Valve Materials

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Overview:

We normally refer to a valve as a Bronze Valve or a Steel Valve. The reference is being made to the material of construction of the Shell. (There are valves made in plastic or PP as well, but this article addresses the materials of metallic valves only).

The main function of the parts like Body, Bonnet, and Cover is to withstand the pressure as well as to withstand the corrosive and abrasive effects of the fluid passing through the valve. The selection of these parts primarily depends on these parameters.

The shell bolting is normally protected from the fluid by gaskets & seals; hence strength and resistance to atmospheric conditions are the primary considerations in their selection.

Those parts of the valves inside the shell and in contact with the fluid are referred to as the Valve Trim. Trim parts vary depending on the type and design of the valve but typically they are the Stem, the flow control element and the body seating surfaces. These parts play a key role in performance & operation of the valve & hence apart from the adequate strength the resistance to corrosion & erosion from the fluid and wear resistance is of major importance.

In many cases the materials used to make the valve shell do not possess the required properties to be used as the trim material. This is the main reason that separates parts such as seat rings and back seat bushings are screwed, pressed or welded into shell parts rather than being provided as integral parts. Also the trim materials are generally more expensive than the shell materials. This is the reason, in large size valves the parts such as wedges & discs are of the same material as that of shell, but provided with an overlay of trim material on the important seating surfaces. In many cases the trim materials could differ in the same valve, especially for seating surfaces.

Gaskets and packing are those parts whose function is to prevent fluid leakage. Gaskets form a static seal between the joints, such as shell & bonnet / cover. They must have the strength to contain fluid pressure, be soft enough to deform and make a tight seal, be as corrosion resistant as is the shell material, be able to withstand high service temperatures and be able to maintain their properties over a period of time.

Packing forms a seal between the shell and the valve stem / shaft. Under normal conditions when the valve is not being operated the seal is static. However during the valve operation packing must also function dynamically. It must be compressible enough to deform and seal tightly against the sides of the packing chamber (stuffing box) and the stem / shaft. Packing must be corrosion resistant and capable of withstanding the temperature specified. It should also have low coefficient of friction or contain a lubricant to permit easy stem or shaft movement.

The buyer normally specifies the Shell and the Trim material. The manufacturer decides on the Bolting, Gaskets and packing materials based on their design and application. But by and large, the materials of construction have been standardized and most of the valve manufacturers offer the same choice of materials.

This article focuses mainly on the commonly used Shell & metallic Trim materials.

SHELL MATERIALS:

Shell material is classified in to three broad categories. Cast Iron, Steel & Bronze (Non ferrous). Valves are also made from special steels / exotic materials such as Duplex steel, Monel, Hastelloys etc. These special steels are expensive & hence the valves in such materials are manufactured only against specific orders to suit a particular application / service condition.

Cast Iron & Bronze shell parts are always castings; where as Steel shell parts can be cast, forged or wrought (plate / bar) form. Steel valves in sizes less than 2" are usually made of forgings; those larger than 2" are usually castings.

1. CAST IRON: Cast Iron is an alloy of Iron, (carbon between 2% to 6.67%), Silicon & Manganese. Cast Iron is less susceptible to atmospheric corrosion than is Carbon Steel. The following grades are usually used to produce valves.

- Gray Iron, ASTM A 126, Class B or IS210 FG260: This basic cast Iron is easily cast & machined. It is widely used for valves used in Water, Steam, Oil, Non Corrosive Gas & some dilute acid services at temperatures from 0º F to 450º F.
- Nickel Gray Iron (ASTM A126 Class B) : The addition of 3% Nickel to Gray Iron improves its grain structure & provides greater corrosion and wear resistance. It is widely used in Petroleum & Paper Industries.
- Ni-Resist (ASTM A436 Type 2) : This Austenitic Gray Iron, highly alloyed (20% Nickel) is widely used as a shell material for valves used in corrosive environments handling caustics, alkalis, ammonia solutions, food products and similar services. It is nor recommended for Steam service.
- Ductile Iron: Known as Nodular Iron, is unique because the addition of magnesium causes its graphite to be in nodular or spheroidal form rather than flake form as is found in other cast irons. As a result, the strength is similar to that of carbon steel and a substantial increase in ductility and toughness over that of gray iron are obtained. Its resistance to atmospheric condition is better than gray iron and superior to carbon steel in many cases. It can be used at temperatures up to – 20º F.

2. STEEL: Steels are alloys of iron, carbon (less than 2%) and elements such as manganese and silicon in small amounts. Other elements such as molybdenum, chromium & nickel are added to impart desired properties of strength, hardening and corrosion resistance. The following grades are usually used to produce valves.

