Stainless Steel and Miniature Flow Control Valves Guide

Stainless steel miniature flow control valves for demanding environments

Why stainless steel?

Stainless steel is a steel and so it is typically very strong. This gives it great pressure and temperature resistance. It is also a tougher, more durable metal than cast iron, ductile iron, brass or copper.

Stainless steel materials get their designation from the fact that they are very corrosion resistant. This plus their toughness and strength make stainless steels a useful material option for compact miniature flow control valves. This is despite being more difficult to shape and therefore more expensive.

Industrial stainless steel piping and processing equipment.

Read this guide on the web

Why metal valves if plastic ones are usually more corrosion resistant and more economical?

It's true, plastic valves are more corrosion resistant than metal valves in most applications. But metal valves are more durable and can resist both higher pressures and higher temperatures better than plastic valves.

Get more information about choosing between plastic, brass and stainless steel for valve bodies in our blog post: ***Miniature Ball Valves: Plastic, Brass or Stainless Steel?***

The basic rules of thumb for stainless steel chemical resistance:

- Resistant to most acids
- Resistant to most weak bases
- Selectively resistant to organic solvents

Resistance to organics and organic solvents varies among stainless steels and depends on the chemical, its concentration and the stainless steel alloy or recipe.

Some examples of why you need to know more about stainless steels used in miniature and compact flow control valves.

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BVSS Series - 2 Way Stainless Steel Ball Valves

These full port and standard port ball valves have a great working temperature and pressure range. The body of the valves are CF8M stainless steel, but internal and external components are made of both CF8M and 304 stainless steels.

- CF8M stainless steel body, end cap, ball and stem stainless steel
- 304 stainless steel gland nut, spring washer, lever and lever nut

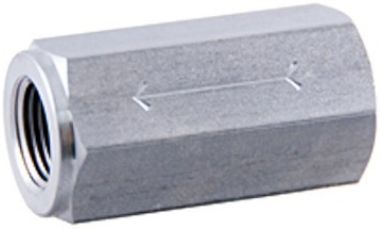
BVSS series two-way ball valve

CSP series 5000 psi stainless steel poppet check valve.

CSP Series - 5000 psi Check Valve – Poppet

These poppet check valves have a good working temperature and a great operating pressure range. The body and most of the components of these valves are 316 stainless steel but the retaining ring is 15-7 stainless steel.

- 316 stainless steel body, poppet retainer and spring
- 15-7 stainless steel retaining ring



CSP series poppet check valve

What's CF8M stainless steel? Why use both CF8M and 304 stainless steel in the same valve? Are CF8M and 304 equally corrosion resistant? What's 15-7 stainless steel? If 316 stainless steel is so corrosion resistant, why use one part made of 15-7 when all the other metal used in the valve is 316?

Read on to find the answers to these and other questions plus useful information and FAQs about the stainless steels most commonly used to make compact and miniature flow control valves.

More about steel and some of the whys of stainless steels

What's the difference between iron and steel?

Iron is a metal, an element, and it is pretty reactive. That is, it oxidizes or rusts easily. But steel is an iron-carbon alloy. It is much stronger than iron while still being fairly easy to work with and shape.

The amount of carbon in steel is the most important factor in determining its strength. The ratio of iron to carbon also affects a steel's ductility or workability. More carbon is stronger but harder to work while less carbon is easier to work but not so strong.

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What is ductility and workability and why does this matter?

Five axis machining.

Metal ductility is the ability of a metal to be shaped and stretched without breaking. Brittleness is the opposite of ductility. Typical metal working processes include roll forming, bending, cutting with a guillotine shear, drilling and stamping.

The workability of a metal is how easily it can be shaped without cracking when it is subjected to different metal working processes. If a metal has high ductility it is easier to work. Workability varies with the shaping process used and the metal's physical characteristics.

There are over 250 different stainless steel alloys

Steel is an alloy of iron and carbon. It also includes one or more additional elements, usually metals. These added ingredients give different steel types their particular chemical and physical properties such as corrosion resistance, strength, workability and so on.

