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Engine Poppet Valve Information Report

**SAE Information Report
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Ø ENGINE POPPET VALVE INFORMATION REPORT

1. INTRODUCTION:

Poppet valves control combustion chamber induction and exhaust gas flow in reciprocating combustion engines. Poppet valves are manufactured from iron, nickel, titanium, and cobalt based metallic alloys - often welded together in various combinations.

Martensitic and austenitic steels are used for intake valves. Specially designed high temperature martensitic alloys, austenitic alloys, and superalloys are used for exhaust valves. Titanium alloys have been used for both intake and exhaust valves in some limited production, high performance applications. Special iron, nickel, and cobalt based alloys are welded to many of the valve head alloys to improve seat face wear and corrosion resistance.

2. PURPOSE AND SCOPE:

This specification supplies engineers and designers with:

- 1) Poppet valve nomenclature
- 2) Poppet valve alloy designations
- 3) Chemical compositions of poppet valve alloys
- 4) A guide to alloy metallurgy and heat treatments
- 5) General information on properties of valve alloys
- 6) A guide to the applications of alloys
- 7) A description of valve design and construction, and their relation to valve alloy selection
- 8) Valve gear design considerations that affect valves

3. VALVE NOMENCLATURE:

Valve nomenclature and constructions are illustrated in Figs. 1 - 5.

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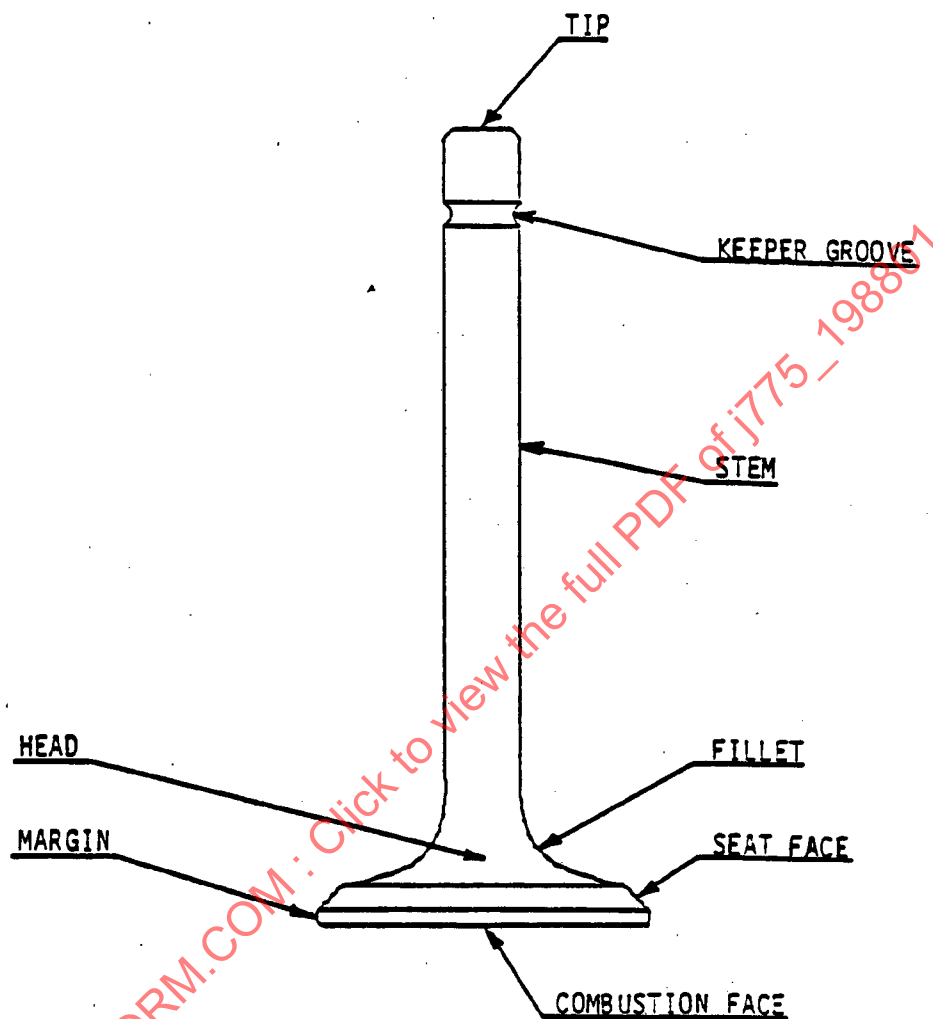


FIGURE 1 - One-Piece Construction

The majority of intake valves for all applications are one-piece construction which also has significant usage in spark ignition engine exhaust valves.

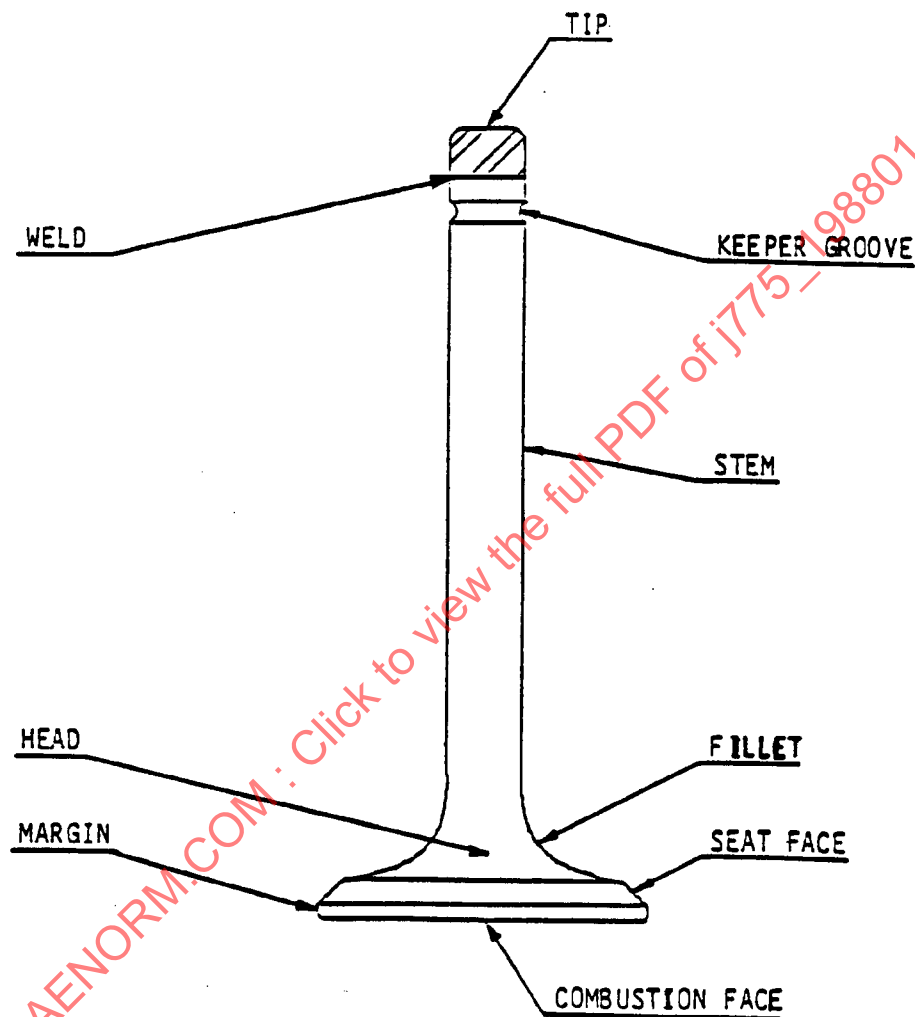


FIGURE 2 - Welded Tip Construction

Welded tip construction has significant usage in spark and compression ignition engine exhaust valves.

