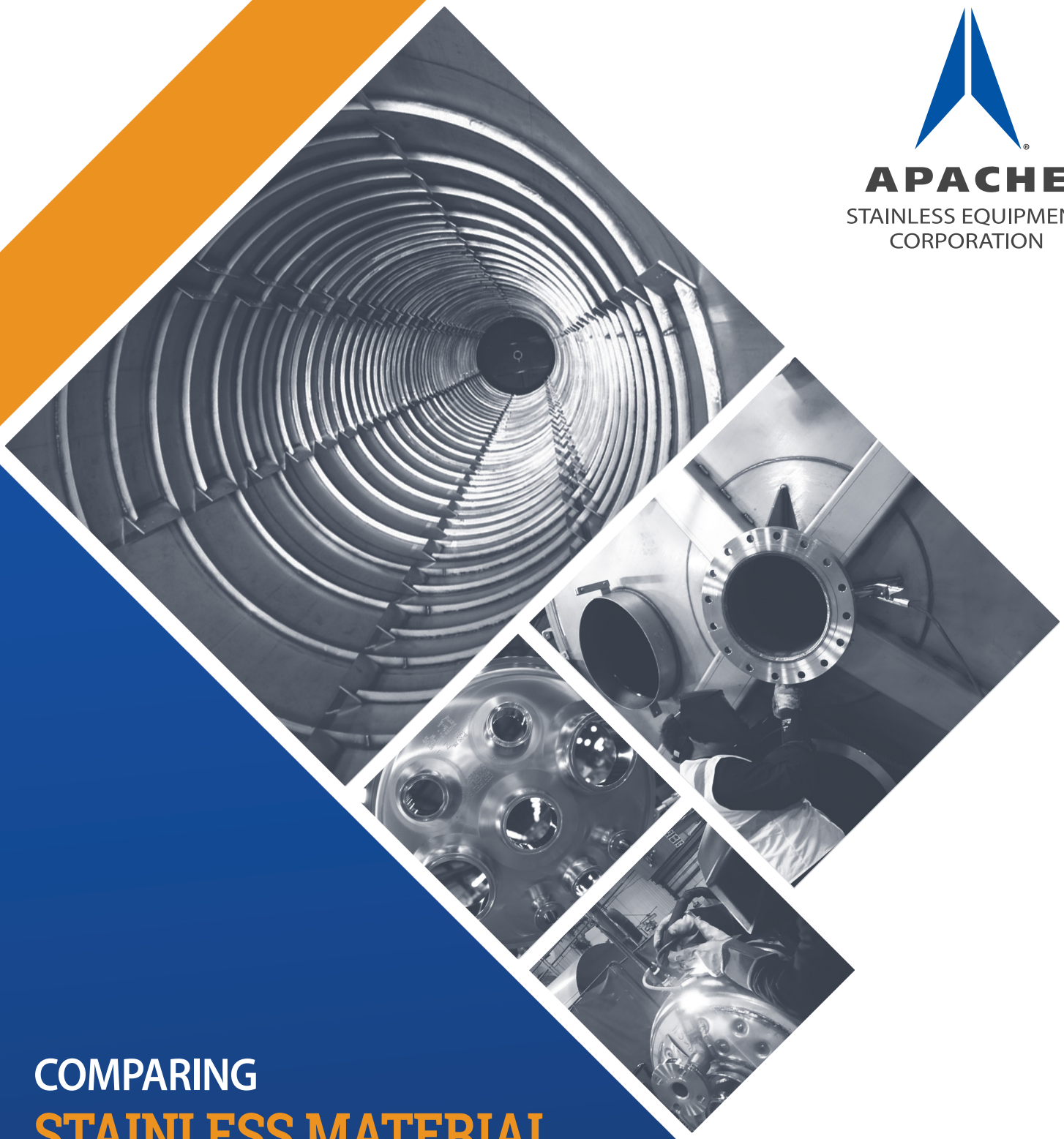

COMPARING
STAINLESS MATERIAL
used in vessel manufacturing

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COMPARING STAINLESS MATERIAL

More than 100 grades of stainless steel are available to manufacture a wide range of applications, from building construction to appliance manufacturing. Stainless metal is an alloy composed of several elements, with the most common additive of chromium, which provides noncorrosive benefits. The durability of stainless material allows for use in highly caustic environments.

Apache's background in pharmaceutical, medical, water purification, and chemical industries has driven expertise in seven types of high-alloy material used in vessel construction. In the following chart, Apache's vessel team shares application, sanitary conditions, availability, and performance comparisons of 304, 316, Duplex, Hastelloy®, Monel®, AL6XN®, and Alloy 20.