- ASTM A 216 Grade WCB (Castings) / ASTM A105 (Forgings) / ASTM A517Grade 70 (Plate) Carbon Steel,: This is the basic steel used for valve shell parts. It's strength and toughness ensure high resistance to shock, vibration, piping strains & fire and freezing hazards. It is suitable for saturated or superheated steam, hot or cold water, hot & cold non-corrosive oils, gases, air and other fluids. Temperature limitations are from – 20º F minimum to 800º F maximum for continuous service.
- ASTM A352 Grade LCB (Castings) and ASTM A350 Grade LF2 (Forgings) Carbon Steel for Low Temperature Service: This steel has the same composition and applications as plain carbon steel, but it is heat- treated to produce similar physical properties at low temperatures. It is recommended to service down to – 50º F, but not above 650º F.
- ASTM A217 Grade WC6 (Castings) and ASTM A182 Grade F11 (Forgings). 1.25% Chromium – 0.5% Molybdenum Alloy Steel: The addition of Chromium & Molybdenum to carbon steel improves high temperature strength and resistance to graphitisation and creep. It is recommended for valves operating at temperatures up to 1000º F.
- ASTM A217 Grade WC9 (Castings) and ASTM A182 Grade F22 (Forgings). 2.25% Chromium – 1% Molybdenum Alloy Steel: This alloy has higher resistance to graphitasation, creep & higher strength than Grade WC6 castings. It is also recommended for valves operating at temperatures up to 1000º F. This is weldable but

required pre-heating and heat treatment after welding.

- ASTM A217 Grade C5 / ASTM A 182 Grade F5 (5% Chromium Alloy Steel) & ASTM A217 Grade C12 / ASTM A182 Grade F9 (9% Chromium Alloy Steel): These steel castings have increased resistance to corrosion, erosion & scaling. It is particularly recommended for oil refinery service due to its corrosion resistance properties and ability to withstand temperatures up to 1050º F.
- ASTM A351 Grade CF8 (Castings) and ASTM A182 F304 (Forgings). 18-8 Austenitic Stainless Steel: This 18% Chromium – 8 % Nickel Stainless Steel is suitable for oxidizing & very corrosive fluids. It is also recommended for extremely corrosive oil & liquid oxygen service and it is particularly suited for nitric acid service. It is frequently used above 1000º F and below – 150º F. It is weldable without heat treatment.
- ASTM A351 Grade CF8M (Castings) and ASTM A182 F316 (Forgings). 18-8-3M Austenitic Stainless Steel: The addition of 3% Molybdenum to 18-8 stainless steel results in improved resistance to corrosion and high and low temperatures for oil, dilute hydrochloric acid & other acids, brine & other process fluids. It is weldable.
- ASTM A351 Grade CN-7M (Castings) – Alloy20. This 20% Chromium, 29% Nickel alloy has excellent resistance to sulfuric acid over a wide range of concentrations. It also has good resistance to dilute hydrochloric acid and it is used extensively in manufacture of high-octane, gasoline, solvents & other process fluids.

3. Bronze: Bronze is a copper alloy, with tin as the primary alloying element. Lead & Zinc are also added in varying proportions to produce the desired properties. ASTM B61 & ASTM B62, are the grades normally used to make shell castings of Bronze valves. The valves are used in air, water, steam, oil & many solvents up to 450º F.

TRIM MATERIALS:

Some generallisations can be made about Trim materials. Bronze valves generally have Brass or Bronze trim. Cast Iron valves have mostly bronze or iron trim. Carbon & alloed steel valves are available in a wide range of trim materials, including bronze and stainless steel. The trim material for stainless steel valves is generally the same as the shell material.

Most manufacturers of Cast Steel gate, globe, and check valves offer different combinations of metal trim materials. These are shown in the table.

* From API standard, Table 3

** Solid or facing

Trim*	Wedge/Disc	**Seat(s)	Stem	Application
1	CR 13	CR 13	CR 13	For Oil & Oil vapor,air,water,steam at temperatures to 1000º F.
5	Hardfaced	Hardfaced	CR 13	Suitable for high pressure steam and water up to 1200º F
8	Cr 13	Hardfaced	CR 13	For Oil & Oil vapor,air,water,steam at temperatures to 1000º F.
9	Monel	Monle	Monel	For handling Alkalies,sea water, brine, organic substances
10	18-8-3M	18-8-3M	18-8-3M	For corrosive oil service & for acetic, hydrochloric, phosphoric acids up to 850º F.
12	18-8-3M	Hardfaced	18-8-3M	
13	Alloy 20	Alloy 20	Alloy 20	For Concentration of sulfuric acid and dilute hydrochloric acid
N/A	Bronze	Bronze	Bronze	For slat water and fresh water up to 450º F