Stainless steels get their name from the fact that they are very corrosion resistant. This corrosion resistance is provided by adding chromium. Other ingredients (elements) are added to stainless steels to balance the increased corrosion resistance with desirable physical traits.

Chromium gives a stainless steel its special advantage

Stainless steels generally contain at least 10.5% or more chromium by weight. But chromium content can range up to 30%. It provides stainless steel with its passivity, another way of saying its corrosion resistance.

Chromium crystals and a cubic centimeter cube.© Heinrich Pniok under GDFL

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What is meant by metal passivity?

Metal passivity is when an oxide film forms on the metal's surface. This film prevents any additional chemical corrosion of the metal. Adding chromium to stainless steels forms an extremely thin but uniform, continuous, tenacious and stable chromium-rich oxide film on the surface of the steel.

The most important differences between different stainless steel types are their workability relative to their corrosion resistance. It is important to remember that the more workable a metal is, the easier it is to form into useful shapes. A stainless steel that is easier to shape means cheaper parts.

Key elements added to stainless steel alloys or formulations that provide corrosion resistance

- Nickel
- Nitrogen
- Chromium
- Manganese
- Molybdenum

There is more detail about what how these added metals influence the characteristics of a stainless steel type further along in this post.

Some general information about stainless steel types

There are five families of stainless steel (see below) and every one of them gets most of their corrosion resistance from the chromium component of the alloy.

Why stainless steel metal valves if they are more expensive?

- Steel valves are especially strong. This allows them to be used in higher pressure applications than brass or plastic valves.
- Steel valves are durable. Stainless steel valves are especially tough because they are made of steel and because of their corrosion resistance.
- Steel valves can handle both high and very low temperatures. Steel valves are usually rated for a broader range of operating temperatures than brass or plastic valves.

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Corrosion resistance

Stainless steel chemical resistance to acids

As a rule of thumb, stainless steels tend to be resistant to acidic corrosion. This is not a hard and fast rule though. Exact resistance levels vary by the type of stainless steel, the concentration of the acid, the type of acid and its temperature. If there are mixtures of chemicals or their concentrations vary, testing is probably a good idea. In general, best practice is to obtain part samples and test them in real operating environments.

Stainless steel chemical resistance to bases

Stainless steels generally have a strong resistance to corrosion from weak bases, even in high concentrations and in high-temperature environments. Strong bases can cause cracking or etching. Be especially careful with chloride solutions such as sodium hypochlorite.

Stainless steel chemical resistance to organics, organic solvents and organic chemicals in general

The resistance of stainless steels to different organic chemicals varies by the chemical, its concentration and the chemistry of the steel alloy. In general, 300-series stainless steels are the best stainless steels at resisting corrosion from organics. Environmental conditions such as temperature and the availability of free oxygen have significant effects on a stainless steel's corrosion resistance to organics.

There are five stainless steel types or families

- Austenitic
- Ferritic
- Martensitic
- Duplex
- Precipitation hardening (PH)

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What are the key elements added to iron to make stainless steel alloys?

Chromium as a steel alloying element

As mentioned earlier, chromium is an alloying element added to steel to increase its resistance to oxidation. Chromium is the key ingredient in stainless steel formulas that makes them “stainless”.

Nickel as a steel alloying element

Nickel is added to stainless steels to increase their strength, ductility and toughness. It is the addition of nickel to stainless steel that makes it non-magnetic. It also improves any stainless steel’s resistance to strong acids.

Nickel chunk.

Nitrogen as a steel alloying element

Nitrogen increases a stainless steel’s resistance to pitting corrosion and corrosion between the grains or small crystals that make up the metal. In austenitic stainless steels, nitrogen increases the yield strength. Yield strength is the amount of force required to permanently distort or deform the metal.