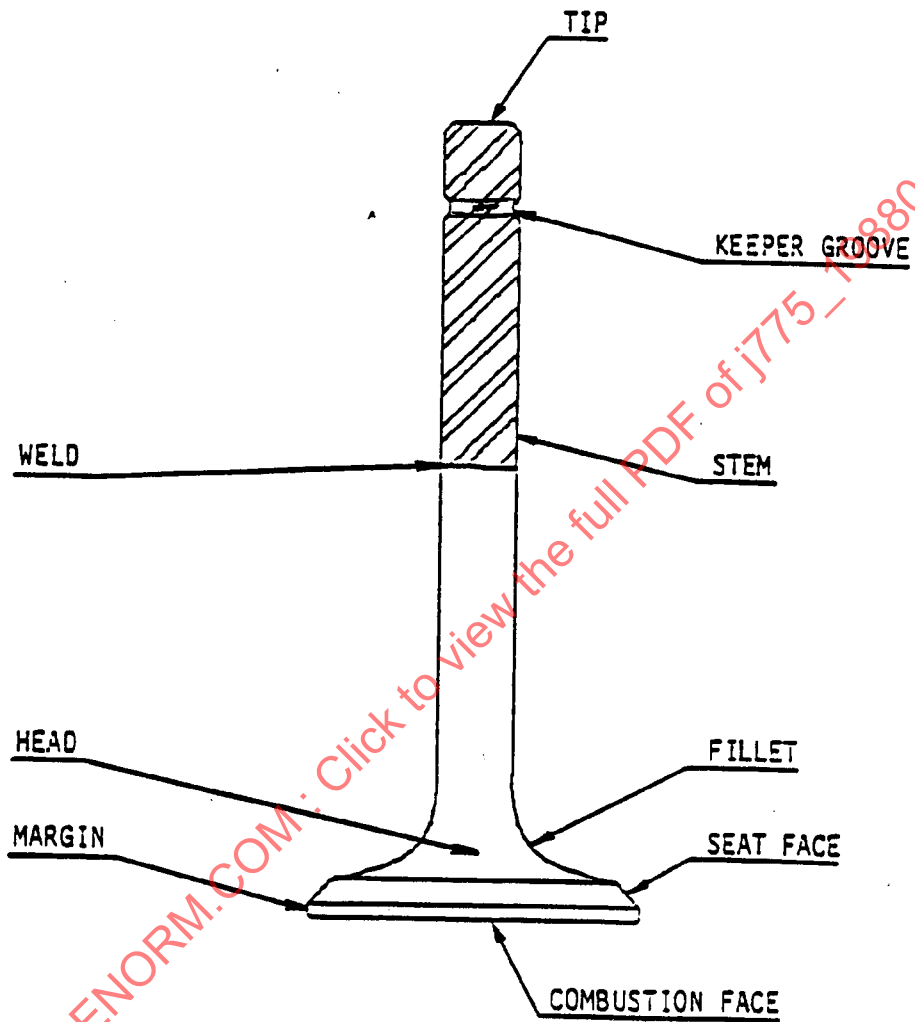


FIGURE 3 - Two-Piece Construction

Two-piece construction has significant usage in spark and compression ignition engine exhaust valves.

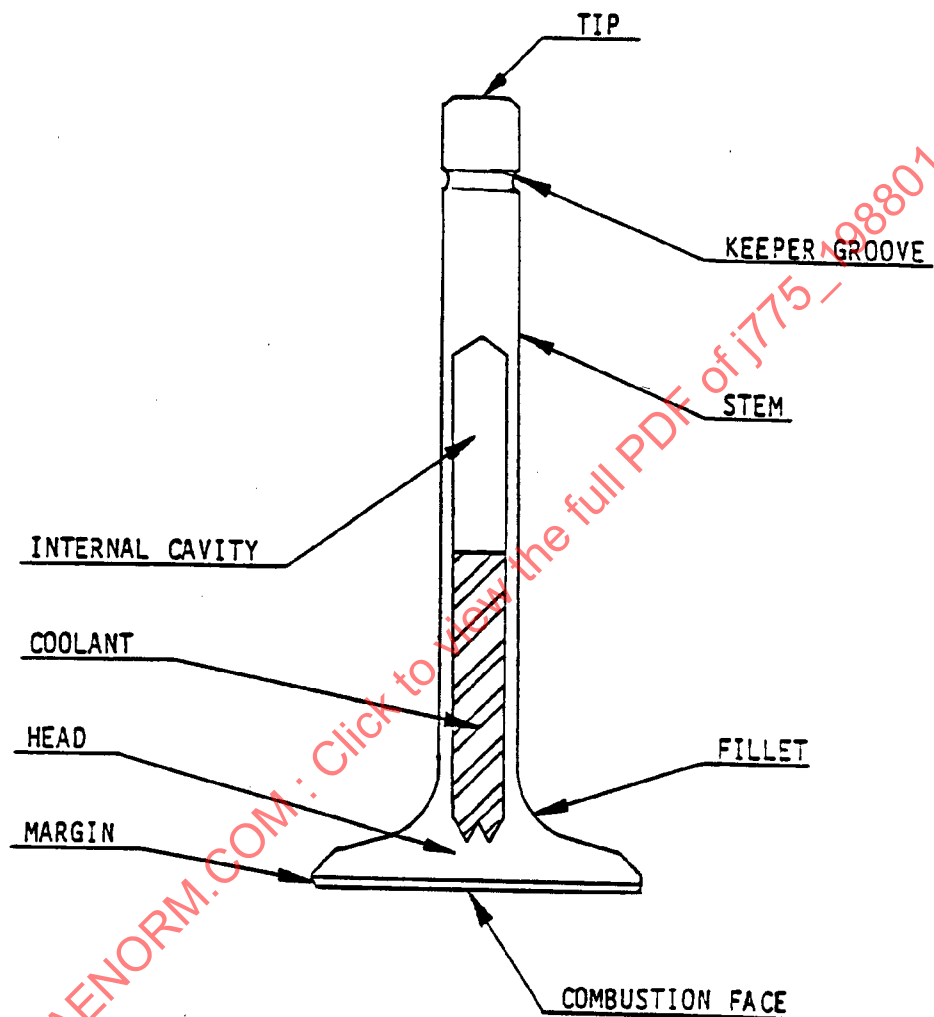


FIGURE 4 - Internally-Cooled Construction

Internally-cooled construction is used in extreme duty truck, high performance, and aircraft spark ignition engine exhaust valves.