304 UNS S30400	316 UNS 31600	Duplex UNS S32205
Composition 18% Chromium and 8% Nickel	**Composition** 10-14% Chromium, 10 - 14% Nickel, 2-3% Molybdenum	**Composition** 22% Chromium, 5-6% Nickel, 3% Molybdenum
Corrosion Resistance Good corrosion resistance in general applications. Pitting and crevice corrosion can occur in chloride environments. Stress corrosion cracking can occur in higher temperatures.	**Corrosion Resistance** 316 stainless material has good corrosion resistance in chemical, dairy, food processing, medical and pressure applications. The material also resists most oxidizing acids and salt spray.	**Corrosion Resistance** Extremely corrosion resistant even in chloride and sulfide processing.
Cost Entry-level cost for stainless material for vessel construction	**Cost** A cost increase from 304 stainless material	**Cost** May cost up to 10% premium over 316 material
Availability This is one of the most used grades across our industry and is readily available under normal circumstances.	**Availability** 316 stainless is readily available in a variety of forms.	**Availability** Duplex steel grades are not as readily available and typically have to be specially ordered.
Performance The 304 stainless series does not electropolish as well as higher stainless grades.	**Performance** 316 provides higher temperature performance than 304, and performs well in cryogenic temperatures.	**Performance** Duplex has excellent oxidation resistance, outstanding performance in caustic and water applications, low thermal expansion coefficients, and high heat conductivity. It is subject to brittle condition when exposed to 572° F temperatures. Duplex requires specific pre- and post welding procedures.
Applications Widely used in food and life science production equipment. The strength, durability, and noncorrosive qualities provide the safety and cleaning effectiveness required under general sanitary conditions.	**Applications** 316 has high corrosion resistance and may be used in applications requiring higher strength and hardness. 316 material can be used for fuels, food processing, chemical, medical and pharmaceutical processes.	**Applications** Duplex series are extremely versatile stainless alloys, with many applications in fuel and chemical processing industries, and pharmaceutical applications.

Hastelloy®
UNS N06022
UNS N10276

Composition
16-22% Chromium, 56-57% Nickel, 13-16% Molybdenum

Corrosion Resistance
Excellent corrosion resistance and resistant to oxidizing agents and acids.

Cost
Base price can be up to 4 times greater than 316 stainless

Availability
Hastelloy® is a special order on a per-project basis. Availability is dependent on supplier stock and size.

Performance
Hastelloy® is a nickel base alloy, which is easy to form and weld with exceptional resistance to stress corrosion cracking. Hastelloy® is OSHA-enforced.

Applications
Hastelloy® works well in heat exchangers, columns, and pressure vessels as well as nuclear and chemical reactors. It is used in chemical process equipment applications and high-performance pharma-ceutical vessels.

Monel® 400
UNS N04400

Composition
63% Nickel, 28 - 34% Copper, 2% Manganese

Corrosion Resistance
Monel® has excellent corrosion resistance to salt water and steam at temperatures up to 1000° F.

Cost
Costs six to eight times more than stainless steel.

Availability
Monel® 400 is a special order, long lead-time material.

Performance
Monel® 400 is resistant to sulfuric and hydroflouric acids, with good weldability and moderate to high strength.

Applications
Due to the cost, Monel® 400 is only used in applications where other materials will corrode.

AL6XN®
UNS N08376

Composition
24% Nickel, 22% Chromium, 6.3% Molybdenum.

Corrosion Resistance
Good resistance to chloride stress-corrosion cracking and pitting. The nitrogen contents further resists pitting and give higher strength than typical 300 series stainless steels.

Cost
May be a cost effective alternative to Duplex in some applications

Availability
Readily available

Performance
AL6XN® has high strength and toughness, up to 50% stronger than stainless steel, ASME coverage up to 800° F.

Applications
Low PH applications in food, oil and gas industries, reverse osmosis, scrubbers, and distillation columns.