Trim Material	Application
ASTM B16 / Commercial brass	Used for Stems in cast iron & cast steel valves, & balls & stems for Bronze Ball Valves.
ASTM B61 / Cast Steam Bronze	Used for wedges, discs and seat rings in ductile iron valves
ASTM B62 / Cast Composition Bronze	Used for discs and seat rings in cast iron & cast steel valves
ASTM B148 / Aluminum Bronze	Suitable for medium-corrosive service & is used for discs in ductile iron & steel butterfly valves
ASTM B371 / Wrought Cu-Si Bronze	Standard bronze valve stems. Bears good corrosion resistance, high strength
ASTM B584 / Cast Cu-Ni Bronze	Used in seating surfaces in bronze valves
ASTM A108 Grade 1018 / Cold drawn Steel Bar	Stems in all-iron valves. It is chemically treated or plated to inhibit rust.
ASTM A217 Grade CA15 / ASTM A182 Grade F6a / ASTM A276 Type 410	Most widely used trim material for stems, wedges & body seats on steel gate, globe, check valves stems on ductile iron, steel butterfly valves, plug valves
ASTM A351 Grade CF8 / ASTM A182	Used for stems, discs, wedges & body seats on steel

Grade F304 / ASTM A276 Type 304	gate,globe,check valves, discs on steel butterfly valves and stems on plug valves
ASTM A351 Grade CF8M / ASTM A182 Grade F316 / ASTM A276 Type 316	Used for stems, discs, wedges & body seats on steel gate,globe,check valves, discs, shafts & seating surfaces on butterfly valves, balls, stems & seat rings on ball valves, and all trim parts on austenitic gray iron valves
ASTM A494 Grade M-25S / Monel	Used for stems, wedges, discs & body seating surfaces in steel gate,globe,check valves, disc and shaft in butterfly valves, balls & shafts in ball valves. Monel has excellent resistance to corrosion from many acids, alkalies caustic soda,organic substances,salt solutions & brine Suitable for hydrofluric acid and chlorine serivce
ASTM A494 Grade CW-12MW / Hastelloy C	Used in severe service conditions involving acids at high temperatures. It is resistant to strong oxidizers & has high temperature strength. Used for stems, wedges, discs and body seats in steel gate,globe,check valves
CoCr-A Hardfacing	This cobalt based alloy includes trademarked materials such as Stellite 6. It maintains its wear resistance, corrosion resistance & hardness under high temperature, high pressure conditions. It is used as welded overlay to form seating surfaces on gate, globe & check valves

The other trim materials and their applications are mentioned below.

BOLTING:

The bolting material is should be compatible with the other shell materials & to satisfy valve standards. The following are the typical bolting materials used on valves,

- Commercial Brass: used to make nuts for bronze valves
- Carbon Steel Bolts & Studs: ASTM A307 Grade A is commonly used in bronze valves Grade B is used on Cast Iron Valves
- Carbon & Alloy Steel Nuts: ASTM A563 Grade A. These nuts are used with A307 bolts & studs on cast iron & steel valves.
- ASTM A193 Grade B7: Alloy and stainless steel bolting materials for high temperature service up to 1000º F is a standard material for bolts and studs used on Steel Valves.
- ASTM A194 Grade 2H: Carbon and alloy steel nuts for high pressure and temperature service, is a standard grade nut for use with B7 Studs and Bolts.

GASKETS AND PACKINGS

Gaskets:

The common types of gaskets used in valve construction are flat, spiral-wound & ring-joint gaskets. Flat gaskets are used on low-pressure valves and are made of either non-metallic material or metal. Spiral-wound and ring-joint gaskets are used on medium- and high-pressure valves. Spiral-wound gaskets are composed of alternate piles of preformed metal bands and non-metallic filler; ring-joint rings are metal.

Non-metallic gaskets are cut from sheets of material that can be classified in 3 categories,

- Compressed sheets comprised of a mixture of fibers, fillers and an elastomer binder. In recognition

with the health hazards associated with asbestos it is not used as the fiber anymore.

- Homogeneous sheets of Teflon. Teflon gaskets have low service temperature, high-corrosion applications.
- Laminated sheets of flexible graphite foil made from natural flake graphite. Metal reinforcing inserts are sometimes included for added strength. These gaskets are highly temperature and corrosion resistant.

Metal gaskets can have smooth or corrugated surfaces. These gaskets are commonly made of iron or soft steel. Sometimes stainless steel is also used.

A wide range of metal and filler combinations is available in spiral-wound gaskets to match corrosion resistance and sealing requirements.

Packings:

The basic packing materials and construction commonly used for valve stem and shaft packing are the following:

- Braided: As Asbestos is no longer used, today carbon fiber and synthetic yarns are used almost exclusively. Inconel wire is usually twisted with or inserted into the yarns for added strength. Flake graphite or molybdenum disulfide is used as lubricants and sacrificial metals such as zinc are added to inhibit corrosion.
- Molded plastic: Formed rings of solid plastic, typically TFE are used in low temperature, high corrosion applications.
- Die-formed, flexible graphite. Flexible graphite foil is slit into ribbons and corrugated. The ribbons are then wound in dies and compressed into dense rings. A suitable agent is included to inhibit corrosion. As with molded plastic rings, these rings can be formed in to different cross-section shapes. When used with braided top and bottom rings that act as wipers and limit extrusion, these rings are very effective packing sets for use against gas and vapor leaks.