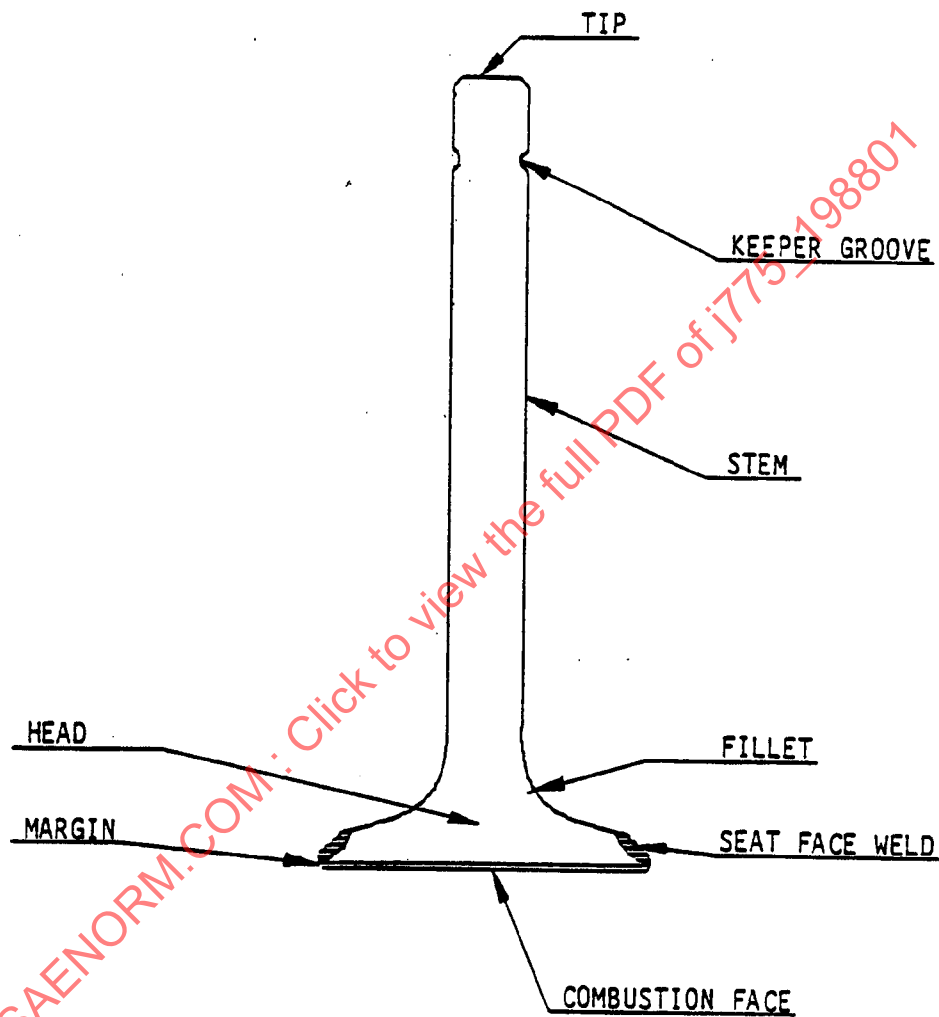


FIGURE 5 - Welded Seat Face Construction

Welded seat face construction predominates in compression ignition engine exhaust valves and has some usage in other valves. It supplements other types of valve construction.

4. VALVE ALLOY DESIGNATION:

- 4.1 UNS Designations: SAE, in conjunction with American Society of Testing and Materials (ASTM), has adopted the Unified Numbering System (UNS) for the identification of all metallic alloys. Table 1 uses the UNS identification codes for valve alloys. These UNS numbers supersede the previous SAE functional numbering system, which is still included for reference purposes.

Each UNS designation is a five digit identification number preceded by a type identification prefix letter. Valve alloys have six identification prefixes:

- G - General purpose carbon and low alloy structural steels
- H - Controlled hardenability carbon and low alloy steels
- K - Special purpose iron based alloys
- N - Nickel based alloys
- R - Cobalt, titanium and other refractory alloys
- S - Stainless steels, heat resistant steels, corrosion resistant steels, and iron based superalloys

The five digit identification number often incorporates the most popular previous designation for the alloy. The UNS designations are controlled by individual SAE and ASTM committees which work in concert.

- 4.2 Obsolete SAE Functional Designations: The former SAE numbering system was based on the type of valve for which the material was commonly used. Numbers were assigned on the following bases:

- 1) Letter Prefix: Intake valves may be made of carbon, low alloy, or heat and corrosion resistant high-alloy steels. The prefix NV designated carbon and low alloy intake valve steels. HNV designated high alloy intake valve steels.

Exhaust valves may be made of hardenable martensitic steels, austenitic steels, or superalloys. Alloys used for exhaust valves may be iron, nickel, or cobalt based alloys. The prefix letters EV designated austenitic exhaust valve steels. The letters HEV were used for high strength alloys in severe spark and compression ignition engine service.

The prefix VF designated high alloy welded overlays used at critical points of wear or corrosion.

The prefix X designated experimental and limited usage alloys preceding a conventional prefix, such as XEV.

- 2) Number Suffix: A number was arbitrarily assigned, based on the order in which the alloy was codified.

- 4.3 Other Designations: Table 2 lists other important national and international valve alloys, together with their specific chemistries. The International Standards Organization (ISO) designations and compositions are expected to preempt individual national standards in the future.

5. VALVE ALLOY CHEMICAL COMPOSITIONS:

- 5.1 General: There are many overlapping and conflicting specifications for the chemical compositions of valve alloys. This specification adopts the ISO chemical compositions from their Regulation 683/XV. Unfortunately, a number of alloys in common use are not listed in this regulation, so lowest common-denominator compositions, conforming with most specifications in common usage, were developed.
- 5.2 UNS (SAE) Compositions: The UNS (SAE) standard compositions for valve alloys are listed in Table 1.
- 5.3 Other Compositions: The compositions of other nations' valve alloys are listed in Table 2.

6. VALVE ALLOY METALLURGY AND HEAT TREATMENT:

- 6.1 General: Valve performance is a cross product of alloy composition and heat treatment. Alloy selection depends upon stresses, corrosive agents, and temperatures encountered in service, as well as the economic and durability objectives. Heat treatments used to improve the mechanical properties of valves depend upon the specific alloy, economics, and the level of properties desired. They can be general or selective, and it is not uncommon for a single valve to be subjected to two or more heat treatments in different regions.
- 6.2 Martensitic Alloys: Plain carbon, low alloy, and high alloy martensitic steels are primarily used for intake valves. Extreme duty martensitic steels generally have the highest carbon and alloy content to resist wear and seat face indentation by deposits, and to provide increased strength. Elements such as chromium and silicon are added when increased oxidation or corrosion resistance is needed. Manganese and nickel are added as strengthening agents. Occasionally, refractory elements, such as molybdenum, tungsten, and vanadium are used to enhance certain elevated temperature properties.

Martensitic valves are most often quench-hardened and tempered to hardnesses within the 25 - 45 Rockwell 'C' scale range. This is a compromise among good strength, adequate ductility, impact performance, and wear resistance along the stem. In some less demanding applications, martensitic valves can be used in the annealed condition.

Tips and seats are often selectively hardened to create high hardness and wear resistant surfaces. These surfaces are selectively hardened to resist wear, generally to the greatest hardness practical for the alloy. Tip hardening may extend beyond the keeper groove to improve the fatigue strength of this region.