Alloy 20
UNS N08020

Composition
32-38% Nickel, 19-21% Chromium, 2-3% Molybdenum

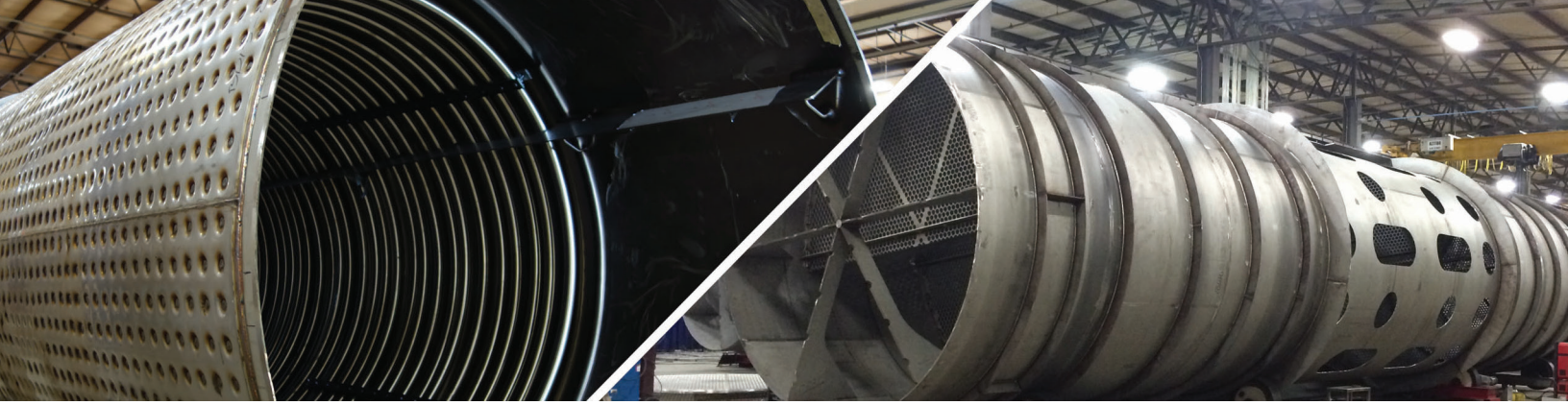
Corrosion Resistance
Exceptional corrosion resistance in chemical environments containing phosphoric acid, nitric acid, chlorides and sulfuric acid.

Cost
Less expensive to use in fabrication than Hastelloy® 276

Availability
Not as common as 300 series stainless, becoming more readily available

Performance
Maximum operating temperature of 986° F.

Applications
Used to manufacture pharma-ceuticals, food, explosives, chemical and petroleum refinement. It is also used in heat exchangers, mixing tanks, and heat resistance applications.



▲ *Hastelloy® fabricated vessel for chemical processing*

▲ *Duplex fabricated vessel for oil industry*

OVERVIEW of VESSEL FABRICATION STEELS

304 Steel / 304 L / 304 H

Stainless Steel 304 (UNS S30400) is the most versatile and widely used stainless material. The 304 L designation is used for heavy gauge applications for improved weldability. A 304 H variant has high carbon properties which makes the material suitable for high temperatures.

316 Steel / 316 L / 316 H / 316 Ti

Stainless Steel 316 (UNS 31600) is a chromium-nickel material containing molybdenum, which enhances corrosion resistance. The type 316L is often specified for welded applications because it is a low-carbon version that eliminates chromium carbide precipitation and improves the corrosion resistance in the as-welded condition. The type 316 H variant has high carbon properties which makes the material suitable for high temperatures. Type 316 Ti is another variation available that contains .5% Titanium, allowing higher temperature performance for more extended periods.

Duplex 2205 / 2207 / 2594

Duplex 2205 (UNS S32205) is a two-phase material characterized by high yield strength, double that of standard steel grades. It is a grade with an annealed structure that is equal parts austenite and ferrite. It demonstrates good fatigue strength and outstanding stress corrosion cracking in severe environments. Super Duplex 2594 (UNS S327500) is a variant of steel that provides very high tensile and yield strength ratings. It is resistant to stress corrosion cracking with excellent weldability. Duplex 2594 (UNS S31260) is a super austenitic stainless steel with high alloy content and higher corrosion resistance than other Duplex grades.

Hastelloy® C22 / C276

Hastelloy® is a trademark of Haynes International. Hastelloy® is a nickel metal alloy that provides increased corrosion resistance in moderate and severe corrosive environments. C276 (UNS N10276) grade is the most popular in Apache's project experience. C-22 (UNS N06022) is considered an upgrade from C-276 with better overall corrosion resistance.

Monel® 400

Monel® 400 is considered a pure alloy offering many advantages compared to other alloys. Nickel corrosion resistance of Monel 400 and copper increases its ductility and electrical conductivity.

AL6XN®

AL6XN® (UNS N08376) is a low carbon, high purity, nitrogen-bearing "super-austenitic" nickel-molybdenum alloy.

ALLOY 20

Alloy 20 (UNS N08020) is an austenitic nickel alloy design to offer high levels of resistance to sulfuric and nitric acids.

Apache has been producing complex tanks since 1975. Our engineers, technicians and fabricators are experts at working with stainless and high alloys and adept at high compliance protocols. Apache's tanks and vessels are found in fuel refineries, ethanol plants, chemical industries, food and beverage processing facilities, pharmaceutical and biotechnology companies, and in water treatment facilities.

Resources: NeoNickel Alloy Perfomance Guide, Apache Archives, Apache Tank Team and Supplier References

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