Molybdenum as a steel alloying element

Molybdenum is added to stainless steels to increase corrosion resistance. It is especially effective at preventing pitting and crevice corrosion from environments where chlorides are found such as exposure to sea water or deicing salts. It also improves corrosion resistance to sulfuric, phosphoric and hydrochloric acids. An added benefit is that it improves the mechanical properties of stainless steels at high temperatures.

Molybdenum in the form of the mineral molybdenite.

Manganese is also used in some stainless steel alloys

Manganese improves a stainless steel’s hot working properties and increases its strength, toughness and hardenability.

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Electrolytically refined manganese chips and a cubic centimeter manganese cube.
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What is austenitic stainless steel?

Austenitic stainless steels are the most widely used corrosion resistant steel alloys. They are typically what is meant when the generic term "stainless steel" is used. These alloys provide toughness and corrosion resistance even at very low temperatures. Austenite stainless steels give up some ease of shaping in exchange for gaining greater durability and corrosion resistance. They generally cannot be hardened by heat treatment but work-hardening will make them stronger.

What is work hardening?

Metal is work hardened by changing its shape without the use of heat. This process is also known as plastic deformation. Forging is a common work hardening process.

Austenitic stainless steels are widely used to make valves and valve components

Austenitic stainless steels are the most widely used stainless steels for manufacturing valves. Austenitic steels are particularly useful because they are tough while remaining fairly ductile. A ductile metal is one that can be formed and worked without breaking.

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Why are austenitic stainless steels so popular for making miniature valves?

All austenitic stainless steels have very good corrosion resistance, strength and toughness.

Austenitic stainless steels are very corrosion resistant

Austenitic steels are the most corrosion resistant family of stainless steels.

Austenitic steels are the most corrosion resistant family of stainless steels. This added corrosion resistance is provided by the addition of molybdenum and copper. Molybdenum helps prevent pitting and crevice corrosion, especially where there is exposure to chlorides and sulfur. Copper provides greater corrosion resistance to sea water and sulfuric acid. Nitrogen also increases its overall corrosion resistance.

Austenitic steels are strong and durable

The austenitic family of stainless steel alloys have impressive mechanical properties. These include excellent strength and toughness. Austenitic stainless steels also maintain these mechanical properties in conditions ranging from sub-zero to elevated temperatures.

Austenitic steels have broad operating temperature ranges

Austenitic steels have excellent toughness, particularly at low sub-zero or cryogenic temperatures. Miniature valves made of austenitic stainless steels have very good normal operating temperature ranges that frequently ranging from well below zero up to 400°F (about 200°C).

Typical austenitic stainless steels used in valves

These are the most common austenitic stainless steel types or alloys used to make compact and miniature flow control valves and valve components:

- 303
- 304
- 316
- 316L
- CF8M
- 15-7

Typical valve components made of stainless steel

- Balls, poppets and pistons
- Retaining clips
- Springs

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About 303 stainless steel

- 17 to 19% Chromium (Cr)
- 8 to 10% Nickel (Ni)

This is the most machinable stainless steel in the austenitic family of stainless steels. The addition of sulfur provides the improved machinability. Unfortunately, this also reduces its corrosion resistance and slightly reduces its toughness. But, the corrosion resistance of 303 stainless steel is still good in mild environments. Its toughness also remains excellent, typical of all the austenitic stainless steels. 303 type stainless steel is typically used for stainless steel parts that require a lot of machining.

Get a copy of the ISM 303 Stainless Steel Chemical Compatibility guide.

About 304 stainless steel

- 17.5 to 19.5% Chromium (Cr)
- 8 to 10.5% Nickel (Ni)

This is the most versatile and the most widely used stainless steel. It has excellent corrosion resistance when exposed to corrosive liquids and gases. It does suffer from pitting and crevice corrosion when exposed to chlorides such as sea water or de-icing salts. 304 stainless steel has good machinability but it is not quite as easy to shape as the 303 type.

Get a copy of the ISM 304 Stainless Steel Chemical Compatibility guide.