- 6.3 Austenitic Alloys: Austenitic alloys have a face-centered cubic crystal structure which is termed austenite. The elements that stabilize the austenitic structure are carbon, manganese, nickel, and nitrogen. Chromium, silicon, and, sometimes, aluminum are added for oxidation or corrosion resistance. Refractory elements such as molybdenum, niobium, tantalum, tungsten, and vanadium may be added for high temperature strength. These alloys are termed steels when iron based. The cobalt and nickel based austenitic materials are termed superalloys. Iron based austenitic steels are hardened by carbonitride precipitation. Nickel based superalloys are hardened by precipitation of aluminum, nickel, niobium, tantalum, and titanium in the form of intermetallic compounds. They may be used in either wrought or cast form; although cast valves are diminishing in commercial importance.

Austenitic valve alloys may be as simple in composition as 18 - 8 stainless steels, or as complicated as gas turbine alloys. The selection is strongly influenced by economic considerations, as well as the mechanical, physical, and chemical attributes required to satisfy specific engine requirements.

Mechanical properties are improved in austenitic valve alloys by precipitation hardening, rather than the martensitic transformation hardening of low alloy steels. The most common valve heat treatments are:

- 1) High temperature forging followed by aging heat treatment(s).
- 2) High temperature forging followed by a solution treatment and then aging heat treatment(s).

In less demanding applications, austenitic engine valves are frequently used in the forged and aged condition. More severe service generally requires solution treatment followed by one or more aging treatments. These operations produce hardnesses in the 20 - 40 Rockwell 'C' scale range; hardnesses that depend upon the capability of the individual alloy. These alloys develop fatigue, creep, wear, and seat face indentation resistance from the heat treatments.

- 6.4 Titanium Alloys: Titanium alloys can be divided into three categories, alpha, alpha-beta, and beta alloys. Alpha alloys have a close-packed hexagonal structure, beta alloys have a body-centered, cubic-structure, and alpha-beta alloys have mixtures of the two different structures. The alloying elements that stabilize the alpha structure include oxygen, nitrogen, aluminum, and carbon. Alloying elements that stabilize the beta structure include vanadium and molybdenum. Zirconium and tin have minor effects upon phase stability, but are widely used as solution strengtheners in both alpha and beta alloys.

Most titanium intake valves are made from alpha-beta alloys which have superior low temperature strength. Exhaust valves are generally manufactured from alpha or near alpha alloys because they have better high temperature creep properties. Beta alloys have not been used in any engine valve applications of consequence.

Titanium alloy heat treatment for engine valve applications is less established than the heat treatments for higher volume production alloys. Most titanium alloys used in engine valves are precipitation hardenable and receive some type of solution treatment and aging after forming.

6.4 Titanium Alloys: (Continued)

It is important to note that the development of titanium alloy engine valves has been primarily in high performance applications where extended durability is not a primary concern. Heat treatment procedures and precision are believed to be critical parameters in long term titanium valve durability.

6.5 Seat Facing Alloys: Seat facing alloys are composed of hard precipitates in cobalt, nickel, or iron based austenitic matrices. The hard precipitates are generally chromium, molybdenum, tungsten, or vanadium carbides. Some compositions use intermetallic compounds as the hard precipitates. Chromium is usually added to the matrix to increase corrosion resistance. Silicon additions provide the fluidity necessary for welding the facing to the valve seat.

Seat facing alloys derive their wear resistance from the volume fraction of precipitates, which possess great hot hardness and compressive strength. A significant proportion of the adhesive wear resistance in these seat facing alloys, as well as other high chromium alloys, is derived from the tenacious chromium oxide layer formed on the wear surface by oxidation during service. When extremely severe conditions of corrosion are encountered, such as those which occur when sulfur-containing fuels are used, cobalt or iron based hardfacing alloys may be required to assure valve seat durability.

Selection of a particular seat facing alloy usually depends upon temperatures, stresses, and corrosents encountered in service. Manufacturing considerations may preclude some seat facing alloy/valve head alloy combinations.

7. VALVE ALLOY PHYSICAL AND MECHANICAL PROPERTIES:

7.1 General: No single property can define the varying conditions encountered in different internal combustion engines. Spark and compression ignition engines place different demands on engine valves, so the properties of interest vary.

Common causes of valve failures include:

1) Adhesive or Abrasive Wear

- of the stem surface
- of the seat surface
- of the tip surface

2) General or Localized Corrosion

- primarily at elevated temperatures
- often combined with fatigue

3) Fatigue

- head radial cracking by thermal fatigue
- head chordal cracking by mechanical fatigue
- fillet transverse cracking by mechanical fatigue
- keeper groove transverse cracking by mechanical fatigue
- often assisted by corrosion

7.2 Wear Properties: The wear resistance of valve materials cannot be adequately assessed by a single type of wear or mechanical property test because of the different modes of wear encountered at different locations on the valve. Often a secondary mode of wear can be initiated by the wear particles generated by the primary wear mode. Valve wear service must be considered individually at each of these locations: valve tip, stem, and seat.

- 1) Valve Tip: Against rocker arm type valve gear, valve tips are subjected to combined sliding and rolling contact with the rocker arm surface, potentially causing adhesive wear.
- 2) Valve Stem: Valve stems are subjected to a normal amount of sliding wear, which is not severe unless aggravated by inadequate lubrication or applied transverse loads. Transverse loads are often due to rocker arm geometry or thermal distortion of the valve seat.
- 3) Valve Seat: The valve seat-cylinder head seat contact is characterized by high normal stresses and severe sliding conditions, generally at high temperatures and in a corrosive environment. The high combustion pressures in heavy-duty compression-ignition engines impose high shear stresses across the contact interface which damage the seat face surfaces by sliding.

Valve wear performance is most often determined by evaluating valves run in durability test engines, but some laboratory tests are also used to rate the relative performance of alloys:

- 1) Pin on disc tests
- 2) Crossed cylinder wear tests
- 3) Thrust washer tests
- 4) Cylinder - vee block tests
- 5) Functional tests of components

At the present time, there is little experience to suggest that the data generated by these tests can be used to design an engine valve from first principles, but test data are invaluable in improving the wear performance of existing valve designs.

7.3 Corrosion Properties: Because of the variety of corrosive environments, there is no industry standard laboratory corrosion test. Some of the tests used to rate the corrosion resistance of valve alloys are:

- 1) Crucible immersion tests with various corrodents
- 2) Engine tests with a hole drilled through the head of the valve
- 3) Air oxidation tests run at high temperatures to shorten testing time
- 4) Sulfidation tests using gas atmospheres or immersion

The corrosion of valves is accelerated by their temperature and environment. Corrosion occurs through four mechanisms:

- 1) Oxidation
- 2) Attack by various metal oxides and salts
- 3) Attack by combustion products
- 4) Attack by fuel and lubricant additives or contaminants

Valve manufacturers and valve steel suppliers can generally supply representative corrosion resistance data.

7.4 Fatigue Properties: Fatigue data and corrosion-accelerated fatigue data are limited because of the lengthy testing programs required to generate meaningful data. The situation is improving, and more data are being gathered by valve and steel manufacturers. In lieu of these data, estimates of fatigue resistance are usually established on the basis of elevated temperature tensile, creep, and stress rupture performances.

The tensile properties of finished valves are dependent upon processing and heat treatment during manufacture. Typical tensile data for individual alloys are provided in Table 3. Because these data are of unknown origin and its accuracy cannot be presumed, it should be used only as a guideline. Valve manufacturers can generally supply expected mechanical properties in different regions of a valve, once a design envelope is established.

7.5 Physical Properties: The physical properties of various valve steels and alloys are listed in Table 4. These data are of unknown origin and their accuracy cannot be presumed. The data should be used only as a guideline.

8. VALVE ALLOY APPLICATION:

- 8.1 General: Alloys are selected for the body of the valve after considering the required mechanical and physical properties. Final selection and validation are usually decided based on the outcome of engine tests. It is well worth noting that there are many thermodynamic adjustments that can be made to an engine system which dramatically change the operating environment of the valves. The cost penalties of the more sophisticated valve alloys which may be required must be considered when analyzing the benefits of thermodynamic cycle improvements.

The severity of valve duty is determined by the operating environment in which the valve functions. The preeminent environmental factors are temperature, imposed stress, and chemical activity. Poppet valve operating temperature is generally a function of combustion process efficiency and engine cooling system effectiveness. Peak engine firing pressures and the valve seating velocities determine the stresses of most concern in a valve. The combustion gases which flow past the exhaust valve can be quite active chemically and generally dictate the use of corrosion resistant alloys.

- 8.2 Intake Valves: Intake valves require wear resistance and strength sufficient to resist fatigue and creep. Intake valves for light duty service are generally manufactured from carbon or low alloy steels. Heavy duty service intake valves are typically made from highly alloyed martensitic or austenitic steels. Titanium alloys are used in selected high speed spark ignition engine valves where valve train mass reduction is a prime design criterion.

Maximum intake valve temperatures are typically less than 425°C (800°F) in light duty spark ignition engines and 500°C (930°F) in heavy duty compression ignition engines. Plain carbon steels are used for the lowest temperature intake valve applications. Low alloy martensitic steels, high alloy martensitic steels, and austenitic steels are used progressively as intake valve temperatures and peak firing pressures increase.

Spark ignition engine intake valve seats that operate at moderate temperatures achieve adequate adhesive wear durability by using low alloy martensitic steels hardened to 35 Rockwell "C" scale or harder. Higher temperature spark ignition engine valves generally use hardened high carbon, high chromium alloys. In the most demanding applications, intake valve seats are hardfaced with a seat facing alloy.

- 8.3 Exhaust Valves: Principal exhaust valve requirements are resistance to seat face burning (commonly referred to as guttering), resistance to wear, fatigue strength to resist bending loads, and creep strength sufficient to prevent head doming (commonly referred to as tuliping). Exhaust valves are typically made from austenitic steels or superalloys. Titanium alloys are also used in spark ignition engine exhaust valves when mass reduction is a paramount consideration.

Austenitic exhaust valve operating temperatures are typically 700 - 760°C (1300 - 1400°F), but transient temperatures as hot as 815 - 850°C (1500 - 1560°F) are encountered in service. UNS S3XXXX series austenitic stainless steels are used for the lowest temperature exhaust valve applications. Low nickel content nitrogen strengthened austenitic steels, high nickel content nitrogen strengthened austenitic steels, and superalloys are used progressively as exhaust valve temperatures increase. Superalloys' maximum service temperatures can be as high as 870 - 900°C (1600 - 1650°F), depending upon imposed stresses.

Seat face burning resistance is achieved by alloy composition rather than valve design (for example, valve face angle). The precipitation strengthened austenitic stainless steels used in light duty spark ignition exhaust valves possess adequate hot hardness and oxidation/corrosion resistance to prevent undue seat wear. In demanding applications, the seats are face welded with a high hot hardness alloy.

Many exhaust valves have martensitic steel wafers welded to their stem tips or martensitic steel stems welded to their austenitic heads. These martensitic steel tips, when hardened, generally provide sufficient wear resistance. When a martensitic stem extends into the valve guide, the valve is referred to as a two-piece construction. This construction minimizes stem wear, provides superior fatigue strength in the keeper groove, and conserves alloying elements.

9. VALVE DESIGN RELATIONSHIP TO MATERIALS:

- 9.1 General: The design of a valve and its application to the engine are as important as the selection of the valve's alloy(s). Valve durability is limited by the operating temperature and stress imposed on it. It is sometimes possible to select a stronger or a more temperature resistant material to overcome limitations in valve design and application.

Optimizing stresses, temperatures, and cooling may impede overall engine efficiency, particularly when advanced thermodynamic concepts are employed. Fortunately, many of the valve design enhancements can compensate for excessive temperatures; delivering satisfactory valve durability under otherwise difficult circumstances.

9.2 Design Enhancements: When valve alloys with the properties necessary to obtain the desired durability are not available (or cannot be used economically), various valve design enhancements are employed. The most important of these are:

- 1) Seat Face Welding: When wear, corrosion, or duty service conditions are extreme, the valve face of an otherwise satisfactory head alloy may be inadequate. In these cases, the valve seat may be welded with a hard overlay alloy to better withstand wear and corrosion at the valve seating surface. Special cobalt, nickel, or based iron alloys have been developed for this purpose.
- 2) Seat Face Strain Hardening: When seat wear conditions are moderately beyond the endurance of an otherwise satisfactory head alloy, the valve seat may be strain hardened to better withstand wear. This is accomplished by mechanically cold working the seat face region after high temperature heat treating operations.
- 3) Stem Surface Treatments: Chromium plating, nitriding, and other surface treatments are often applied to valve stems to reduce friction or wear, or both, in service. A light film of engine oil generally prevents stem-guide wear, but adhesive wear can still occur under some circumstances. Valve stem surface treatments have effectively prevented adhesive wear in these instances.
- 4) Aluminizing: This is a special type of protective coating. A thin layer of aluminum is deposited on the valve seat face and, sometimes, the combustion face. The aluminum diffuses, alloying with the base material, resulting in a hard, oxidation-resistant coating that improves corrosion resistance, particularly in a lead oxide environment.
- 5) Internal Cooling: Hollow valves, partially filled with metallic sodium or sodium-potassium mixtures, transfer heat by convection from the hot head end of the valve to the stem. Internal cooling reduces peak valve temperatures, which may reduce engine octane sensitivity, and permit a reduction in valve alloy content.
- 6) Tip Caps: Occasionally a hardened martensitic steel cap is mechanically fitted on the end of the valve stem to improve tip wear resistance. These tip caps are sometimes used on valves where dissimilar metal welding is a problem.

10. VALVE GEAR DESIGN CONSIDERATIONS:

- 10.1 General: The design of a poppet valve is generally dictated by a pre-established operating environment. Since overall engine cost effectiveness is paramount, valve gear design parameters that intensify valve stresses must be carefully considered. Actuating geometry and valve gear dynamic performance are the most significant parameters.

- 10.2 Actuating Geometry: Valve actuating mechanisms often have a resolved force vector at the valve tip that is not coaxial with the valve stem. The greater the divergence, the greater the concentration of stem-guide contact forces at the ends of the guide. This concentrates the contact forces at the guide ends that may cause severe adhesion of the guide material to the valve stem.

Valve rotators are mechanical devices which rotate the valve during the opening portion of the operating cycle. Valve rotation dissipates hot spots and reduces deposits on the seat face, so heat transfer to the seat is improved. Valve rotators also tend to reduce stem and guide wear and stem scuffing.