303 vs 304 stainless steel

The 303 and 304 stainless steel alloys have very similar mixes of metal elements. 303 stainless steel is frequently called the free-machining grade of 304 stainless steel. This machinability comes from adding sulfur to its recipe. It is relatively easy to shape 303 using high-speed, automated machining techniques. The corrosion resistance of type 303 is lower than 304. 303 stainless steel it should not be used where it will be continuously exposed to salt water.

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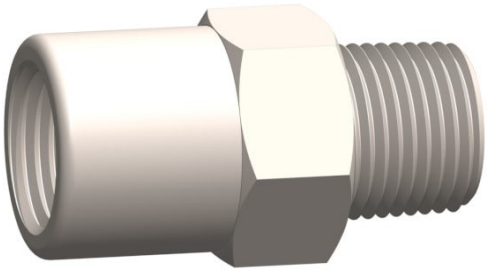
These check valve series are examples of stainless valves with bodies made of 303 stainless steel and internal assemblies or parts made of 304 stainless steel.

- **CHHB Series - NPT Check Valve**
- **COFB Series - Nipple Check Valve**
- **CSB Series - Female UNF Check Valve**



CHHB series NPT thread check valve

Using a 303 stainless steel makes small, intricate valve bodies easier and more economical to shape with high-speed automated machining. 304 stainless steels provide additional corrosion protection for the internal working parts of the valves.

About 316 stainless steel

- 16 to 18% Chromium (Cr)
- 10 to 14% Nickel (Ni)
- 2 to 3% Molybdenum (Mo)

316 stainless steel is in the austenitic family of stainless steels. Next to the 304 type, 316 stainless steel is the most commercially important stainless steel. 316 stainless steel has added molybdenum while 303 and 304 do not. Molybdenum together with nickel provide improved corrosion resistance, even in aggressive environments. The added molybdenum is especially useful for improving corrosion resistance to chlorides like sea water and de-icing salts.

Get a copy of the ISM 316 Stainless Steel Chemical Compatibility guide.

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A fairly typical high-quality stainless steel ball valve series using both 316 and 304 stainless steels:

BVSS Series - 2 Way Stainless Steel Ball Valves

BVSS series two-way ball valve

316 stainless steel for the BVSS valve body and internal parts

These surfaces will be in contact with the gas or liquid (the media) flowing through the valve. 316 provides excellent corrosion resistance to aggressive gases and chemicals.

304 stainless steel for the BVSS external parts

These surfaces will not be in continuous contact with potentially aggressive chemicals. 303 parts are cheaper and easier to make and have good corrosion resistance.

Here is another fairly typical high-quality stainless steel ball valve series. This one uses 316 stainless steel for the body, ends and ball. It is offered in three different O-ring seal materials to provide the broadest range of chemical compatibility and corrosion resistance:

- Buna-N (nitrile rubber, NBR)
- EPDM (ethylene propylene)
- Viton® (fluoroelastomer)

SSBV Series - 2 Way Stainless Steel Full Port Ball Valves

SSBV series two-way full port ball valve

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About 316L stainless steel

- 16 to 18.5% Chromium (Cr)
- 10 to 14% Nickel (Ni)
- 2 to 3% Molybdenum (Mo)

316L is the low-carbon version of 316 stainless steel. 316L is one of the best stainless steels for very high temperature, high corrosion applications. 316L is highly durable but it is also relatively easy to fabricate and shape. Like 316 stainless steel, the added molybdenum significantly increases its corrosion resistance.

Get a copy of the ISM 316L Stainless Steel Chemical Compatibility guide.

316 vs 316L stainless steel

The main difference between 316 and 316L stainless steel is the difference in carbon content. 316 stainless steel has a maximum carbon content of about 0.08%. 316L has a maximum carbon content of about 0.03%. 316L also has lower percentages of other elements such as sulfur, phosphorus and copper. The 316L stainless steel is more ductile than 316 when annealed. It is also significantly more corrosion resistant, especially after being welded.