- 10.3 Dynamic Performance: Valve stresses arise primarily from the dynamics of the valve gear and from the manner in which the valve closes against its seat. Compression ignition engines generate peak combustion pressures several times higher than spark ignition engines. Careful analysis of the valve gear kinematics and pressure induced stress is essential in assuring adequate valve durability.

Hydraulic valve lifters compensate for wear and thermal expansion/contraction in the valve gear. Automatic lash adjustment eliminates the undue stress caused by excessive lash and the extreme valve temperatures that develop from inadequate lash.

Optimizing actuating geometry and dynamic performance may impede overall engine efficiency, particularly when advanced concepts are employed. Fortunately, many of the valve design enhancements compensate for suboptimal geometry and dynamics, permitting adequate valve durability under difficult circumstances.

The phi (ϕ) symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

TABLE 1 - Current Valve Alloys (Martensitic Steels)

UNS NR	COMMER- CIAL	FORMER SAE GRADE	C	Mn	P	S	Si	Cr	Ni	N	W	Mo	Fe	Other
H15410		1541H	0.35/0.45	1.25/1.75	0.040 max	0.050 max	0.15/0.30	-	-	-	-	-	Base	
H15470		1547H	0.42/0.52	1.25/1.75	0.040 max	0.050 max	0.15/0.30	-	-	-	-	-	Base	
G31400		3140	0.38/0.43	0.70/0.90	0.040 max	0.040 max	0.15/0.30	0.55/0.65	1.10/1.40	-	-	-	Base	
H86450		8645H	0.42/0.49	0.70/1.05	0.035 max	0.040 max	0.15/0.30	0.35/0.65	0.35/0.75	-	-	0.15/0.25	Base	
H51500		5150H	0.47/0.54	0.60/1.0	0.035 max	0.040 max	0.15/0.35	0.60/1.0	-	-	-	-	Base	
H41400		4140H	0.37/0.44	0.65/1.10	0.035 max	0.040 max	0.15/0.35	0.75/1.20	-	-	-	0.15/0.25	Base	
GM-8440		NV 8	0.35/0.45	0.20/0.40	0.030 max	0.040 max	3.60/4.20	1.85/2.50	0.25 max	-	-	0.10 max	Base	Cu 0.25 max
S65007		S11 1	0.40/0.50	0.80 max	0.040 max	0.030 max	2.75/3.75	1.5 /9.5	0.50 max	-	-	-	Base	
S65006		S11 XB	0.75/0.85	0.80 max	0.040 max	0.030 max	1.75/2.50	19.0/21.0	1.0/1.70	-	-	-	Base	
S42200		422 SS	0.20/0.25	0.50/1.0	0.025 max	0.025 max	0.50 max	11.0/12.5	0.50/1.0	-	0.90/1.25	0.90/1.25	Base	V 0.20/0.30

All chemical contents are expressed in weight percent.



TABLE 1 - Current Valve Alloys (Austenitic Steels)

UNS NR	FORMER COMMER- CIAL GRADE	C	Mn	P	S	Si	Cr	Ni	N	Co	Mo	Fe	Other
S63017	21-12N EV 4	0.15/0.25	1.0/1.50	0.045 max	0.030 max	0.70/1.0	20.0/22.0	10.5/12.5	0.15/0.20	-	-	Base	
S63014	Si1 10 EV 5	0.30/0.45	0.80/1.30	0.040 max	0.030 max	2.75/3.25	18.0/20.0	7.50/8.50	-	-	-	Base	
S63015	Si1 10 N EV 6	0.30/0.45	0.80/1.30	0.030 max	0.030 max	2.75/3.25	18.0/20.0	7.50/8.50	0.15/0.25	-	-	Base	
S63008	21-4N EV 8	0.48/0.58	8.0/10.0	0.050 max	0.035 max	0.25 max	20.0/23.0	3.25/4.50	0.38/0.55	-	-	Base	
S63009	IPA EV 9	0.35/0.50	1.0 max	0.045 max	0.030 max	0.30/0.80	12.0/15.0	12.0/15.0	-	0.20/0.50	-	Base W 1.50/3.0	
S63011	Si1 746 EV 11	0.65/0.75	5.50/7.0	0.050 max	0.025/0.065	0.45/0.85	20.0/22.0	1.40/1.90	0.18/0.28	-	-	Base	
S63012	21-2N EV 12	0.50/0.60	7.0/9.50	0.050 max	0.035 max	0.25 max	19.25/21.5	1.50/2.75	0.20/0.40	-	-	Base	
S63013	Gaman H EV 13	0.47/0.57	11.0/13.5	0.030 max	0.030 max	2.30/3.0	20.5/22.0	-	0.40/0.50	-	-	Base	
Nitronic 20 EV 15													
		0.28/0.38	1.50/3.50	0.040 max	0.015 max	0.40/0.90	22.0/24.0	7.0/9.0	0.28/0.35	0.50 max	0.50 max	Base	
23-8N													
S30430	302 HQ EV 17	0.10 max	2.0 max	0.045 max	0.030 max	1.0 max	17.0/19.0	8.0/10.0	-	-	-	Base Cu 3.0/4.0	
21-4Nb	XEV-F	0.45/0.55	8.0/10.0	0.050 max	0.030 max	0.45 max	20.0/22.0	3.50/5.50	0.40/0.60	-	-	Base W 0.80/1.50	
													Nb + Ta 1.80/2.50

All chemical contents are expressed in weight percent.

TABLE 1 - Current Valve Alloys (Superalloys)

UNS NR	FORMER COMMER- CIAL GRADE	C	Mn	P	S	Si	Cr	Ni	N	Co	Mo	Fe	Other
N07750	Inconel X 750	0.08 max	1.0 max		0.010 max	0.50 max	14.0/17.0	70.0 min	-	-	-	5.0/9.0	Ti 2.0/2.75 Al 0.40/1.0 Cu 0.50 max
	Inconel X 751	0.03/.10	0.50 max	0.015 max	0.015 max	0.50 max	14.0/17.0	Base	-	1.0 max	0.50 max	5.0/9.0	Ti 2.0/2.60 Al 1.10/1.35 Ta+Nb 0.70/1.20
N07080	Nimonic 80 A	0.10 max	1.0 max	0.045 max	0.030 max	1.0 max	18.0/21.0	Base	-	2.0 max	-	3.0 max	Ti 1.8/2.7 Al 1.0/1.8
	Pyromet 31V	0.03/0.06	0.20 max	0.015 max	0.015 max	0.20 max	22.30/22.90	55.0/58.0	-	1.0 max	1.70/2.30	Balance	Ti 2.1/2.40 Al 1.15/1.40 Nb 0.75/0.95 B 0.003/0.007 Cu 0.50 max
N07001	Waspaloy XEV-H	0.03/0.06	1.0 max	0.030 max	0.030 max	0.75 max	18.0/21.0	Base	-	12.0/15.0	3.50/5.0	2.0 max	Ti 2.75/3.50 Al 1.20/1.60 Zr 0.02/0.12 B 0.003/0.010 Cu 0.50 max

All chemical contents are expressed in weight percent.