About CF8M stainless steel

- 16 to 20% Chromium (Cr)
- 10 to 15% Nickel (Ni)
- 2 to 3% Molybdenum (Mo)

CF8M stainless steel is also called cast 316 stainless steel. It is slightly magnetic while 316 is nonmagnetic. CF8M is slightly magnetic because it is not entirely austenite with more iron in it, about 5 to 20 percent.

CF8M vs 316L stainless steel

CF8M is essentially a cast version of 316 stainless steel. 316 valves are shaped by forging. Like the differences between 316 and 316L stainless steel, the key difference between CF8M and 316L is a tradeoff between a slightly reduced corrosion resistance and the advantages of casting. It is cheaper and easier to cast stainless steel valve bodies with complex shape.

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About 15-7 stainless steel

- 14 to 16% Chromium (Cr)
- 6.5 to 7.75% Nickel (Ni)
- 2 to 3% Molybdenum (Mo)

15-7 stainless steels are semi-austenitic stainless steels. 15-7 stainless steel has used for its high strength and hardness plus its good corrosion resistance. It is fairly easily to shape when this is done correctly. This stainless steel is particularly useful for applications that require high strength at high temperatures. 15-7 stainless steel gets its name from its 15% chromium and 7% nickel content. 15-7 is also known as stainless steels grade 632.

What is semi-austenitic?

Semi-austenitic means that a stainless steel is hardened by a process called precipitation hardening. Precipitation hardened semi-austenitic stainless steels are very strong, tough and have good corrosion resistance. They are frequently used to make springs and retaining rings.

15-7 stainless steel vs 304 and 316 types

15-7 type stainless steel is much stronger with a much higher tensile strength than type 304 or 316 stainless steels. The tradeoff is that 15-7 is not quite as tough or durable.

What is precipitation hardening?

Precipitation hardening is also called age hardening or particle hardening. It is a complex process that produces some of the strongest stainless steels. It is called precipitation hardening because it adds particles or precipitates to the steel to increases its strength.

A simplified description of the precipitation hardening process

Precipitation hardening requires a high temperature. It also usually needs to be done in either a vacuum or in a space filled with a gas that keeps out oxygen and will not react with the metal. The process typically takes from one to four hours but sometimes longer. After the initial production of the precipitation hardened metal, there is also an aging process. Many times, this is cold aging where the metal is kept at temperatures below freezing for hours.

Needless to say, precipitation hardened stainless steels are more expensive than most other types of stainless steel.

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What is heat treatment?

Heat treatment or heat treating are metalworking processes used to change the physical properties of a metal. Heat treatment processes include annealing, case hardening, precipitation strengthening, tempering, normalizing and quenching. The main benefits of heat treating a metal are improving a metal's

- Strength
- Hardness
- Toughness
- Machinability
- Formability
- Ductility
- Elasticity

Keep these key takeaways in mind when buying a stainless steel miniature valve

Corrosion resistant does not mean invulnerable

Greater corrosion resistance does not mean invulnerable. You need to know the environment the valve will be installed in and what chemicals will be flowing the stainless steel part.

Keep in mind that mixtures of chemicals mean you cannot completely rely on published chemical compatibility reference information. Use chemical corrosion guides to make the best choices of valve materials for your application, get samples of the parts and test them in real conditions.

Get more information about material chemical compatibility and corrosion resistance in our article: How to Choose an In-line Filter – Chemical Compatibility

Stainless steel performs well in heat but internal parts of a valve, especially sealing surfaces, may not have the same operating temperature range as the stainless steel parts. Stainless steel miniature valves are strong but they are still rated for specific temperature and pressure ranges. This is because elastomers and engineered plastics are frequently used for seals and sealing surfaces.

Stainless steel valves will be more expensive

Stainless steels are noticeably more expensive than brass and plastic. Part of the reason for this is because stainless steels are so tough. It takes more effort and special tooling to shape them. The results in stainless steel valves having significantly higher prices than brass and plastic valves.

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Stainless steel valves are heavier

Does weight matter in your application? If so, remember that stainless steels are steel so they are heavy. Going with the right valve made of engineered plastic may give you the strength and temperature range you need without the added weight.

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