TABLE 1 - Current Valve Alloys (Facing Alloys)

UNS NR	COMMER- CIAL	FORMER SAE GRADE	C	Mn	P	S	Si	Cr	Ni	Co	W	Mo	Fe	Other
R30006	Stellite 6	VF 2	0.90/1.40	1.0 max	0.030 max	0.030 max	0.40/2.0	26.0/32.0	3.0 max	Base	3.0/6.0	1.0 max	6.0 max	0.50 max
N06005	Eatonite	VF 3	2.0/2.75	0.50 max	0.030 max	0.030 max	0.50/1.0	27.0/31.0	Base	9.0/11.0	14.0/16.0	-	8.0 max	
N06782	X 782	VF 4	1.75/2.25	1.0 max	0.030 max	0.030 max	0.50 max	25.0/27.0	Base	0.50 max	8.0/9.50	-	4.0 max	
R30002	Stellite F	VF 5	1.50/2.0	1.0 max	0.030 max	0.030 max	0.80/1.50	23.0/27.0	20.5/23.5	Base	10.5/13.5	1.0 max	6.0 max	
R30001	Stellite 1	VF 6	2.0/3.0	1.0 max	0.030 max	0.030 max	0.40/2.0	26.0/33.0	3.0 max	Base	11.0/14.0	1.0 max	6.0 max	0.50 max
R30012	Stellite 12	VF 7	1.20/1.70	1.0 max	0.030 max	0.030 max	0.40/2.0	26.0/33.0	3.0 max	Base	7.0/9.50	1.0 max	6.0 max	0.50 max
Triballoy T-400		VF 8	0.80 max	-	0.030 max	0.030 max	2.20/2.60	7.50/8.50	-	61.0/63.0	-	27.0/29.0	-	Fe+Ni 3.00 max
Eatonite 3		VF 9	1.80/2.20	0.05 max	0.030 max	0.030 max	0.80/1.20	28.0/30.0	Base	-	-	4.0/6.0	1.0/8.0	
Eatonite 5		VF 10	1.80/2.20	1.0 max	0.030 max	0.030 max	0.80/1.20	28.0/30.0	Base	-	-	7.0/9.0	1.0/8.0	
VNS 585		VF 11	2.0/2.50	-	-	-	0.80/1.30	22.0/26.0	10.0/12.0	-	-	5.0/6.0	Base	
Eatonite 6			1.50/2.0	0.50/1.0	0.025 max	0.020 max	1.10/1.50	26.0/30.0	15.0/18.0	-	-	4.0/5.0	Base	

All chemical contents are expressed in weight percent.

TABLE 1 - Current Valve Alloys (Titanium Alloys)

UNS NR	COMMER- CIAL	FORMER SAE GRADE	C	Al	V	Zr	Mo	Sn	O	Fe	H	Yt	Ti	Other
R56401	Ti 6-4	XEY-J	0.80 max	5.50/6.50	3.50/4.50	-	-	-	0.13 max	0.25 max	0.0125 max	0.005 max	Base	N 0.05 max
R54620	Ti 6-2-4-2		0.05 max	5.50/6.50	-	3.60/4.40	1.80/2.20	1.80/2.20	0.12 max	0.25 max	0.015 max	0.005 max	Base	Si 0.10 max N 0.05 max

All chemical contents are expressed in weight percent.

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TABLE 2 - ISO Valve Alloys

ISO 683/XV TYPE	UNS NR	C	Mn	P	S	Si	Cr	Ni	N	W	Mo	Fe	Other
	S65007	1	0.40/0.50	0.80 max	0.040 max	2.75/3.75	7.5/9.5	0.50 max	-	-	-	Base	-
		2	0.35/0.45	0.80 max	0.040 max	1.80/3.00	9.5/11.5	-	-	-	0.70/1.30	Base	-
		3	0.80/0.90	1.50 max	0.040 max	1.00 max	16.5/18.5	-	-	-	2.00/2.50	Base	V 0.30/0.60
	S65006	4	0.75/0.85	0.80 max	0.040 max	1.75/2.50	19.0/21.0	1.00/1.70	-	-	-	Base	-
		5	0.35/0.50	1.00 max	0.045 max	2.00 max	12.0/15.0	12.0/15.0	-	2.00/3.00	-	Base	-
		6	0.40/0.50	0.80/1.50	0.045 max	2.00/3.00	17.0/20.0	8.00/10.0	-	0.80/1.20	-	Base	-
	S63017	7	0.15/0.25	1.00/1.50	0.045 max	0.70/1.0	20.0/22.0	10.5/12.5	0.15/0.20	-	-	Base	-
	S63008	8	0.48/0.58	8.00/10.0	0.050 max	0.25 max	20.0/23.0	3.25/4.50	0.38/0.55	-	-	Base	-
		9	0.48/0.58	8.00/10.0	0.050 max	0.25 max	20.0/23.0	3.25/4.50	0.38/0.55	-	-	Base	-
		10	0.65/0.75	5.50/7.00	0.050 max	0.45/0.85	20.0/22.0	1.40/1.90	0.18/0.28	-	-	Base	-
	N07080	11	0.10 max	1.00 max	0.045 max	1.00 max	18.0/21.0	Base	-	-	-	3.00 max	Al 1.0/1.8 Ti 1.8/2.7 Co 2.00 max
		12	0.08/0.16	1.00/2.00	0.045 max	1.00 max	20.0/22.5	19.0/21.0	0.10/0.20	2.00/3.00	2.50/3.50	Base	Co 18.5/21.5 Nb 0.75/1.25

All chemical contents are in weight percent.

TABLE 2 - DIN Vertilwerkstoffe (Valve Alloys)

UNS NR	DIN 17480 Stoff NR	C	Mn	P	S	Si	Cr	Ni	N	W	Mo	Fe	Other
	1.0906	0.60/0.68	0.70/1.00	0.050 max	0.050 max	1.50/1.80	-	-	0.007 max	-	-	-	-
615410	1.1167	0.32/0.40	1.20/1.50	0.035 max	0.035 max	0.15/0.35	-	-	-	-	-	-	-
	1.2731	0.45/0.55	0.60/0.80	0.035 max	0.035 max	1.20/1.50	12.0/14.0	12.5/13.5	-	1.50/2.80	-	-	V 0.30/1.0
686450	1.2769	0.42/0.48	0.50/0.70	0.035 max	0.035 max	0.30/0.50	0.80/1.10	0.40/0.60	-	-	0.10/0.30	-	-
	1.3817	0.40/0.55	17.0/19.0	0.100 max	0.030 max	0.80 max	3.0/5.0	-	-	-	-	-	-
	1.4704	0.40/0.50	1.00 max	0.045 max	0.030 max	3.50/4.50	2.5/3.0	-	-	-	-	-	-
565007	1.4718	0.40/0.50	0.80 max	0.040 max	0.030 max	2.70/3.30	8.0/10.0	-	-	-	-	-	-
	1.4721	2.00/2.25	1.00 max	0.045 max	0.030 max	0.50 max	11.0/12.0	-	-	-	-	-	-
	1.4731	0.35/0.45	0.80 max	0.040 max	0.030 max	2.00/3.00	9.0/11.0	-	-	-	0.80/1.30	-	-
	1.4732	0.75/0.85	0.80 max	0.040 max	0.030 max	1.80/2.20	14.0/16.0	0.60/0.90	-	0.80/1.20	0.80/1.20	-	-
565006	1.4747	0.75/0.85	1.00 max	0.030 max	0.030 max	1.75/2.75	19.0/21.0	1.00/1.75	-	-	-	-	-
	1.4748	0.80/0.90	1.50 max	0.040 max	0.030 max	1.00 max	16.5/18.5	-	-	-	2.00/2.50	-	V 0.30/0.50
563008	1.4871	0.48/0.58	7.00/10.0	0.050 max	0.02/.06	0.25 max	20.0/22.0	3.25/4.50	0.38/0.50	-	-	-	-
	1.4873	0.40/0.50	0.80/1.50	0.045 max	0.030 max	2.00/3.00	17.0/19.0	8.00/10.00	-	0.80/1.20	-	-	-

All chemical contents are in weight percent.

TABLE 2 - DIN Verteilwerkstoffe (Valve Alloys)

DIN 17480 UNS NR	Stoff NR	C	Mn	P	S	Si	Cr	Ni	N	M	Mo	Fe	Other
S63012	1.40875	0.50/0.60	7.00/10.0	0.05 max	0.02/0.06	0.25 max	19.5/21.5	2.00/2.75	0.20/0.40	-	-	-	-
S63011	1.40881	0.65/0.75	5.50/7.00	0.050 max	0.02/0.06	0.80 max	20.0/22.0	1.40/1.90	0.10/0.28	-	-	-	-
S42200	1.4935	0.17/0.25	0.30/0.80	0.045 max	0.030 max	0.10/0.50	11.0/12.5	0.30/0.80	-	0.40/0.60	0.80/1.20	-	V 0.25/0.35
	1.5122	0.33/0.41	1.10/1.40	0.035 max	0.035 max	1.10/1.40	-	-	-	-	-	-	-
G31400	1.5711	0.38/0.43	0.70/0.90	0.035 max	0.035 max	0.15/0.35	0.55/0.75	1.10/1.40	-	-	-	-	-
G51500	1.7006	0.42/0.50	0.50/0.80	0.035 max	0.030 max	0.40 max	0.40/0.60	-	-	-	-	-	-
G41400	1.7225	0.38/0.45	0.60/1.00	0.025 max	0.025 max	0.30/0.60	0.80/1.20	-	-	-	0.20/0.30	-	-
N07080	2.4631	0.04/0.10	1.00 max	0.030 max	0.015 max	1.00 max	18.0/21.0	Base	-	-	-	1.50 max	Ti 1.8/2.7
													Al 1.0/1.8
													Co 2.00 max
													Cu 0.20 max
													B 0.008 max
N07090	2.4632	0.13 max	1.00 max	0.030 max	0.015 max	1.00 max	18.0/21.0	Base	-	-	-	-	Ti 2.0/3.0
													Al 1.0/2.0
													Co 15.0/21.0
													Cu 0.20 max
													Zr 0.15 max
													B 0.02 max

All chemical contents are in weight percent.

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TABLE 2 - Euronorm Aciers Pour Soupapes d'Échappement (Valve Alloys)

UNS NR	EURODORM 90 Nuances d'acier	C	Mn	P	S	Si	Cr	Ni	N	W	Mo	Fe	Other
S65007 X 45 CrSi 8		0.40/0.50	0.80 max	0.035 max	0.035 max	2.80/3.50	7.5/9.5	-	-	-	-	-	-
S65006 X 80 CrSiNi 20		0.75/0.85	0.80 max	0.035 max	0.035 max	1.75/2.50	19.0/21.0	1.0/1.75	-	-	-	-	-
S65008 X 53 CrMnNiN 21 9		0.48/0.58	8.00/10.0	0.050 max	0.035 max	0.25 max	20.0/22.0	3.25/4.50	0.38/0.50	-	-	-	-
S65012 X 55 CrMnNiN 20 8		0.50/0.60	7.00/10.0	0.05 max	0.03 max	0.25 max	19.5/21.5	2.00/2.75	0.20/0.40	-	-	-	-
X 40 CrSiMo 10		0.35/0.45	0.80 max	0.045 max	0.030 max	2.00/3.00	9.5/11.5	-	-	-	0.80/1.30	-	-
X 45 CrNiW 18 9		0.40/0.50	0.80/1.50	0.045 max	0.035 max	2.00/3.00	17.0/19.0	8.00/10.0	-	0.80/1.20	-	-	-
X 42 CrNiW 14 14		0.35/0.50	1.50 max	0.045 max	0.035 max	1.00/2.00	13.0/15.0	13.0/15.0	-	1.00/3.00	-	-	-
X 12 CrCoNiMoNb		0.08/0.16	1.00/2.00	0.040 max	0.030 max	1.00 max	20.0/22.5	19.0/21.0	0.10/0.20	2.00/3.00	2.50/3.50	- Co 18.5/21.0	-
21 20 20												Nb 0.75/1.25	

All chemical contents are in weight percent.

TABLE 2 - JIS Heat Resisting Steels (Valve Alloys)

JIS UNS NR	GRADE	C	Mn	P	S	Si	Cr	Ni	Co	W	Mo	Fe	Other
R30001	Co Cr 1	2.00/3.00	1.00 max	-	-	0.40/2.00	26.0/33.0	3.00 max	Base	11.0/14.0	1.00 max	3.00 max	0.50 max
R30006	Co Cr 6	0.90/1.40	1.00 max	-	-	0.40/2.00	26.0/32.0	3.00 max	Base	3.00/6.00	1.00 max	3.00 max	0.50 max
R30012	Co Cr 12	1.20/1.70	1.00 max	-	-	0.40/2.00	26.0/33.0	3.00 max	Base	7.00/9.50	1.00 max	3.00 max	0.50 max
JIS UNS NR	GRADE	C	Mn	P	S	Si	Cr	Ni	Co	W	Mo	Fe	Other
G15470	SMnC443H	0.39/0.46	1.30/1.70	0.030 max	0.030 max	0.15/0.35	0.35/0.70	-	-	-	-	-	-
JIS UNS NR	GRADE	C	Mn	P	S	Si	Cr	Ni	Co	W	Mo	Fe	Other
G86450	SMCH 240	0.38/0.43	0.70/0.90	0.030 max	0.030 max	0.15/0.35	0.40/0.65	0.40/0.70	-	-	0.15/0.30	-	-
JIS UNS NR	GRADE	C	Mn	P	S	Si	Cr	Ni	Co	W	Mo	Fe	Other
S65007	SUH 1	0.40/0.50	0.60 max	0.030 max	0.030 max	3.00/3.50	7.5/9.5	0.60 max	-	-	-	-	-
S65006	SUH 4	0.75/0.85	0.20/0.60	0.030 max	0.030 max	1.75/2.25	19.0/20.5	1.15/1.65	-	-	-	-	-
S63008	SUH 35	0.48/0.58	8.00/10.0	0.040 max	0.030 max	0.35 max	20.0/22.0	3.25/4.50	-	-	-	-	N 0.35/0.50
S63017	SUH 37	0.15/0.25	1.00/1.60	0.040 max	0.030 max	1.00 max	20.5/22.5	10.0/12.0	-	-	-	-	N 0.15/0.30
S42200	SUH 616	0.20/0.25	0.50/1.00	0.040 max	0.030 max	0.50 max	11.0/13.0	0.50/1.00	-	0.75/1.25	0.75/1.25	-	V 0.20/0.30

All chemical contents are in weight percent.